Physics Teaching for the 21st Century: Developing Resources to Connect Physics to the Real World

by

Brittany Tymos

Department of Physics and Astronomy

The University Of British Columbia
6224 Agricultural Road, Vancouver, British Columbia, Canada, V6T 1Z1

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Abstract

The degree to which students make connections between physics, their daily lives, and problems faced by society is not clear, but it is thought that by relating the teaching of physics to the real world, these connections will become explicit and students' interest in physics will increase. This study sought to uncover the barriers and impacts of connecting the curriculum to the real world in the context of Science 10, Physics 11 and 12 and introductory physics at post secondary institutions. Both qualitative and quantitative data were obtained from instructors in the form of surveys, focus groups and interviews. Upon establishing that conceptual understanding and connecting physics to the real world are important goals in physics teaching, it became evident that the development of resources that aim to accomplish these goals is worth pursuing. The instructors' opinions of the various topics and types of resources on the site were then compiled to make recommendations for improving teaching resources, especially those on the UBC Physics Outreach website. It is hoped that by implementing these recommendations, the resources will be more useful for teachers and appropriate for the contexts in which they are taught, and the connection between physics in the real world and physics taught in classrooms will increase.

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Acknowledgements

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Chapter 1

Motivation

Most physics teachers are eager to transmit their knowledge and enthusiasm for physics to their students in hopes of transferring skills and information in order that their students can come to appreciate the beauty and power of physics [1]. But in light of this, many students emerge from their study of physics with serious gaps in their understanding of important topics and it becomes evident that there needs to be improvement between how teachers teach and students learn [2].

1.1 Decreased Student Interest in Physics

A number of studies have found that students' attitudes and view of the relevance of physics to the real world actually decline after taking an introductory physics course[3], [4]. The more students study physics, more they come to view physics as the study of concepts and phenomenon which they may find fascinating, but which have little relevance to their personal experience and the real world around them [5],[1].

Category	Pre-Course Test	Post-Course Test
Real World Connections	72 %	65 %
Personal Interest	67 %	56 %
Perceived Conceptual Understanding	63 %	55 %

Table 1.1: Typical CLASS Survey Results: The percent of students who ranked the categories favourably. (Adapted from Adams et al., 2006 [3]).

This has been established through a variety of surveys including the Colorado Learning Attitudes about Science Survey (CLASS), a short 10 minute Likert-scale (strongly disagree - strongly agree) survey, which measures students' beliefs about physics and learning physics by asking students to rank their opinion of 50 statements. Since 2003, these surveys have been administered to over 7,000 students in 60 physics courses both before and after students have taken an introductory physics course. As seen in Table 1.1, it was found that over the duration of the course, students' opinions of the connection that physics has to the real world decreases from 72% to 65%. It has also been found that personal interest in the subject drops from 67% to 56% and perceived conceptual understanding decreases from 63% to 55% [3].

In another study, Wieman and Perkins found that after instruction, regardless of the quality of it, students were found to have less expert like thinking, meaning that they saw physics as being less relevant to the real world, less interesting and more based on memorization than they had thought when they entered the class [6] Furthermore, these beliefs are still unimproved in classrooms using programs that have been developed to improve students' conceptual understanding of physics [7]

The Maryland Physics Expectations (MPEX) Survey, another Likert-style (strongly disagree - strongly agree) questionnaire, probes into some aspects of student expectations at both the beginning and end of a first semester calculus-based physics class at 6 post secondary institutions. In all cases of this survey being offered there has been found to be a increase in unfavourable responses and a decrease in favourable responses regarding the link between physics and the real world, the role of math in physics, and their expectations of how much effort they will put into the course [5].

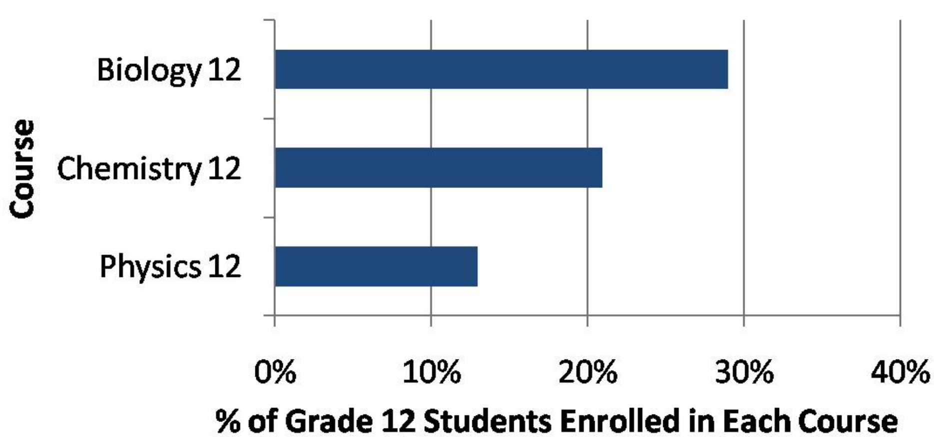

Figure 1.1: The enrolment in Science 12 classes in BC during the 2003/2004 school year. (Data from Nashon and Nielsen, 2007 [8]).

More locally, this problem is demonstrated in BC as seen in the senior sciences where enrolment is considerably lower in Physics 12 than in Biology 12 and Chemistry 12, as seen in figure 1.1. Nashon and Nielsen conducted a qualitative study, involving surveying and interviewing senior science teachers and their students, to explore the cause of the lowered participation in physics and how more students could be inspired to study physics. Answers to those answers revealed that the main reasons for not studying physics stemmed from a lack of application, relevance, and interesting content [8]. They found that physics seemed removed from real life because of the examