Using Socio-Constructivist Techniques as a Framework to

Integrate Physics 11 and 12

by

Bill Deagle
B.Ed. University of Alberta, 1999

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Department of Curriculum and Instruction

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Critical reflections and pedagogical insights into the processes, challenges, and positive outcomes of integrating Physics 11 and 12 together into a half-day, semester-long course taught at a Vancouver Island school is the focus of this project paper. Utilizing constructivist techniques such as inquiry/discovery learning, problem-based learning, and project-based learning allowed students to expand their learning options in order to attain a deep understanding of the material presented in the class. Evaluation was moved from unit tests to research projects that required thoughtful approaches by the students, including: data collection with a number of tools, careful analysis of results, collaboration with other students, and written reflections. Allowing for student choice of project topics, coupled with their ability to collaborate with peers, shifted the teacher’s and learners’ experiences from a constructivist approach to one of socio-constructivism (Vygotsky, 1978).
Table of Contents

Abstract.............................................................................................................i
Table of Contents..........................................................................................ii
Acknowledgements..........................................................................................iv
Dedication......................................................................................................v

Chapter 1: Introduction..................................................................................1
  About Me.....................................................................................................1
  Rational for a Change................................................................................2
  Classroom Setting.......................................................................................3
  My Old Style...............................................................................................4
  The Seed of an Idea....................................................................................5
    From imagination to reality......................................................................6
  My Project...................................................................................................7

Chapter 2: Literature Review........................................................................9
  Constructivist Methods of Teaching: Definitions and an Introduction.........10
    Problem based learning...........................................................................10
    Inquiry based learning............................................................................11
    Project-based learning............................................................................12
  Constructivist or Not: How Can You Tell?...............................................13
  Positive Implications of Using Constructivist Methods............................16
    A continuum of change.........................................................................19
  Challenges of Constructivist Learning Environments...............................21
  What Makes Physics so Challenging in a Constructivist Way?...............21
    Practice makes perfect..........................................................................22
    Teachers aren’t the only ones that need to change...............................24
  Farming and Teaching, a Positive Correlation.........................................25
  Conclusion and Summary...........................................................................26

Chapter 3: The Integrated Physics 11/12 Class.............................................28
  Layout, Structure, and the Building Blocks of Integrated Physics 11/12....31
  Constructivist Learning in the Integrated Physics Classroom..................33
    Inquiry/discovery learning.....................................................................34
    Problem based learning.........................................................................36
    Project based learning............................................................................38
  The Good, the Bad, and the Indifferent....................................................42
    Positive aspects of Integrated Physics 11/12: student perspectives........42
    Negative aspects of Integrated Physics 11/12: student perspectives......44
    Positive outcomes of Integrated Physics 11/12: teacher perspective......46
    Negative outcomes of Integrated Physics 11/12: teacher perspective.....47
  Culminating Thoughts on the Integrated Physics 11/12 Project.................48
Chapter 4: Ending Thoughts

Project Summary
Changes to my Personal Teaching Approaches
Change Isn’t Just for the Sake of Change
In Conclusion

References

Appendix 1: Integrated Physics 11/12: Course Outline
Appendix 2: Integrated Physics 11/12: Student Formula Sheet
Appendix 3: Lab Inquiry Planning Model
Appendix 4: Integrated Physics 11/12 Finding ‘μ’ Lab
Acknowledgements

I would first like to thank the staff and administrators at the school for their support, understanding, and encouragement as I navigated through uncharted waters during the planning, preparation, and deployment of the Integrated Physics 11/12 course. Without their support I would not be able to call the class a success. Secondly, many thanks are offered to the students who bravely branched out and tried something new. Our school is filled with tremendously adaptable young adults, and it is their dedication, encouragement, and passion for learning that pushes the teachers at the school to improve their practice in order to meet their needs. Finally, the biggest thank you goes to my family, who gave up their dad and husband for what seemed an eternity over the past two years. The early morning alarm will thankfully be put to rest, and I will eagerly and without guilt play board games, mini sticks, and take bike rides now when asked.
Dedication

I would like to dedicate this paper to my family. My three children, Liam, Ryan, and Emma are a constant reminder of how unbelievably lucky I am to have found my wife, Mary. Without their constant support, encouragement, and sacrifice, I wouldn’t be writing this dedication at the end of a two year journey. When times were hard and the project would get me down, they always found a way to get me past it, to lift me up, and for that I am eternally grateful.
Chapter 1: Introduction

About Me

I was born in Edmonton, Alberta in the middle of winter to excited parents and with two older sisters to protect was given the name William. I lived on a farm outside of Edmonton until I was married at twenty-two. I spent my childhood cheering for the Edmonton Oilers hockey team as they made their runs to the Stanley cup finals in the mid to late 1980’s. Born to a millwright/mechanic father and office administrator mother I was well cared for, happy, and had a keen sense of both learning and fun. School did not interest me very much until high school science classes. I was bright enough, had an excellent work ethic from years of hard labour on the farm, loved sports, and was not passionate about much else except hockey, science, or outdoor activities like hunting and fishing.

With an innate ability to understand the basic physics principles of most sports, I quickly became a multi-sport athlete. Playing high level Rep hockey for seven seasons allowed me to go to a few junior team camps, I was a staple on the volleyball and rugby teams throughout high school, and could pick up nearly any sport in a short period of time. I see the same sort of athletic drive in my own three children as they begin to excel in their respective sports; competitive gymnastics, hockey, and acrobatic dance.

I entered into the profession of teaching in order to expand my knowledge of science in society and how it can be applied in all situations. My father told me from a very young age to ‘stay in school and save your elbows by not pulling wrenches your whole life like me.’ It was a bit of an ironic statement though, as my father has a very sharp mind in mathematics and can build or repair almost anything from scratch. He had
little use for K-12 schooling himself, but was able to use his natural abilities and the knowledge of his trades education extremely well on the farm and throughout his life. As I look back on it now, I realize that he had a lot of wisdom and information to offer me, in a setting much different than my traditional school experience. The mental list of dad’s advice is ever growing. The wisdom he has shared with me in childhood and still throughout my adult life have come to help me in many ways and for that I am thankful. I am also cognizant that my role as a father is to impart similar knowledge to my own children. I hope that their mental list will one day be as long as mine.

Rationale for a Change

Lists are a commonplace sight in everyday life, for nearly all people. Lists for groceries, yard work, kid’s chores, meetings, the email inbox grows longer by the minute and contact lists are always increasing. Lists have their merits, they have organizational powers that can help the most scattered of us. To teachers however, lists can run our careers; student roster lists, phone number and email lists, helper of the week, earthquake preparation and fire drill procedures, and the list of lists goes on. Of all the lists I look at in my teaching, likely the most important is the one of student outcomes to be covered in a course as prescribed by the Ministry of Education in the Integrated Resource Package (IRP). Each course or grade will have a particular number of outcomes that are quantifiably measurable during the school year. Each of these outcomes is preceded with a small checkbox (◻), which when compiled makes a neat little checklist of everything a student should know as they leave your classroom upon completing a course. How tidy, organized and convenient for everyone.
**Classroom Setting**

I have taught in two different districts since graduating from the University of Alberta with my B.Ed. in 1999, the first being in Alberta for two years, the other being in central Vancouver Island, where I have taught since 2001. In both teaching positions I have taught numerous academic courses such as; junior science, chemistry, mathematics, and physics to grade ten to twelve students. It is physics that is truly my passion, and it is the teaching of physics that has compelled me to undertake this journey of discovery to finish my Masters of Education. When a beginning teacher’s first job is to teach academically driven senior Physics students barely younger than himself and prepare them to complete a mandatory Government exam which can make or break their entrance to university, (50% in Alberta, 40% of total grade in BC) it pays to have a checklist to know what you have covered and what you have left to cover. It is convenient such a checklist is provided in the IRP for the teachers completing the courses being taught.

Looking at the content specific to a course like Physics 12, there are 128 content specific outcomes that need to be covered in the course of one semester and 86 in its Physics 11 counterpart. (BC Ministry of Education, 2006). These outcomes do not include the general skills expected to be taught such as proper lab procedure, graph making and interpretation skills, metric conversions, among numerous others. During the time within a course, these non-content outcomes specifically mentioned above are taught concurrently with the content specific outcomes to relate physics concepts directly to real-life situations. Relating concepts to real-life will become one of the foci of this M.Ed. work. With, on average, 88 lessons per semester in which to teach the required outcomes, the pace can be positively ceaseless. Still, the checklist looms.
My Old Style

Stand and deliver, the sage on the stage, the expert, or the formal authority are all methods that I have put into practice in my years of teaching. All the listed methods are excellent ways to disseminate information, however, as I become a more experienced teacher, I have come to realize that providing information merely to check off a particular outcome does not result in the student retaining much knowledge, it only provides a check in a box, or a line through an outcome. My journey to change the way I teach physics, which has recently become a reality, will still allow me to cover information in class, but more importantly, will leave the students with an understanding of science, the joy of learning and perhaps a new passion for physics. Outcomes don’t need to be *talked to* in class by lecture format, they can be *talked about*. I’ve come to understand that my role is not to just fill their vessel with knowledge. I do need to teach them content but at the same time help create students who are confident and independent enough to find the answers themselves. I want to make the learning deep, rather than just scratching the surface. Teach less, but do it better.

I no longer want to be a slave to the checkboxes, in truth, I want to integrate physics concepts into real-life situations, to bring forth a new passion for science in today’s youth, and have this passion grow into an ever-changing entity throughout their lives. How can I change the way physics is taught in my class but still keep the interest level high so students will want to take the course? It is a bit of a long process to describe how I got to this point, but I think it is necessary to lay down the context of my decisions.
The Seed of an Idea

After the BC Ministry of Education removed the mandatory Provincial exam in Physics 12, I struggled with teaching the new course without the exam to push the pace. Lessons were shortened, lab explorations were changed or dropped, and the more difficult questions became less of a priority. Some students seemed to begin to take more liberties with assignments saying things like, ‘there isn’t anything else to work for now that the Provincial is gone.’ Teaching physics seemed to have lost something for me, and I wasn’t sure how to take it back. The answer emerged when a group of teachers from our school were expressing similar concerns. A conversation over a Pro-D lunch provided a spark to the discussion. Questions arose like ‘why don’t our academic students like physics kids, who will be the engineers of the future, take shop classes like metal work, woodwork, or mechanics to understand the nature of materials and how they can be used together to complete a project?’ or ‘do any senior science academic students even know how to weld, or build a simple wood frame to support something?’

Taking these new ideas to the next level, a new afterschool club was born that was founded to take the two extremes in high school – the shops and the sciences – and have them work together to design, build, test, and reflect on projects together. After some initial start-up organization, the club began to meet twice a month after school.

After only a few months engagement was not as high as we had hoped. The students were unsure how to interact with each other, the shop students working by themselves and the science students doing the same. Clearly the plan was fraught with challenges, that we, the facilitating teachers were unsure how to mediate. Even though the club stopped meeting a few months after inception, the seed of the idea was planted
and it continued to grow in my mind, waiting for the right conditions to sprout and take shape.

**From imagination to reality.** Over the course of the next few years the idea of different types of classes came to the surface many times inside other discussions with colleagues, classes that followed our original after school plan. These discussions occurred at other Pro-D seminars, staff meetings and during informal discussions with students to gauge interest. Our principal had said at a staff meeting in January of 2012 that to keep up with innovations in teaching in the 21st century model that if we have 30 kids and a good idea he will work his hardest to fit it into the timetable. I took the opportunity to refine my thoughts and put them down to paper, proposing my idea to the administration at our school.

After much deliberation on the various possibilities, I proposed that combining Physics 11 with Physics 12 in a ½ day setting would be beneficial and worthwhile to try. I had many reasons for this proposal:

- Students were becoming disinterested in physics as a stand and deliver course.
- My teaching energy was diminishing as I taught a stand and deliver course.
- I felt students deserved a more well-rounded education in the field of Physics.
- Physics 11 and 12 have a number of outcomes that are nearly identical and can be easily combined to save time instead of being retaught in Physics 12 as review.
- A greater opportunity to prepare students for post-secondary education with higher quality materials, cooperative tasks, experiential learning, and a greater reflective process.
- Longer classes (½ day vs. a seventy-five minute block per day) would give extra time to complete more complex questions, labs, take field trips, and to have guest speakers visit the class for an extended session.
The proposal and rationale were put forward and were accepted as an option to be entered into the course selection book for the spring of 2013. I was on the way to building a one-of-a-kind course in BC. Many questions were asked and numerous emails/phone calls were made to promote this new eight credit class to our student population. Counsellors actively advertised the course during student course selections, with fingers crossed and bated breath, I was told forty-nine students signed up during the first round of selections. After the school timetable was built, and students were sorted based on required courses and the rest of their requests, twenty-nine students joined me on a journey through Integrated Physics 11/12. I was on the way to experience teaching Physics in a new way, to give some new methods a try, to step off the stage and move to the side in order to facilitate, and to give myself and my students a much needed new outlook in physics.

My Project

Will a change to a new teaching method and course philosophy address the growing concern that the essentials of Physics were being taught (the checkboxes) but not the width and breadth of all its wonder in my regular physics class? I hope to answer the following question within the pages that follow: is an experiential, project/inquiry based immersion approach to teaching physics a beneficial method so that students retain more knowledge in the subject and will this knowledge become more applicable throughout their lives?
To narrow the scope of this question, I plan on using guiding questions as I read the literature to pinpoint specific concepts that I hope to achieve with this new class. These questions include:

i. How can experiential or project-based learning benefit students in science, in particular, physics?

ii. Are students who are given more authentic opportunities to explore physical concepts more likely to learn and retain these concepts?

iii. Can an alternate delivery method to ‘sage on the stage’ give students a way to compile and comprehend the massive number of outcomes required in senior level academic courses like Physics?

With these questions to guide the research, will I find that indeed gaining knowledge is more than just retaining information, but is instead, the proper application of this knowledge in applicable situations?
Chapter 2: Literature Review

“Education implies a seeking to understand, the preparedness to approach difficult problems—problems of significance to human beings” (Davis-Seaver, 2000 p.29).

As I embarked on the personal journey a number of years ago to reflect on and re-energize my teaching style, I asked myself a number of questions: why is this change necessary, will this different style make my students better learners, or will I find that a more constructivist approach is something that my students aren’t willing to try? After reading the above quote from Davis-Seaver I imagine my current Integrated Physics 11/12 students ten or fifteen years into the future, using something that we learned in class to solve a problem they encounter, perhaps explaining friction, acceleration, or a conservation law to someone else, maybe even to their own children.

In the end, the ultimate goal of changing my teaching style to this new constructivist fashion is to have the students feel comfortable in the everyday uses of physics as teenagers so they can be scientifically literate citizens in society after leaving school. Ones that are capable of tackling difficult problems, use critical thinking skills, or making judgment calls using an objective, data-driven response to a situation that may occur in their lives. My students are not empty vessels that become full when I check off all the boxes on the PLO list, rather, I have found them to need guidance in order to help discover the applications of science in everyday aspects of life, to solve worldly problems, not just those constrained in formulas on paper in a four walled school setting.

In my review of the literature that pertains to this pioneering Physics class in British Columbia, I will define constructivist learning techniques such as; problem based learning, inquiry/discovery learning, and project based learning. Although these techniques are separate entities, they share common features as well as some related
challenges. I will also generate points that support and refute constructivist teaching methods and its application in science classes, specifically in physics. I intend to frame my research around possible uses of a constructivist approaches in my new class and will expand on some of the results found in the third chapter of this paper.

Constructivist Methods of Teaching: Definitions and an Introduction

“All learning involves knowledge construction in one form or another, it is therefore a constructivist process”

(Hmelo-Silver, Duncan, & Chinn, 2006, pg.99)

Many forms of constructivist teaching methods are available to teachers as long as they are willing to step away from the whiteboard or LCD projector in order to use them properly. Methods commonly identified as constructivist include; problem-based learning, inquiry/discovery learning, and project-based learning. These methods allow teachers to cease using a typical stand and deliver model and to take on more of a facilitator role on the side of the class; guiding the progress, giving hints and tips, and allowing time for discovery to occur, within the time and curricular constraints of the course. Numerous studies have been completed that identify the implementation of constructivist models, their goals, struggles, and successes. I will highlight a few of these studies that I believe pertain directly to the style of course that I am beginning to teach and what I can expect as I move along the continuum from a teacher-centered classroom to one that is learner centered.

Problem based learning. Savery (2006), defines problem based learning (PBL) as one of the forms of constructivist learning the following way, “PBL is an instructional
and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to an ill-defined problem” (p. 12). Pecore (2012), conducted a qualitative case study of four high school science teachers in which each participant was observed ten times in their classroom setting, and then were interviewed at the conclusion of the study. Pecore identifies problem based learning in the following way,

Students working in groups are presented with a problem and asked to analyze preliminary data. With instructor assistance, the group determines the issues to research. Groups then share their research with the class, receive additional information and/or conduct an exploratory activity, and continue researching the problem. (p. 8)

Each of these definitions of problem based learning favour a more student centered approach of learning, with the instructor leading discussions, giving gentle nudges from the side instead of dictating curriculum from the front of the class. Problem based class assignments must be complex, require knowledge acquisition, research, and benefit from collaboration. Savery (2006) supplements the definition of problem based learning in his paper by identifying the teacher as tutor and that the role of the tutor is to support the process of the learner in relation to the problem, not to lead the learner directly to a solution, perhaps acting like a sage on the side. In addition, the teacher expects that the learners’ thinking is progressing along a path that includes the ability to recognize that identifying the problem and solving it are important aspects of real life. (p.16)

Inquiry based learning. Inquiry/discovery learning has been traced back to the works of Jean Piaget, Lev Vygotsky, and David Ausubel and is defined by Minner, Levy,
& Century (2009) as, “how students learn (e.g. actively inquiring through thinking and doing) into a phenomenon or problem, often mirroring the processes used by scientists” (p. 3). Minner, Levy and Century go on to add that “…learners design and conduct their own experiments” (p. 3) as a meaningful way to utilize inquiry learning as a method to understand a new topic. Inquiry learning has become a standard way of learning in my Integrated Physics 11/12 class.

**Project-based learning.** Many of the principles of project-based learning are common to problem-based learning as well. Students are expected to produce a learning artifact (project) by the end of the activity/unit and in doing so will ultimately (and hopefully) obtain and retain the knowledge that was intended to be covered by the teacher in a direct instruction setting. These projects must be well-defined but allow for student freedom, be assessable in a meaningful way, and must not overwhelm students. While the emphasis in project-based learning may center on the production of a learning artifact, all of these constructivist learning styles strive for “the acquisition of new knowledge and the solution may be less important than the knowledge gained in obtaining it” (Prince & Felder, 2006, p. 130). Karelina and Etkina (2007) expand on the ideas of Prince and Felder by saying,

[Students] will probably not remember the details of Newton’s Third Law or projectile motion while treating patients or studying the effects of chemicals, but all of them will need to make decisions based on evidence and use this evidence to test alternative explanations, deal with complex problems that do not have one right answer, and deal with other people. (p. 1)

Each of the above mentioned methods of constructivist learning can in part be rooted in the social aspect of schools and how individuals interact with
one another. Vygotsky (1978) believed that changes in thought processes were neither random nor individually initiated. He concluded that social interactions in class allowed for modelling of expertise, for people to clarify, modify, or recreate learning throughout their social experiences. The term socio-constructivism was later coined to describe this process of learning throughout the social atmosphere of the classroom.

Constructivist or Not: How Can You Tell?

The constructivist teacher and the more typical teacher as depicted on TV or in movies are vastly different. In this section many of the ideals, methods, and concepts that define each type of teacher are identified. Mulhall and Gunstone (2012) completed a qualitative case study to identify the differences between constructivist (conceptual) teaching and traditional teaching and how students learn in each style used for instruction. In table 1 (p. 435) of their paper reproduced below, they give an overview of the different teaching styles. These differences clarified for me the need to impact some sort of change in my teaching style to better serve my students.
Table 1  

<table>
<thead>
<tr>
<th></th>
<th>Conceptual teacher</th>
<th>Traditional teacher</th>
</tr>
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<tbody>
<tr>
<td>Teaching focus</td>
<td>Getting students to reveal their ideas about physics in a particular situation</td>
<td>Getting students to solve problems</td>
</tr>
<tr>
<td></td>
<td>Getting students to discuss and reason about which of a range of explanations is best</td>
<td>Getting students to perform cookbook style laboratory work</td>
</tr>
<tr>
<td>Developing conceptual understanding</td>
<td></td>
<td>Developing explanations using algorithms</td>
</tr>
<tr>
<td>The role of questions</td>
<td>To promote student engagement with physics ideas</td>
<td>To provide correct physics information</td>
</tr>
</tbody>
</table>

Mulhall and Gunstone then go on to explore the root meaning of being a conceptual teacher vs. a traditional teacher later in their paper. Firstly, a conceptual teacher outlook,

The typical Conceptual teacher considers that doing ‘problems’ helps students’ learning in physics. Given that the word ‘problem’ in physics teaching is a generic expression that includes both qualitative and quantitative exercises, does this mean that the Conceptual teacher regards both types as equally useful? Firstly, the Conceptual teacher considers he/she should focus on developing conceptual understanding using qualitative exercises before introducing students to formulas. Secondly, he/she believes that students can do quantitative problems without understanding. Hence it is likely that he/she sees qualitative problems as being more valuable than quantitative ones in terms of promoting student conceptual understanding. (p. 438)

In comparison to the conceptual teachers’ framework, a more common caricature of a senior high school physics teacher emerges as Mulhall and Gunstone discuss traditional teacher methods,
The typical Traditional teacher thinks that students learn physics by:
• doing ‘problems’, which develops students’ ability to answer examination type questions and consolidates their learning. While, as noted above, ‘problems’ may be either quantitative or qualitative, the typical Traditional teacher values and emphasizes the former, in keeping with his views that physics is mathematical.
• doing laboratory work, and that this learning comes from the experience itself; that is, the experience alone teaches students.
• the teacher revealing physics ideas through telling, explaining, and demonstrating. (p. 438-439)

Mulhall and Gunstone (2012) identify that traditional teacher’s viewpoints are that physics ideas are revealed through observation and experimentation, and that physics knowledge is unproblematic. (p. 439) They then argue that conceptual teachers recognize the social aspect of classroom life to be important, that class discussions and interactions with others using physics language is important to building knowledge in physics, similar to a language immersion setting. Whereas the traditionalist teacher conventions of learning physics becomes a game of acquiring information, mainly through preparation for exam type problems and completing step by step laboratory procedures. (p. 439-440).

I can see myself, as most teachers see themselves early in their careers in the traditionalist teacher role especially when the Provincial exam still existed in Physics, at the time I didn’t see a way around covering all the information without using a method to deliver the content quickly and purposefully. I endeavor to move into a more conceptual method of teaching as I become more familiar with constructivist methods. The next section will identify some of the positive aspects of constructivist methodologies and will help me open up a new set of possibilities as I move forward in teaching this new conceptual-based class.
Positive Implications of Using Constructivist Methods

A paper by Larkin (2013) in the International Journal of Engineering Pedagogy helped to concentrate my focus on this new Integrated Physics course. Larkin describes an introductory physics class for non-physics majors in which the students prepare during the entire year to present a final project in the form of a properly researched, analyzed, written, and peer reviewed scientific paper at a mock conference in which members of faculty and of the scientific community around the university are invited to attend. Students had choice on the types of projects they could complete within the scope of the material covered during the course, how these learning artifacts would be presented, and they also had an active role in the assessment process. Students had to present their paper during a ten minute presentation at the conference.

Larkin used a reflective writing process instead of the traditionalist methods described by Mulhall and Gunstone (2012) during the class as a way of making physics seem less intimidating to students (p.43), as even the word ‘physics’ instills fear in some people that the content will become overwhelmingly difficult. This fear is deeply rooted in; the abstract mathematical nature of physics, the perception of many learners that they do not have the special attributes or are not in the ‘top tier’ of students, and can also be traced to students’ present misconceptions that they bring into the class from their upbringing (Mulhall and Gunstone, 2012, p.444). By overcoming these fears, the ongoing reflective writing process used by Larkin often led students to further develop sections of their reflections for their final written paper to be presented at the conference. Two main themes arose while reading this paper were that, individuality breathes life into a stale curriculum, and projects that cause students to become critical thinkers will lead them
down a path of active rather than passive learning. I believe that active learners who are engaged in high school classes are more motivated to complete higher order mental process questions and projects than their passive counterparts. I have seen this dichotomy in my own class numerous times during my teaching career. Larkin elaborates in the article on the use of exams as an assessment method by saying,

> [w]hile traditional examinations and quizzes may provide faculty members with some information about what students are learning, this more summative type of feedback really comes too late for in terms of allowing students time to make any adjustments to their understanding. (p.39)

Larkin instead suggests using writing as a possible way for more active learning to occur in the class while maintaining a high level of academia in the following way, “a carefully crafted writing activity or set of activities can provide a more formative and authentic assessment of student learning; and give students and professors time to correct any misconceptions or flaws in reasoning as the learning is ongoing” (p. 39). Traditional assessments will likely still be used to help alleviate the parent and administration fears that the curriculum isn’t being covered in its entirety.

These writing assignments must ensure that the students who are fluid writers are still mastering their physics knowledge, as this may become a problem for some students. The goal is to not have an English/writing class sprinkled with Physics content, but to use the writing as a tool to properly identify and display the scientific knowledge gained. Using this writing process a guide, I began to use written reflection as part of the process in my class, and while students were unsure at first, they quickly found success. With these ideas in mind that individuality is important in classes such as physics and active learning is a process that takes time to master, I delved into other readings.
Pecore (2012) adds that through constructivist learning methods students naturally “become less dependent on teachers and texts for answers and more reliant on the content knowledge they acquire through personal research, their own judgment, and common sense” (p. 9). This further strengthens the case for individuality in the classroom as put forth by Larkin. Students in my integrated class routinely build projects or research problem solutions for final unit assessments and the individualism that comes from their completed projects is quite vast. Each student brings a different focus to the same topic, which leads down a different path each time. Pecore identifies 5 constructivist learning outcomes and measuring these outcomes becomes the focus of his paper.

1. Personal relevance relates content to students’ everyday interests and uses their everyday experiences as a meaningful context for learning.
2. Critical voice involves fostering students’ critical attitudes toward the teaching and learning activities by encouraging a sense of personal autonomy as a way of providing student ownership.
3. Uncertainty deals with learning that is reflective of the discipline’s complexities, such as understanding scientific knowledge as evolving and provisional, shaped by social and cultural influences, and arising from human interest and values.
4. Shared control includes active engagement through inquiry where the learning environment values and challenges learners’ thinking by providing students with opportunities to manage their own learning activities and negotiate social norms of the classroom.
5. Student negotiation engages students in collaboration to support testing ideas against alternative views, reflecting on the viability of their own ideas, and encouraging development of self-regulated learners. (p.10)

I am most interested in how points one (1) and five (5) work in my classroom. Students will chose topics for research or projects based on personal interests to gain a better understanding of the physics involved with some of their favorite activities (e.g. curling, Frisbee, hockey, etc.). While in consultation with myself and their classmates,
new ideas or different ways to measure an intended outcome are often brought up that had not yet been considered. It is a challenging experience for most students to step away from the normal rote problem solving method in senior a science class, however utilizing a shared control model actively engages their minds to search for deeper meaning. Allowing this shared sense of control and accomplishment further strengthens the case put forth by Mulhall and Gunstone (2012) that students do not need to be fearful of physics, only that they attack it an a way that most benefits their learning. Mulhall and Gunstone conclude their findings with the major differences between conceptual and traditional physics teachers; traditional teachers may not differentiate the knowing component of physics principles with the understanding of these components, whereas the conceptual teachers trust that students will construct their own physics meaning according to their personal frameworks, and that though collaboration with others will tease out understanding of the physics ideas being presented. (p. 444)

A continuum of change. Effective teachers are constantly looking for ways to motivate students in their classes to perform better, achieve personal goals, extend learning opportunities, and become more active members of society. Neo and Neo (2009) identify constructivist methodologies being used to “gauge students’ attitudes and perceptions on their acquisition and experience with skills such as critical-thinking and creativity skills, teamwork and group skills, communication and presentation skills, multimedia technology skills, and the ability to properly apply them” (p. 261). It is these skills that teachers who choose constructivist teaching methods are trying to advance, invoke, and inspire.
Larkin’s (2013) study mentioned earlier is an exemplar of this type of thinking and puts it into action. Savasci and Berlin (2012) added to the discussion by identifying a continuum on which teachers are placed based on their teaching styles. In their multiple, cross-case qualitative analysis, Savasci and Berlin studied four teachers over a four month period and identified a five layered scale which begins at the fully teacher directed didactic phase where almost all teachers begin their careers; it then moves through transitional constructivist, emerging constructivist, and progressing constructivist with the final phase being expert constructivist teaching methodologies which fully enhance the teacher’s ability to utilize the student as the means of directing their own learning (p.73).

Savasci and Berlin’s (2012) continuum expands on the 2 groupings of teacher types, conceptual and traditional from Mulhall and Gunstone (2012) discussed earlier. As I become more familiar with the research in this area of constructivist teaching I begin to see the core of the reason that I have chosen to adapt my style into this new method for this new class more clearly, instead of simply continuing on the same teacher directed traditional didactic path I was teaching on and was taught with. Although I am not on the expert conceptual constructivist side of the continuum laid out by Savasci and Berlin, I believe that I am at least moving in this direction. As teachers move away from didactic, traditional methods such as: formal instruction, worksheets, quizzes, tests and step by step lab procedures, the learning processes will be strengthened for the students, increasing motivation, invoking deeper understanding, and active thinking. The students will become, by default, critical of their own actions and make appropriate changes to ensure the growth of their learning. This, of course, is the ultimate goal of education.
Challenges of Constructivist Learning Environments

Whenever shifts away from trusted methods and paradigms are attempted, struggle, resistance, and difficulties will arise. Many challenges will arise from a paradigm shift in public schools as we are always in the spotlight, under scrutiny, and making do with what we have, which is often not enough. The usage of constructivist teaching methods has been no different. Roadblocks such as; resources, money, release time, professional development, willing teachers and administrators are all a part of the puzzle in changing a particular ideal or structure in our educational system.

What Makes Physics so Challenging in a Constructivist Way?

In the case study completed by Mulhall and Gunstone (2012), it was noted that in their study of thirty-seven teachers, only 14% had constructivist viewpoints towards physics education (p. 433). Mulhall and Gunstone, who are both former physics educators, collected their data to distinguish traditionalist teachers from conceptual (PBL) teachers. Data was collected mainly through semi-structured interviews and classroom observation of classroom teaching. Participating teachers were asked a number of questions based on their ideas of how physics and math were related; why is physics so challenging for some students? Why it is challenging for so many teachers to teach physics effectively? And how is physics knowledge produced in the student (p. 446)? Senior sciences such as physics are straightforward courses in which to place these constructivist approaches as many students will already have preconceived notions of physics ideas before they start the class. These notions will lead to them having difficulty
if they are looking for easy answers and not understanding the bigger picture (Mulhall and Gunstone, 2012, p. 438).

With students making meaning for themselves in a constructivist manner, learning becomes an active process, no longer a passive one, which strengthens the case put forth by Larkin (2013) earlier in this review. When students construct their own meaning, various different constructions may occur, meaning everyone may get something different from the learning, and these differing understandings may lead to confusion between students when having group discussions. The teacher/sage/facilitator/tutor must step in to bring everyone back to a focal point to coalesce their scattered views and findings into a combined thought or outcome that would cover a learning outcome for the course. Often, teachers trying to be conceptual/constructivist forget or skip this most important culminating step, this would then stall their progress along Savasci and Berlin’s (2012) continuum to the fully competent constructivist teacher.

**Practice makes perfect.** Another of the many challenges that teachers face in the design, delivery, assessment, and reflection of problem or project based learning is the time needed to become proficient at teaching it. Practice is always required to become better at something new, and teaching in a new style will most certainly require practice. As any new teacher would recognize, the preparation for a new course often seems unsurmountable sometimes, changing to a new teaching style would be no different. Time to build challenges that are grade or course-level appropriate, practice on how to deliver the challenges and how/when to step away, and when to step back in to offer help will all take time to learn. Unfortunately, it seems that time is the determining factor for all those involved and is always in short supply.
Effectively, a student centered science classroom must first start with educated teachers. It is through these teachers who have trained in these new methods that the growth in this discipline will occur. Unfortunately, in many of the research articles in recent years, the concepts of; time, district support, and the money to properly train teachers for these new programs or methods of teaching (e.g. constructivist ideologies) to flourish has been found to be lacking or in some cases non-existent. Professional development in this area is underused as it is difficult to engage teachers in new fields of teaching strategies once they have built up their teaching arsenal, especially as it pertains to the senior academic sciences. Richardson (2003) identifies nine core features of professional development that must be followed in order for the experience to be impactful. These key aspects of worthy professional development are as put forth by Richardson are:

- be school-wide;
- be long-term with follow-up;
- encourage collegiality;
- foster agreement among participants on goals and vision;
- have a supportive administration;
- have access to adequate funds for materials, outside speakers, substitute teachers, and so on;
- develop buy-in among participants;
- acknowledge participants’ existing beliefs and practices; and
- make use of an outside facilitator/staff developer

In the Pecore (2012) study, a two week summer training session was held for all participants wanting to learn more about the process of problem based and project based learning styles. After the summer development session was completed teachers were expected to utilize the newly acquired skills in their regular classroom teaching the following year. In one case, a high school biology teacher faltered in a school without administrative support for the program, clearly contravening one of Richardson’s 9 points
of effective professional development. Other teachers in Richardson’s study had a wide range of successes and failures due to a variety of circumstances. A few of these were; money or district/administrative support being present or not, a willingness for teachers to give up control, and the general classroom atmosphere (p. 20-22).

Teachers aren’t the only ones that need to change. Changes that take time are sometimes very difficult to maintain enthusiasm for by interested parties. Tamim and Grant (2013), follow up on the 9 points made by Richardson by stating,

\[t\]herefore, teachers adopting PBL need professional development and support to hone their skills on how to implement this instructional model, even after they express interest and show motivation to a PBL environment. Moreover, they need appropriate resources in order to overcome the barriers that hinder their implementation of PBL to its fullest potentials. (p.75)

Savery (2006), a proponent of problem based learning, addresses the challenges of constructivist methodologies in the following way, “[t]he adoption of PBL in public education is a complicated undertaking. Most state-funded elementary schools, middle schools, and high schools are constrained by a state-mandated curriculum and an expectation that they will produce a uniform product” (p. 17-18). Unfortunately, this passage reads true of our school system in British Columbia as well. If the Ministry of Education and ultimately, post-secondary institutions, are expecting a uniform product from my senior physics students, how can teachers promote individuality in their teaching and how can students access their individuality as Larkin endorses? Would it not be a more useful to have students, and eventually citizens in society, well versed in numerous ways to identify, analyze, deconstruct, and ultimately solve problems?
English and Kitsantas (2013) identify typical challenges to constructivist learning environments for both students and teachers,

\[
\text{[t]he student’s role in PBL is to take responsibility for their learning and make meaning of the knowledge and concepts they encounter. To do this effectively, it is clear that students in the PBL environment must be motivated to learn and be able to focus their efforts and attention appropriately, monitor and evaluate their progress, and seek help as needed. However, teachers report that many students do not possess these skills. (p. 131)}
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As identified by the above quotes, teachers are not in this alone; it will require the collaboration of many agencies and groups of people, including the students themselves that will be result in the most positive change possible.

**Farming and Teaching, a Positive Correlation**

Ultimately, within the classroom, the teacher has the final call in regards to the learning environment. The atmosphere in which this learning occurs is very important to all those involved, a classroom has four walls that give it physical structure, within those walls, in the case of many teachers and schools, are perceived silos or compartments in which their teaching and ultimately the learning of their students are encased (Asghar, Ellington, Rice, Johnson, & Prime, 2012).

These silos are the individual science courses that can be taken at high schools: physics, chemistry, and biology. Constructed, filled, and taught separately for decades, these silos, or individual curricular topics, have been and will continue to be difficult to open and combine unless teachers are willing to expand their vision to include other options for teaching. The silos contain only one type of knowledge, just as a farmer
would not mix the grains collected from different fields, teachers tend to not mix their disciplines of teaching. Asghar et al. (2012) state with a direct quote from one of the participants in their qualitative case study that, “[y]ou can bring the knowledge as a team and solve the problems and model behavior for students to help student make connections across science, math, engineering, and technology, and solve real-world problems” (p. 100). This would address points from Richardson’s professional development analysis nicely, these changes need to be school wide, possibly district or province wide.

By working together in interdisciplinary groups rather than in isolated islands teachers can effectively begin dismantling those constraints, barriers, and silos that so often drive our teaching practices. It is no act of trickery or magic that will aid in teachers and students using these constructivist strategies, it will be a full effort between teaching staff, administration, school districts, and provincial or state ministries that will shift the paradigms of learning for today’s students.

**Conclusion and Summary**

As a result of my search into the literature and learning about many of the possibilities of a student-centered approach to teaching and learning, I have identified a number of aspects that I believe are important for me as I move along the continuum of constructivist teaching as laid out by Savasci and Berlin (2012). Both the students in my classes and I were ready for a change, students became too comfortable in the ‘is this a notes day again or a work day on our questions’ mentality, and frankly so had I. Teaching in this constructivist method has been and will continue to be difficult, but ultimately will be rewarding for both students and for teachers, and will need to be
supported from a number of different angles to become and remain successful in my class.

The paper by Larkin (2013) has set my course for the next year(s) in Integrated Physics as I would like to emulate his approach in having writing become a major focal point in class, first for reflection, moving on to data analysis, and finally to produce a polished, ‘publishable’ paper to present to the community in a forum or conference setting. Understanding that many students taking the senior sciences are not the strongest writers, I must be careful to offer assistance and opportunities to show learning in other ways. It is my goal that through the rest of this paper I can continue to identify the needs of my class as a constructivist teacher and address those needs in order to serve my students well as move across the continuum from didactic to constructivist. As I move forward in my teaching and in this paper, I will take many of the points raised by reading this literature and apply it in a way that benefits everyone in the Integrated Physics 11/12 class.
Chapter 3: The Integrated Physics 11/12 Class

As was shown in my review of the literature, constructivist approaches to teaching include: inquiry/discovery, problem-based, and project based methods. The rationale for my structuring and offering the Integrated Physics 11/12 course as presented is that this allowed myself and the students who chose to take the class to highlight these constructivist types of learning, and to utilize these methods to allow a sense of learning rooted in the authentic experiences of everyday life as they pertain to physics. As I reflect on my practice and the launch of this new course I have come to realize that a more specific form of constructivism shines through, that of socio-constructivism. Socio-constructivism is rooted in the works of Vygotsky and is identified by the use of the social aspects of the classroom to help the students grasp concepts that were previously too problematic to handle on their own. Some of these social aspects in the Integrated Physics 11/12 class could be, group work, solving problems that require a variety of skills not attributed to a single student, peer-evaluations, or discussing current class topics with terminology learned in class with other students in the school community.

Within this chapter focus will be given to the integrated class itself along with various examples of what a typical student would be expected to complete. In addition to these examples of student expectations, the course design and layout will be discussed in detail and the three types of socio-constructivist learning styles that were utilized during the course and many examples of their uses will be reviewed. These three types of socio-constructivism were; inquiry/discovery learning, problem-based learning, and project based learning. The chapter will also include a discourse regarding some of the negative
and positive aspects and outcomes of the course from both a teacher and student perspective.

As a context for this project, the Integrated Physics 11/12 course is typically taught at a middle sized high school setting (approximately 900 students) on central Vancouver Island. This school follows a standard five month semester system. Each school day consists of four, seventy-five minute blocks with a non-rotating block order. The school demographic is made up of grades 9-12, and includes students from rural farming areas, outlying islands, numerous First Nations reserves, upper middle class families, impoverished city center students, and the French Immersion cohorts of the district. The school’s student population is diverse and the staff often remark how much they enjoy the mix of these students in their classes. We have found that the students benefit from an exposure to each other’s experiences, and that they often can learn together as a group better than as individuals.

After teaching Physics 11 and 12 for a number of years, I proposed to have the two courses taught simultaneously in a half day setting for the a number of well-defined reasons. Some of these included: to cut down on the amount of time needed to properly review Physics 11 material in a Physics 12 class as it takes nearly a month of time to do this properly. The ½ day setting would allow for more opportunities for in-depth analysis and for field trips or guest speakers with no impact on other classes. It is in these settings where I believe that the authentic, experiential learning will be most valuable in this course.

As stated in the literature review by Larkin (2013), students that have the opportunity to reflect about their progress in a science-based class, and have the
opportunity to discuss with other like-minded students using terminology learned from class will have a better understanding of the concepts presented to them. The format chosen to run this course allows this reflection to occur more frequently than in a standard semester system. Another reason that I proposed this course is that it allowed students to use a socio-constructivist approach during the laboratory component of the course in order to have a deep understanding of the principles behind a well-constructed laboratory task instead of merely following directions to get an intended and obvious result during a ‘cookbook’ style lab which I have previously used for years in my standard physics classes. Finally, the extended time in class allows me to connect with the students in the course and have them feel connected to a group at the school as a community of learners. As stated before, our school prides itself on being welcoming to our very diverse population and being part of this class cohort for some students allows them to have a place to call their own for the semester.

The change to a new course structure also allowed me to change the assessment strategies and tools that I used in the class. The use of rubrics has become a standard practice by me throughout the course. Students were given input on the production of the rubric and how it would be utilized. The class shifted from traditional methods such as tests quizzes, and assignments, and moved towards a more well-rounded approach that focused on project work in each unit.

In my teaching experience, some students can be hesitant to change the learning approach that they knew so well and have typically used for the majority of their schooling. During the teaching of the Integrated Physics 11/12 some students remarked that they preferred the other, more traditional method of class teaching, primarily the
stand and deliver or transmission approach. Some felt that the constructivist approaches we were using made them think *too hard*. Although such a comment may be taken as flippant or humorous, during further conversations with the students, I understood that they did struggle with identifying learning outcomes, using rubrics, and constructivist approaches during the initial phases of the course.

**Layout, Structure, and the Building Blocks of Integrated Physics 11/12**

As stated previously, the Integrated Physics 11/12 course runs for two consecutive, seventy-five minute blocks, either all morning or afternoon, at a middle sized high school on central Vancouver Island. The population of this school fluctuates between 850 and 920 students on a yearly basis. The integrated course runs over the length of one five month semester at the school. In order to accommodate covering the prescribed learning outcomes in both the physics 11 and 12 curricula within the five month semester, I found that the overlaps in a number of similar units could be exploited to give the students a broader look at physics as an entire field of study, rather than as individual topics (PLOs) put together in a unit for the separate courses. For example, kinematics is covered in both grade 11 and 12 courses to varying degrees. Kinematics is the study of how things move, and within the unit terms like acceleration, time, displacement (distance) velocity and the changes in these quantities are discussed in detail both theoretically and algebraically. Physics 11 stops the unit at horizontally fired projectiles while in Physics 12, the entire Physics 11 unit is reviewed with the addition of projectiles fired at an angle is where the quadratic equation might need to be used to solve for time of flight in the parabola.
It was looking at these overlaps that piqued my interest years ago into starting a ‘bigger picture’ physics course. Kinematics, Dynamics - the study of why objects move, Work, Power, Energy, and finally Momentum all coincide to a great degree in the grade 11 and grade 12 courses. The biggest difference in the grade levels is that calculations are carried out in one dimension (straight lines) in Physics 11, and in two dimensions (including angles) in Physics 12. The Integrated Physics 11/12 course outline and student formula sheet handed out on the first day of class are attached as appendix 1 and 2 respectively. The formula sheet was the concrete proof that we were doing real physics even though an in class discussion may lead us down a non-standard path in the class, I always endeavored to bring the discussion back to the equations at hand in the current unit of study. In some cases, student projects were prepared to investigate single formulas on that sheet, it was their most important possession while in the class, and everyone used it differently.

At the beginning of the course, we discussed, as a class how to best approach inquiry, problem, and project based learning in the context of the topics to be discussed. A beginning inquiry model sheet was presented and adapted to give students a starting point in this new socio-constructivist framework in which they were about to begin learning. This beginning inquiry project handout is attached as appendix 3. Introductory inquiries used in the first weeks of class included making the furthest flying paper airplane and an egg drop. When I deemed them ready to move further, students in randomly assigned groups of three to four students had to construct a working sailboat out of nothing more than a small Styrofoam bowl, two playing cards, three wooden skewers, assorted lab masses, thirty centimeters of masking tape and a single sheet of
legal sized paper. After construction, the boats were timed while navigating across a five-foot wide water tank powered by a standard box fan placed on one side of the ‘lake’. Students were encouraged to test float their boats in order to carry maximum mass and reduce time needed to cross, as we took the mass divided by the time ratio to determine an overall winner.

**Constructivist Learning in the Integrated Physics Classroom**

I have taught this new integrated class twice over the past two years; both times a labour dispute effectively shortened the learning time for myself and the students enrolled in it. First, the course was shortened by more than two weeks at the end of the semester, the second cohort was shortened from the beginning by three weeks with a week of time added at the end of the semester. The two classes that have been a part of my new approach were different in a number of ways. There were twenty-nine students during the first year and nineteen in the second year. The larger class was more apt to have deeper physics conversations as a group, whereas the second, smaller cohort contained more analytical scientific thinkers and chose to be less social. Many of the second course cohort students are on the path to engineering as their post-secondary choice. The first cohort would be less likely to take this route. There were also a number of similarities between classes. Both classes had a number of very high achieving students who put a lot of pressure on themselves to perform well in all classes. Each class also had a small number of students who either struggled with concepts, did not actively engage in the new way the class was presented, or had poor attitudes towards school in general.
The main reasons that I chose to have this class run consecutively over two, seventy-five minute blocks every day for a five month semester instead of using one block for the full school year, or to have the standard timetabling of offering Physics 11 in grade 11 and Physics 12 in grade 12, was the opportunity to use the half day block to delve more deeply into the current topic at hand, to have discussions that interested students, to explore ideas, and ultimately to construct learning in a new way for students. This socio-constructive learning process took on a number of forms in these classes: student discussions, having guest speakers join us in class from various fields of science, student initiated projects with research time in the computer lab, and as Larkin (2013) suggests, using written reflections. These reflections became a more prominent feature in the class as I became more comfortable with this approach.

I utilized three of the main ideologies of socio-constructivist learning techniques in this class to varying degrees. We employed inquiry/discovery learning where students mimic actual scientific methods used by professional scientists in order to obtain results. In problem based learning students are given a specific problem in which to solve, often within a small group setting. Finally, in project based learning a tangible learning artifact is constructed in order to meet the end goal of the learning outcome(s). A short description of each method of constructivist styles and examples of how they were incorporated into the Integrated Physics 11/12 class will follow.

**Inquiry/discovery learning.** Inquiry or discovery learning can be thought of as “mirroring the processes used by scientists” (Minner, Levy, & Century, 2009, p.3). In the Integrated Physics 11/12 class, I would often allow students to play with the data
gathering equipment in order to become familiar with it before assigning a task or having the students build a project around the piece of equipment. This discovery learning regarding the data collecting tool allowed students to formulate a plan for what type of data they could collect, how to best collect it, and to identify some of the limitations of the device before trying to use it in a project built for the unit assessment. Having the course taught over half days allowed the students to make use of more time in class with the equipment to identify the potential uses of the data collection tools. Reflecting on the choice to use class time in this way, I found this method of introductory discovery was a valuable instrument in the eventual need for students to build skills as scientists.

Examples of this inquiry/discovery method in class were; using a slow motion camera to capture and analyze data from a number of situations at 400 Frames per Second (FPS) or at 1200 FPS, this data could then be uploaded as part of a project presentation or report. In a different unit of study students used an air track, slider cars, and a double photogate system to investigate the Laws of Conservation of Momentum and Energy for both elastic and inelastic collisions. This conservation lab is commonly done as a ‘follow the steps cookbook style lab’ in standard physics classes but with our extended time period, students could sign up for times to use the equipment to its fullest educational potential.

Using some grant money that the science department had recently obtained to buy portable data-loggers and sensor kits, students could collect data such as; voltage, current, temperature, acceleration, and force from a field position somewhere in the school or even at home, which then could be analyzed at a later time back in the classroom. Opportunities to use an ultrasonic motion sensor record data for position and time of both
lab cars and students in class doing various things were also available. This information is then manipulated to build graphs to determine velocity, acceleration, and displacement of the situation. Lastly, students used simple metre stick optical benches to discover properties of optics materials such as index of refraction, focal lengths of lenses, and multiple lens systems.

Students quickly understood the need for accuracy, precision, reliability, and replicability while using the equipment, as a result they ensured that all group members were fluent in equipment set-up, take down, data gathering and the analysis of collected data. At the end of each course I had asked for student feedback regarding some of their learning highlights. Being allowed to use equipment inquiry time was the most liked activity for a number of students because it gave them freedom to learn by exploration, which would not have been possible in standard class design models due to the lack of time required in order to finish the outcomes as set out by the BC government’s Integrated Resource Package.

**Problem based learning.** Pecore (2102) identifies problem based learning as; “[w]ith instructor assistance, the group determines the issues to research. Groups then share their research with the class, receive additional information and/or conduct an exploratory activity, and continue researching the problem” (p.8). Savery (2006, p.12) identifies that problem based learning best exemplifies socio-constructivist methods when the problem is ill-defined. This allows students to lead themselves down a path of learning, not down one which has been constructed by the teacher. I tried to incorporate as many of these types of “ill-defined problems” into each unit of study as possible.
Below are just a few examples of problem based learning in the Integrated Physics 11/12 course:

◊ Students in small groups were required to produce an experimental set up that could be used to measure torques and tension forces at certain points from a loaded beam (metre stick with weights attached), attached to a fulcrum (pivot point).

◊ Using a free web-based comic strip designer called Pixton, students had to correctly illustrate Newton’s 3 Laws of Motion in three, three-panel strips.

◊ After completing the unit on circular motion and gravitation and learning how to use orbital motion and rocket design software (Kerbal Space Program, edu version), students were tasked with designing rockets capable of orbiting the home planet of Kerbin, going to distant moons or planets, extracting scientific knowledge from these extraterrestrial zones and safely returning to Kerbin. Focused discussions occurred around thrust to mass ratios, designs to reduce atmospheric air friction, rocket stability, fuel consumption/efficiency, vector addition for maneuvering the rocket, supplies required for a return voyage, orbital velocities, and periods of revolution for orbiting bodies.

◊ With limited supplies and time available to them, the student were asked to discover the coefficients of friction (static and kinetic) of two different surfaces somewhere in the school. (See appendix 4) Students were given planning space on the provided sheet and some used it well, others did not think it through first and had to completely restructure their approach after stalling in their attempt to complete the task. This was a lesson for some on what real scientists would do, I
wanted the students to completely follow through on their idea and make the necessary changes as they discovered what worked and what did not.

◊ Using one or more data collection methods, students were required to accurately measure the acceleration of an object and display that information graphically.

◊ As a class, we took a field trip to the local curling rink. At the rink we learned the basics of delivering a rock properly and safety, and used these rocks to measure the coefficient of sliding friction between the ice and the rock. This value was then compared against standard values of the frictional coefficients of curling ice to discuss possible errors in lab design or more accurate ways of obtaining results. Data was also collected with overhead slow motion video shots of colliding curling rocks in order to prove the Law of Conservation of Momentum in a real life situation back at the class.

At the outset of the class, students struggled with these types of tasks as they had never been exposed to many of these socio-constructivist methods before. Many of the students did not want to become the leader in their group or to give direction. As a result, many groups required a little more encouragement from me on the sidelines. Some students refused to participate in the beginning as they did not interact well in groups, but by the end of the semester most, if not all of the students, asked for more problem based work to solve in one form or another.

**Project based learning.** In project based learning, a learning artifact (project) is produced that satisfies the intended outcomes of the assessment or project. The final artifact may or may not be elaborate, visually impressive, or completely as the student
had first envisioned it but as Prince & Felder (2006) identify, “the acquisition of new knowledge and the solution may be less important than the knowledge gained in obtaining it” (p. 130). This quote rings true for this experience for me as a teacher and the students who chose to take this course. The project topics were not in any way mandated by me. The students took their own interests and used the materials at hand in the school and at home to collect data. Students took ownership of their project and molded it to present the intended topics. A sampling of memorable projects (leaning artifacts) constructed in class included:

- As a final course project, one student tackled the physics of the violin, complete with slow motion video of the vibrations in the strings as they were being played and sound level (decibel) readings at different bow speeds and bow pressures.
- To show the basics of projectile motion, a mechanically minded student built a large potato cannon. Using the slow motion camera, a mounted 2.5 metre long scale and the equations of projectiles learned in class, we safely tested the cannon in the school field to determine the muzzle velocity and maximum possible range. The results were astonishing.
- A group of girls that were part of the same dance troupe determined the coefficient of friction between the floor of the hallway and different types of their dance shoes (tap, ballet, jazz) using an ultrasonic motion sensor that measured their decreasing velocity as they slid towards the sensor on their shoes from a running start.
- An avid golfer investigated the angles and velocities of struck golf balls with different clubs and how the angle and/or velocity changed the final range of the
object. He also used dimple-less golf balls and compared their maximum range to standard golf balls to address air resistance and aerodynamics as part of his final project.

◊ A complete working trebuchet was built (less than 75 cm in height) as a final project by one of the dance girls identified above. This machine was capable of throwing small objects in order to understand the concepts of transfer of energies and projectile motion.

◊ More than one final project was completed on the physics of the human eye or the ear and how either light or sound waves are collected, converted from mechanical waves in to electrical nerve impulses, and finally translated by the brain as an image or recognizable sound. In particular, one of these projects explained thoroughly the process that optometrists use to determine the prescription required to correct the vision of a patient who is near-sighted (myopic), far-sighted (hyperopic), or has an astigmatism. This particular student made a specific appointment to interview the optometrist about these equations and build her understanding of them for the verbal presentation she was required to give as part of the final project assessment.

Written assessments (exams and quizzes) were always given as an option to a unit project assessment. But as the students progressed farther into the course most found that the experiential learning gained in attacking a topic they chose and had built a project around was more beneficial than trying to study the many concepts at a more superficial level in order to regurgitate the question styles on a written test. It was interesting to
witness such a change in the students thinking as the rationale for the course included student involvement in their own learning.

When our grade twelve students walk across the stage on graduation night they have a short reflection called ‘walk down notes’ read out for the audience to hear. Often the students thank mom, dad, and their friends for the support that they have given over their years of schooling. A number of students over the past two years have referred specifically to the Integrated Physics 11/12 class and the work that we did in their walk down notes. This informal evidence leads me to believe that a positive, paradigm shifting experience was had in the class and that authentic, well placed learning occurred during our time together. As I am often asked by the graduating students to be the Master of Ceremony at the graduation event I am pleased to hear their comments regarding the course be aired in such a public venue about the positive experiences that many students had in our class. These comments reaffirm that the hard work in putting the Integrated Physics 11/12 course together has been worth it from both a professional educator and on a personal level.

Each of the above constructivist approaches were well suited to particular areas in the physics class as they ask for different skills to be used by the students as they move through the sometimes difficult path of changing their learning style from traditional to non-traditional. As in any paradigm shift in the educational field, some will find the change to be stress-free, while others will find difficulty at every turn. Upon reflecting on my own practice for this project, I have noted changes in both students’ and teachers’ experiences. Positive and negative outcomes in both a teacher and a typical students’ perspective are discussed below.
The Good, the Bad, and the Indifferent

Just as the students in my class needed to adjust to a new learning style when they signed up for the Integrated Physics option, as a teacher I also needed to change the way that I taught, marked, planned, managed instructional time, and envisioned the course unfolding from beginning to end. Each of these new pieces to the puzzle for everyone involved made the switch from traditional to constructivist sometimes seem as smooth as glass, and other times like driving a go-cart with no suspension through a game trail in the forest. Here I will identify both positive and negative aspects for learner and teacher as encountered during the teaching of Integrated Physics 11/12.

Positive aspects of Integrated Physics 11/12: student perspectives. When asked about the comparison to a standard Physics model over 2 semesters and traditional teaching methods one student taking the integrated option replied that their friends who take the standard two semester Physics 11 and 12 separately have remarked that they have no understanding what is going on for their unit tests, they only place the unit test questions into patterns and hopefully come up with the answer. Furthermore, this integrated student stated that the Integrated Physics 11/12 option allows for design, creativity, cooperativeness and during the construction of a unit ending project all of the unit’s learning outcomes would be utilized in some form or another, instead of being addressed by one or two random questions on a test.

Students were given the option to work in small groups for projects and many students mentioned that this co-operative method will better serve them for university level classes, where study groups might be formed as they were able to express their
ideas in a safe atmosphere in class to build confidence in their own knowledge base, instead of feeling isolated on an island in the middle of a unit test. Four male students were instrumental in constructing a number of working roller coasters out of a large K’nex® educational set that the school purchased but had never used. This allowed these four boys to quantify the amount of potential and kinetic energy in the roller coaster at a given time with the slow-motion camera and a photogate timing system as a component of their work, energy, and momentum unit project. All four boys identified this as one of the highlights of their time in the course as they were able to use their kinesthetic learning skills to construct a physical object in order to access the physics behind the roller coaster.

When asked to compare the integrated option to the standard two semester option most students said they will retain more information mainly because of the extra time in each class to ask questions, clarify, reflect, and work through common faults or misconceptions in their learning as a group. This further reinforces my desire to change into this socio-constructivist style of teaching as it seems to be successful so far, with more practice and constant revision, the process will become more uncomplicated to plan and carry out.

In addition to project planning and building, taking notes, and learning new skills in data gathering in the class, the class was tasked with coming up with real life applications of the principles/laws being discussed at the time. Some of the more notable examples were; the Doppler effect of emergency vehicle sirens that passed our classroom window on a daily basis, using torque to open the door on a refrigerator, vector addition in regards to sailing a boat, which is a common pastime for many students in the class.
One sunny day, BC Hydro was working on the power lines outside the school and we took an impromptu field trip to ask a few questions of the linesmen as they were upgrading the power lines on the street. We weren’t even slated to talk about electricity for another month but took the opportunity while it presented itself. We looked at the motion of different sports in terms of acceleration of athlete or object. In addition, the class also looked at the projectile motion of object in different types of sports such as; baseball, basketball, golf, soccer, football, and Frisbee. Students reflected at how they now see physics everywhere they look and will continue to search out physics in everyday life. As this was one of the main goals in presenting this type of class, I was most happy to hear of this cognitive shift in the students while reading their reflections.

When presenting his final project during our assessment week at the school, a male student that had been in trouble with the law in his past completed a first-rate project on power generation in which he spent, in his words, 50 plus hours researching and learning the principles of electromagnetic power production with a family friend who happened to work at a power plant. Together they poured over diagrams and flow rate tables together to gather information on the operation and efficiency of the plant. This particular student relayed that his interest in this field had increased significantly enough to warrant pursuing a career as a power engineer. Considering his sorted past with the law, I was and am still most hopeful that he continues to follow this dream.

Negative aspects of Integrated Physics 11/12: student perspectives. One grade eleven student chose the class expecting to only learn about the interesting physics sections, not expecting to work on classical mechanics, momentum, geometric optics
diagrams and so on. She had expected to go on weekly field trips, have regular guest speakers, and never take notes. Unfortunately it took her too long to determine that the course wasn’t laid out this way and she had been turned off of physics. Similarly, based on the immersion type timeline in the course if a student was away for a sporting event, family trip, leadership event, or any other reason and missed a day of classes, the possibility existed that two blocks per day of new material was covered and they would be required to make it up somehow. Many students felt that the pace of the course was very fast (especially at the beginning until they learned how to cope with a new time frame) and some struggled with keeping up in physics and their other courses at the same time.

A few students expressed concern that the course was becoming too project based and they were running out of project ideas to complete. As mentioned before, every unit had a test option if one wanted to use it. It seemed that the students often wanted to complete a project to get out of writing a test, but couldn’t build a unit project that covered the necessary criteria, and as a result they were stuck in the middle and in typical teenager fashion, rebelled and complained. In the end, one assessment needed to be completed, often it was a test as it required little preparation by them if they chose not to prepare, whereas a project must be verbally presented (5 minutes minimum) to me at the end of a unit in addition to the collected data and analysis work handed in to be assessed.

In another situation, a student had often been reliant on others’ work in her first ten years of schooling, and for the first time had to be self-sufficient in class. She had to complete research work on her own and compile her data into a usable form to build a project that fit our criteria. She often asked “can’t we just do worksheets like your other
physics class does?” These comments gained traction with a few of her friends until her friends saw the benefits of the socio-constructivist work. By the end of the semester this particular student had broken down some of the learning barriers that she had and made positive progressions towards a constructivist attitude.

Teaching this class with a new approach and goal in mind has given me the opportunity to identify the strengths and weaknesses in my own teaching practice, and to build on or change them in order to become a more proficient teacher in all of my classes. The most positive and negative outcomes that emerged for me from this class as a professional included:

Positive outcomes of Integrated Physics 11/12: teacher perspective. The opportunity to collaborate with other teachers in the science department at the school in order to incorporate aspects of other sciences into the physics curriculum in my class. These interdisciplinary partnerships between teachers helped students learn how interconnected their environments were even though the courses are separated by name, grade level, and function. During the pre-planning, unit planning, and reflections of the course I was able to expand my own teaching paradigm to incorporate the socio-constructivist methods to truly explore possibilities that can be taught during each section of the course. This course has allowed me to shed the constraints of ‘stand and deliver’ and become more of a facilitator of learning from the side of the class whenever possible, allowing students to guide their own learning in many cases.

Having students work on projects and ill-defined problems in groups has allowed me to actively listen to the questions and solutions as identified by the students. I could then transfer that information into new ways to construct questions and projects for future
years. I found that being involved with this course has opened many more assessment opportunities for all of my classes.

Following Larkin’s (2013) lead, having students write reflections at regular times during the unit process was a much more effective way of gauging cognitive processing of the students as it gave me a real time, accurate, and up to date idea of the students’ understanding of a topic. These written reflections also allowed me to better grasp their particular struggles and accomplishments instead of five, two question quizzes and a unit test would have. Larkin identifies that written reflections are a way for teachers and students to correct any misconceptions or reasoning flaws during the process of learning, not after learning has occurred as in a test taking method. (p.39)

**Negative outcomes of Integrated Physics 11/12: teacher perspective.** Time, unfortunately is never an unlimited quantity and the truth of that statement was shown in this class. Although I taught the students for half days for an entire semester, the intensity and drive that most students used in researching their projects used up a lot of the time in the course. As a result, we covered all the topics in the two curricula but didn’t have as much time for expanding into what the students called, “more interesting physics.” These more interesting topics could have included; quantum mechanics, the nature of light, space travel, and astrophysics. If I have the opportunity to teach this class again, I would try to limit the student’s research time (within reason) to incorporate some of these other topics as possible learning pathways in the course.

Non-integrated students in the school viewed the Integrated Physics class as an easier way to receive credits and higher marks as there wasn’t an emphasis on test writing and test preparation like in math, biology, chemistry, and even my standard Physics 11
and 12 courses. Although some tests were given in class and there was always an option to write a test for each unit instead of completing a project, most integrated students often chose projects because it interested them. In conversing with the integrated students and reading through their reflections it became clear that during the process of researching, planning, building, and ultimately evaluating a unit project more information was learned, retained, and expressed by each student than in a standard unit test. Convincing the students of this fact that were not in the integrated class was, and will continue to be a struggle.

Physics is a course that can be difficult to understand without guidance from a knowledgeable source. Many students bring preconceived notions and misconceptions into physics class from home life and experiences. I found that in order to have the students know enough of the basics to even begin project work that many topics needed to be taught the old fashioned way with me at the computer and LCD projector. This teacher directed learning helped alleviate some of the misconceptions but took precious time away from a more constructivist, experiential way of learning for the students, which in the end, was the goal for changing to this style of teaching in the first place.

Culminating Thoughts on the Integrated Physics 11/12 Project

As I look back on the thoughts and ideas that led me to this new path of teaching physics, I reflect on the positives, and some negatives. From the students who thanked me when the class was done for a truly enjoyable experience, or those who simply turned their nose and walked out the door, I am proud of what I have accomplished in changing my own teaching practice into a more socio-constructivist mindset. As I ponder the
possibility of having another class of Integrated Physics 11/12 again next year, I ask myself, ‘what do I hope that my students gain from the experience of being in the class, what can my school gain from having this type of class as part of the course offerings, and what can my colleagues, both in and outside of the school gain from the experiences I have gained and shared while completing this project?’

From the outset, I have maintained that the Integrated Physics 11/12 option should be fun, worthwhile, a positive learning experience for both myself and the students in the class, and be able to give students the freedom to take their own learning path on a personal journey throughout the course. It may be a meandering path fraught with obstacles common to high school physics students but the guidance is always there from me if they choose to access it.

The upcoming grade eleven and twelve students that would enroll next year in the course will often approach me in the hall to ask questions, email me, or have their parent phone for clarifications regarding the course before opting for it on their course selection sheets. In the back of my mind I hope that the integrated course allows a breadth of choice for our students while they plan their academic future at the school. A school with a living and changing course offering is more likely to attract interested students and stay ahead of the curve for 21st century learning practices.

In the final chapter of this project work, I will discuss some of the most important aspects from my point of view while I took this personal journey through the Integrated Physics 11/12 journey. Changes to my own personal teaching style were challenging, worthwhile, time consuming, and time sensitive. Also in the concluding pages of this project I will include other courses offered at our school that are outside the standard
courses offered at many typical high schools across the province. I also discuss some hints and tricks that may help other teachers interested in designing this type of class be successful.

As colleagues of mine, both inside and outside my school district hear about the opportunity to offer an integrated option, possibly from reading this Master’s Degree project write-up, I think of the vast network of experiences that could be shared throughout the teachers at conferences, professional development days, informal meetings, emails, Skype sessions, and even phone calls. It is as if the course is waiting to be released, to be channeled in some way so that it may become a future course that is recognized by the BC government as a method to increase interest in an age-old science. Or possibly be changed to include chemistry, biology, pre-engineering, or a host of other choices. Choices that could be entered on any school’s course selection list, to be taken by interested students, and taught by interested teachers.

Wouldn’t that be something to behold?
Chapter 4: Ending Thoughts

Project Summary

As this project comes to a close many thoughts and ideas are still swirling around in my head about how I can make the Integrated Physics 11/12 class better, more engaging for students, and still have it complete the Ministry of Education’s Prescribed Learning Outcomes for both Physics 11 and 12. I think of the need for a different style of class that would attract new students to physics who may not have taken it before, to increase the awareness of physics in the environment around us daily, and to pass on the excitement I feel towards the subject to others. Within these last few paragraphs I share my concluding thoughts on the course and the path that I hope to take in the future. I will review the basics of the Integrated Physics 11/12 option, identify some changes to my personal teaching and learning style, and include a list of courses that use a different delivery model at our school to make it truly unique.

By identifying a need for a change in my own personal teaching style and recognizing an opportunity to vary the course offerings in my school, I was motivated to create a course that contained the outcomes of both Physics 11 and 12 at the same time. In calling this course Integrated Physics 11/12, I was able to mold the courses together so that they flowed together as one. The course was taught over a half day setting (150 instructional minutes per day) for a five month semester. Exploiting this longer class period allowed the students to gain a far deeper understanding than would have occurred if they had taken the traditional Physics 11 and Physics 12 separately.

Utilizing a framework of socio-constructivism modelled after Vygotsky, the students were expected to challenge their learning habits and styles while in the class.
The students were exposed to a number of different constructivist techniques of educational delivery, such as; inquiry/discovery learning, problem-based learning, and project based learning. Due to the nature of the course and availability of equipment at the school, the students often worked together as a group to complete the tasks. Since the students were expected to work together to solve problems the course shifted towards Vygotsky’s model of socio-constructivism and away from the standard constructivist techniques named above.

The Integrated Physics 11/12 course has been taught twice since 2013 and will hopefully continue to be available as a choice for students in the foreseeable future. Typical students who registered for the first two sections of the course included; French Immersion students, pre-engineers, and academically motivated students in grade eleven willing to take an academic grade twelve course. Many students who were kinesthetically gifted were also enrolled in the class - including students with an interest in metalwork, woodwork, carpentry/joinery, and drafting. Interestingly, while the kinesthetic learners may have been a little more academically challenged with some of the algebraic concepts in the course, they used their hands-on skills to complete elaborate project work and as a result, they rounded out the class dynamic well.

As I reflect on the multitude of classes, assignments, readings, and cohort discussions I completed in order to complete this Master’s program I look towards the active participation in discussions as one of the most rewarding experiences. As my project focus had a very specific topic (integrating two senior academic classes into one course), the ideas, thoughts, and examples brought up in conversation with my cohort colleagues allowed me to guide the research, course construction, and troubleshooting
while working through Integrated Physics 11/12. Through these conversations it dawned on me that Vygotsky’s model of socio-constructivism was used for both my Integrated Physics 11/12 class and the M.Ed. program in which it was presented.

**Changes to My Personal Teaching Approaches**

Upon the completion of the courses leading to the M.Ed. degree I believe that I will have built the framework for my teaching to evolve to a new level. For example, allowing students to work as groups to solve ill-defined problems has shown me that a stand and deliver model is not necessary for all learning to occur in the classroom. There are times where the more traditional transmission approach could be more beneficial, as in trying to introduce a specific topic like friction, or electrostatic repulsion forces, but at other times a hindrance as the students need to construct their own learning through reflection, dialogue with like-minded students, and other socio-constructivist opportunities as described in this project.

As a specific example, the graduate course taken that discussed Aboriginal ways of knowing opened my eyes to the absence of these traditional sciences in our westernized curriculum. As part of my standard teaching load every year I teach multiple blocks of Science 10. It is within this Science 10 course that I can apply the Aboriginal ways of knowing that I have learned within the M.Ed. program to their fullest extent. During the Ecology section of the course, a few mere pages in the text are used to describe this *Traditional Ecological Knowledge*, (Sandner, 2008, p. 133-134), I hope to use the knowledge gained during this project to expand on this centuries old way of managing ecosystems.
I understand and internalize that this part of the curriculum needs to be expanded upon. This may occur through opportunities to have speakers from the local First Nations come to class, or perhaps field trips to rivers or traditional lands could be an option. Willing members of Aboriginal heritage in the class who typically would not become engaged in our standard western system will be encouraged and recognized as an asset to the learning, as a resource for the class. I recognize now after my graduate degree is nearly complete that these opportunities of having an authentic, experiential learning environment will benefit all students in the class.

In terms of my standard timetable physics classes at the grade eleven and twelve level, the impact of this graduate degree will be far reaching and paradigm shifting. I plan to continue to teach physics in the school district for many years to come, and the process of researching, analyzing, compiling, and organizing two years of work into this project paper has been very enlightening and motivating. I will continue to use the knowledge, skills, and experiences gained from this project in the teaching of all my classes. Some of the many examples of this new knowledge would include, using inquiry learning to have the students identify some of the capabilities of the measuring equipment we will use in the class before using the equipment to complete project work. This will allow for the project ideas to take shape as the student is constructing their own sense of learning in regards to the equipment. As well, using past students’ projects as exemplars for current and future student projects will help them to identify and address some of the questions that they may have regarding their self-assessment of the projects that they currently are making or building. Also, based on casual conversations with students and parents, field trips and guest speakers had a measurable impact on the learning in
Integrated Physics 11/12. Drawn from the field trip to the curling rink, the physics behind an apparently simple shot become much more meaningful when placed into a real-life situation. Since the students were able to experience the physics first hand, while executing a shot, their own meaning of the physics behind the components of a popular Canadian game was enhanced.

As a result of this M.Ed. experience I will endeavor to incorporate different styles of constructivist and socio-constructivist learning into my future classes. I have found that the research I completed and the implementation of this new cognitive framework during the Integrated Physics 11/12 class will allow me to confidently navigate the waters of a new teaching style safely.

**Change Isn’t Just for the Sake of Change**

As stated earlier in the paper, the school in which I teach has a very diverse population of students, from the lowest income to the upper income families and everything in between. The school prides itself on being welcoming and encourages individuality in its members, students, and staff. There are a number of programs that have been developed in the school that allow it to stand out among other schools of the same size, including the Integrated Physics 11/12 program. As mentioned before, our principal encourages us to investigate alternate delivery methods as schools move towards a 21st century delivery model. With thirty kids and a good idea, he tries to make every class fit inside the school timetable. With a large variety of options for students to choose from during course selections, students are likely to find a class that fits their personal learning style, meets the requirements for graduation in British Columbia,
allows for flexibility in scheduling, and for some students, and prepares them for entrance into a post-secondary education field of their choice.

There has been much talk of integrating other classes at our school since the inception and success of the Integrated Physics 11/12 class over the past 2 years. Currently there is a proposal to combine Physical Education 12 with Biology 12 into a Sport Science 12 class that would run full year (ten months) with one, seventy-five minute block each day devoted to the class. This class would be taught by 2 separate teachers but have a singular focus regarding the mechanics of the human body during different movements in sports. This would lead enrolled students down a path towards physiotherapy, kinesiology, exercise science, and other related fields.

As well, the senior biology teacher and I have discussed with our principal, the opportunity of having an Independent Study Project (IDS) block available to senior science students enrolled in two or more senior science classes such as; chemistry, physics, and biology. Taken concurrently with the standard semester timetable, the students would have a year-long IDS block and a spare block at the school, and during this time the students would put together a large capstone project that would incorporate their interests in one, two, or all three of the academic sciences. The students would then hold a conference to present their ideas and findings – this is similar to the process taken by Larkin (2013) that has been discussed at length in this paper and was a major focal point in changing the way I approached teaching physics. Currently the IDS block idea is still in a pre-planning stage but the standard has been set that increasing motivation of students is possible by providing different choices, interesting topics, and alternate delivery methods. We hope this new class will bring excitement for interested students.
There are a number of other alternate methods of teaching at our school, many of them are double blocks, such as Forestry, Chef’s Training, ACE-IT Carpentry, and Video Productions mixed with English. We also have a one of a kind full day Nautical Sciences program where students refinish old sailboats to a usable standard and sail them to receive credits. With these types of course available to students, I believe our school district is following a path that allows for the 21st Century learning model, as proposed by the BC Government, to be attained and exemplified. I am glad that the Integrated Physics 11/12 course is part of this structure in our district and I hope to teach it for many more years to come.

In Conclusion

As I reflect on the entire experience of this M.Ed. project and the path of learning the Integrated Physics 11/12 course has taken me on, I think of possible learning points and some likely stumbling blocks that others may experience if they chose to follow the same type of project in the future. I can think of three recommendations for future educators or M.Ed. project students that may help them if they choose to complete a project along the same lines as the one laid out by this paper.

First, the need to plan ahead is paramount. Teachers need to shift their teaching focus from a traditional transmission method to a method that utilizes the socio-constructivist framework. Identifying research in the particular field of study is a must. My passion is physics education and that is where I spent most of my research time. Teaching full time with a busy after school schedule and shifting your teaching perspective can seem daunting at times but having a solid knowledge base will help deter
the teacher from slipping back into old habits. Using both quantitative and qualitative research studies during this planning stage will allow for a more solid, well-rounded perspective before attempting to use the tactics in a classroom setting. In addition to pre-researching the topic at hand, teachers might ask the professional development committee at the school board if they can have speakers come in to do workshops or presentations on the shift to constructivist or socio-constructivist techniques. Our district had a presentation that spoke directly to me a number of years ago when the process of teaching the integrated class was still a seed in the back of my mind, and it helped generate questions that needed to be answered as I moved towards the goal of teaching this class.

Second, students are the reason many of us teach, they fill us with the passion for our profession that we bring to class every day, so recognize that and allow them to become active participants in the planning, execution, research, and assessments in the class. I may have been able to teach my students about Newton’s Laws of Motion but as a group they identified what they thought was important about assessing the laws, and how they might best present them. I found that looking in old user’s guides for equipment set up was very time consuming whereas the student themselves would experiment with different modes, settings, and collection techniques and quickly determine the best way to use the equipment for their project or lab. I found that I could trust their judgments and ideas, rather than deliver the course from the top down method that I had been so used to.

And finally, use all the resources available at a school to help plan the path that students can take within the school. Ask for input from other teachers, counsellors, and
administrators regarding the path that you hope to take as a teacher. Gauge student interest regarding the new class by talking to as many students as possible in the hallways, have announcements and displays showing the projects that students built in the class as a way to draw new ideas and participants for future years. Or perhaps, advertise an information night for interested future students and parents to explain these new methods of teaching, or introduce the new course so questions, concerns, and ideas can be generated in a positive and inviting way as a group. I will be making a presentation to the school PAC that identifies the changes in the physics program at our school.

As I end this two year journey of learning that has finishes with this paper, a quote by George Counts (1932, p.47) taken from the first course that our cohort encountered has been in the back of my mind and sums up my thoughts on teaching in general and the Integrated Physics 11/12 course which has been my focus over the recent past.

“This much at least we know today. We shall probably know more tomorrow.”
References


Appendix 1

Integrated Physics 11/12: Course Outline

Course Overview/Rationale:
Integrated Physics will take the prescribed learning outcomes of both Physics 11 and Physics 12 and roll them into 1 large, double-blocked course. Many overlaps exist between the 2 courses and in an effort to bring a more focused, inviting, and hands-on experience to Carihi Physics I have decided to combine the courses. This should lead to more time for lab activities, field trips, guest speakers, time to expand, ask and identify the deeper questions of “Why or Why Not” and have different ways to approach the same ideas. Essentially: ½ day Physics Immersion!

I am expecting full commitment from each student enrolled in Integrated Physics, as you may be quickly left behind if you are unable to keep up with the demanding workload.

Topics of Study:

<table>
<thead>
<tr>
<th>PH 11</th>
<th>PH 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematics (1-D)</td>
<td>Kinematics (2-D)</td>
</tr>
<tr>
<td>Dynamics (1-D)</td>
<td>Dynamics (2-D)</td>
</tr>
<tr>
<td>Work, Power, Energy, Momentum (1-D)</td>
<td>Work, Power, Energy, Momentum (2-D)</td>
</tr>
<tr>
<td>Special Relativity (Einstein)</td>
<td>Statics and Equilibrium</td>
</tr>
<tr>
<td>Wave Motion</td>
<td>Electrostatics</td>
</tr>
<tr>
<td>Geometric Optics</td>
<td>Electric Circuits</td>
</tr>
<tr>
<td>Nuclear Fusion/Fission</td>
<td>Electromagnetism</td>
</tr>
<tr>
<td></td>
<td>Circular Motion and Gravitation</td>
</tr>
</tbody>
</table>

As you can see, the first 3 topics are nearly identical, by saving time combining these units I hope to have time near the end of the course to branch out into other topics: Quantum Mechanics, Astrophysics, Cosmology, Nature of Light etc.

Course Materials: I expect that you will come to class prepared with the following, every day:

- Δ Binder or way to organize handouts (mechanical)
- Δ Coiled notebook (provided)
- Δ Ruler
- Δ Formula booklet
- Δ Pens (multiple colours) & Pencils
- Δ Scientific Calculator (graphing is OK)
- Δ Graph paper
- Δ Completed work
- Δ Textbook/course materials
- Δ Questions/questions/questions
Course Evaluation/Grade Allocation:

.assignment (15%)
As an Integrated Physics student, you are responsible for your actions; therefore, daily homework from the textbook will be assigned but may not be collected on a regular basis. However, each unit will have a number of unit review assignments that will be collected before the unit exam/project. It is my suggestion that you keep up with the assigned work, as it will undoubtedly help you in the completion of the course. Unit Reviews are due on unit test day. No Exceptions!

.labs/projects (20%)
A variety of labs will be provided in cookie cutter form and many others will require planning, organization, implementation of materials, data collection and analysis by you, the physicist. Labs will be conducted as small groups and as individuals. These labs will be marked on accuracy of the scientific method, relevance, self and group evaluations, with class built rubrics and against a standard of high performance. It is my hope that you will become highly proficient at data collection and analysis.

.reflections (10%)
Short quizzes may happen infrequently, also weekly reflections on current ideas, topics, and events will be expected.

.unit tests/projects (30%)
These are larger assessments that cover an entire unit of material...Discussions will occur in each unit on how to best prepare for these larger assessments. Tests or projects are options for each unit of study.

.final (capstone) project (25%)
Given during exam week, this will be the culminating project of the course, this project will require a short (9-12 minute) presentation/defense that will require extensive planning and preparation. Discussions will follow on how to proceed with the major project.

Other Expectations:
Physics is math based applied science. Therefore I expect that you will have a strong math background (B or better in Math 11 is preferred) otherwise the algebraic components of the course may become overwhelming quickly.

Good luck and remember to ask questions, we will all learn from them!
## Appendix 2
### Integrated Physics 11/12 Formula Sheet

### Kinematics

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ddot{v} = \frac{\Delta \dot{d}}{\Delta t} )</td>
<td>Acceleration</td>
</tr>
<tr>
<td>( \dddot{d} = \frac{\Delta \ddot{v}}{\Delta t} )</td>
<td>Distance</td>
</tr>
<tr>
<td>( d = \left( \frac{\ddot{v}_i + \ddot{v}_f}{2} \right) t )</td>
<td>Distance</td>
</tr>
<tr>
<td>( \ddot{v}_f = \ddot{v}_i + \dddot{d} t )</td>
<td>Velocity</td>
</tr>
<tr>
<td>( \dddot{d} = \ddot{v}_i t + \frac{1}{2} \dddot{d} t^2 )</td>
<td>Velocity</td>
</tr>
<tr>
<td>( \dddot{v}_f = \ddot{v}_i^2 + 2 \dddot{d} )</td>
<td>Velocity</td>
</tr>
</tbody>
</table>

### Forces, Dynamics, and Statics

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \vec{F}_g = mg )</td>
<td>Force due to gravity</td>
</tr>
<tr>
<td>( \vec{F} = k \Delta \vec{x} )</td>
<td>Force due to spring</td>
</tr>
<tr>
<td>( \vec{F}_f = \mu \vec{F}_N )</td>
<td>Frictional force</td>
</tr>
<tr>
<td>( \vec{F} = m \vec{\ddot{v}} )</td>
<td>Impulse</td>
</tr>
<tr>
<td>( \Delta \vec{p} = \vec{F} \Delta t )</td>
<td>Impulse</td>
</tr>
<tr>
<td>( T = 2\pi \sqrt{\frac{l}{g}} )</td>
<td>Period of oscillation</td>
</tr>
<tr>
<td>( \vec{F}<em>{net} = F</em>{app} + (-F_f) )</td>
<td>Net force</td>
</tr>
<tr>
<td>( \vec{F}_g = G \frac{m_1 m_2}{r^2} )</td>
<td>Gravitational force</td>
</tr>
<tr>
<td>( \tau = F_\perp d )</td>
<td>Torque</td>
</tr>
</tbody>
</table>

### N1:

### N2:

### N3:

### 1\textsuperscript{st} Condition of Equilibrium:

### 2\textsuperscript{nd} Condition of Equilibrium:

### Work, Energy, Power

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W = \vec{F} \ddot{d} )</td>
<td>Work</td>
</tr>
<tr>
<td>( W = \Delta E )</td>
<td>Energy</td>
</tr>
<tr>
<td>( E_p = mgh )</td>
<td>Potential energy</td>
</tr>
<tr>
<td>( E = mc\Delta T )</td>
<td>Energy</td>
</tr>
<tr>
<td>( E_k = \frac{1}{2} m \ddot{v}^2 )</td>
<td>Kinetic energy</td>
</tr>
<tr>
<td>( P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} )</td>
<td>Power</td>
</tr>
<tr>
<td>Efficiency = ( \frac{W_{out}}{W_{in}} \times 100% )</td>
<td>Efficiency</td>
</tr>
</tbody>
</table>
Special Relativity

\[ t_r = \frac{t_o}{\sqrt{1 - \frac{\tilde{v}^2}{c^2}}} \quad m_r = \frac{m_o}{\sqrt{1 - \frac{\tilde{v}^2}{c^2}}} \quad E = mc^2 \]
\[ \tilde{v}_{total} = \frac{\tilde{v}_1 + \tilde{v}_2}{1 + \frac{\tilde{v}_1 \tilde{v}_2}{c^2}} \quad L_r = L_o \sqrt{1 - \frac{\tilde{v}^2}{c^2}} \]

Wave Motion and Geometric Optics

\[ \tilde{v} = f\lambda \quad T = \frac{1}{f} \quad n = \frac{c}{\tilde{v}} \quad \text{Speed of sound} = 332 + 0.6T \]
\[ \frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f} \quad \frac{\sin \theta_1}{\sin \theta_2} = \frac{\tilde{\lambda}_1}{\tilde{\lambda}_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1} \quad \frac{h_1}{h_o} = \frac{d_i}{d_o} \quad M = \frac{h_i}{h_o} = (-)\frac{d_i}{d_o} \]

<table>
<thead>
<tr>
<th>( d_o )</th>
<th>( d_i )</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Real objects</td>
<td>Real images</td>
</tr>
<tr>
<td>-</td>
<td>Virtual objects</td>
<td>Virtual images</td>
</tr>
<tr>
<td>(never used in PH 11)</td>
<td>Virtual focal points: Convex mirrors or concave lenses</td>
<td></td>
</tr>
</tbody>
</table>

Circular Motion & Gravitation

\[ \overline{F}_c = m \overline{a}_c \quad \overline{F}_g = \frac{G m_1 m_2}{r^2} \quad E_p = -\frac{G m_1 m_2}{r} \]
\[ \overline{a}_c = \frac{\tilde{v}^2}{r} = \frac{4\pi^2 r}{T^2} \quad \overline{F}_c = \frac{m\tilde{v}^2}{r} = \frac{m4\pi^2 r}{T^2} \]
\[ \text{To attain orbit:} \quad E_{Ti} = E_{Tf} \]
\[ \text{While in orbit:} \quad \overline{F}_c = \overline{F}_g \]

Electrostatics

\[ \overline{E} = \frac{\overline{F}}{Q} \quad \overline{E} = \frac{kQ}{r^2} \quad \overline{E} = \frac{\Delta V}{d} \]
\[ \overline{F}_e = \frac{kQ_1 Q_2}{r^2} \quad \Delta V = \frac{\Delta E_p}{Q} \quad E_p = \frac{kQ_1 Q_2}{r} \quad V = \frac{kQ}{r} \]
### Electric Circuits

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I = \frac{Q}{t} )</td>
<td>Current density</td>
</tr>
<tr>
<td>( V = IR )</td>
<td>Voltage</td>
</tr>
<tr>
<td>( P = IV )</td>
<td>Power</td>
</tr>
<tr>
<td>( P = \frac{V^2}{R} )</td>
<td>Power</td>
</tr>
</tbody>
</table>

### Electromagnetism

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \vec{F}_m = BIL )</td>
<td>Force on a conductor</td>
</tr>
<tr>
<td>( \vec{F}_m = QvB )</td>
<td>Magnetic force on a charged particle</td>
</tr>
<tr>
<td>( \varepsilon = B\vec{L}\vec{v} )</td>
<td>Voltage generated in a conductor</td>
</tr>
<tr>
<td>( \vec{B} = \mu_0 n I = \mu_0 \frac{N}{L} I )</td>
<td>Magnetic field</td>
</tr>
<tr>
<td>( V_{back} = \varepsilon - Ir )</td>
<td>Back voltage</td>
</tr>
<tr>
<td>( \varphi = \vec{B}\vec{A} )</td>
<td>Magnetic flux</td>
</tr>
<tr>
<td>( \varepsilon = -N \frac{\Delta\varphi}{\Delta t} )</td>
<td>Faraday's law</td>
</tr>
</tbody>
</table>

Equate forces when needed

\[ \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s} \]

### RHR #1
- Current in a conductor

### RHR #2
- Magnetic field in a solenoid

### RHR #3
- Motor rule, moving charged particle through an external magnetic field

### Lenz’s Law
Useful Information and Constants

\[ g = 9.8 \frac{m}{s^2} \text{ or } \frac{N}{kg} \]  
Gravitational acceleration or field strength \textbf{on Earth}

\[ G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2} \]  
Universal Gravitational Constant

\[ m_p = 1.67 \times 10^{-27} kg \]  
Mass of a proton

\[ m_e = 9.11 \times 10^{-31} kg \]  
Mass of an electron

\[ e = \pm 1.60 \times 10^{-19} C \]  
Elementary charge of a proton or electron

\[ k = 9.00 \times 10^9 \frac{Nm^2}{C^2} \]  
Coulomb’s Constant

\[ \mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A} \]  
Permeability of free space (electromagnetism)

\[ c = 3.00 \times 10^8 \frac{m}{s} \]  
Speed of light in a vacuum

\[ n_{air} = 1.0003 \]  
Index of refraction for air

\[ c_{water} = 4.20 \times 10^3 \frac{J}{kg^\circ C} \]  
Specific heat capacity for water

Earth Data:

\[ m_e = 5.98 \times 10^{24} kg \]  
Mass

\[ r_e = 6.38 \times 10^6 m \]  
Radius

\[ 8.64 \times 10^4 s \]  
Period of rotation on axis (length of a day)

\[ 3.16 \times 10^7 s \]  
Period of revolution around Sun (length of a year)

\[ 1.50 \times 10^{11} m \]  
Orbital radius around the Sun

Moon Data:

\[ m_m = 7.35 \times 10^{22} kg \]  
Mass

\[ r_m = 1.74 \times 10^6 m \]  
Radius

\[ 2.36 \times 10^6 s \]  
Period of rotation on axis

\[ 2.36 \times 10^6 s \]  
Period of revolution around the Earth

\[ 3.84 \times 10^8 m \]  
Orbital radius around the Earth

Sun Data:

\[ m_s = 1.98 \times 10^{30} kg \]  
Mass

\[ r_s = 6.96 \times 10^8 m \]  
Radius
Metric Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Numerical</th>
<th>Exponential</th>
</tr>
</thead>
<tbody>
<tr>
<td>mega</td>
<td>M</td>
<td>1 000 000</td>
<td>$10^6$</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>1 000</td>
<td>$10^3$</td>
</tr>
<tr>
<td>hecto</td>
<td>h</td>
<td>100</td>
<td>$10^2$</td>
</tr>
<tr>
<td>deca</td>
<td>da</td>
<td>10</td>
<td>$10^1$</td>
</tr>
<tr>
<td>deci</td>
<td>d</td>
<td>0.1</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>0.01</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>0.001</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>micro</td>
<td>µ</td>
<td>0.000001</td>
<td>$10^{-6}$</td>
</tr>
</tbody>
</table>

For Right-Angled Triangles:

\[
\begin{align*}
\text{opp} &= \text{hyp} \\
\text{adj} &= \text{opp} \\
\theta &= \text{adj}
\end{align*}
\]

For All Triangles:

\[
\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}
\]

\[
c^2 = a^2 + b^2 - 2ab \cos C
\]

\[
\text{area} = \frac{\text{base} \times \text{height}}{2}
\]

Circles:

\[
\text{circumference} = 2\pi r
\]

\[
\text{area} = \pi r^2
\]

Quadratic Equation:

If \( ax^2 + bx + c = 0 \) then

\[
x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
\]
Appendix 3

Lab Inquiry Planning Model

Lab: __________________________ Date: __________________

**Question.** What is the question you would like to answer? What is the problem you are trying to solve?

**Hypothesis.** What do you predict are three possible answers to this question/problem?

1. 

2. 

3. 

Circle the hypothesis that you will test.

**Possible Tests.** How will you test the hypothesis that you have made? What equipment will you need? What will the test you carry out tell you?
Control and Variable. What will you use as the control and variables in the test/experiment?

Control:

Variables:

Gather Data. What type of data will you gather? Will you need a chart, list, electronic record, or something else?

Graph Data. Use the appropriate type of graph to show your data. What can you find out with this graph?
Appendix 4

Integrated Physics 11/12
Finding ‘µ’ Lab

**Challenge:** To find the coefficient of kinetic (µ\_k) and static friction (µ\_s) for 2 different surfaces in and/or around the school.

**Materials:** Wood block (1 kg), 6-8 lab masses (0.5 kg and/or 1.0 kg), spring scale.

**Requirements:**
1. You **must** use 2 different surfaces with your wood block.
2. You must calculate the stationary friction coefficient (µ\_s) and the moving coefficient of friction (µ\_k).
3. You will need multiple data points for each type of coefficient.
4. You will need to make graphs in order to find these values. These need to be handed in!
5. **Ensure that when the block moves it travels with constant velocity!!**

**Planning Space:** ( /3)

**Calculations space:** You will need to make graphs first! ( /8)

<table>
<thead>
<tr>
<th></th>
<th>Surface 1</th>
<th>Surface 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>µ_s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>µ_k</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>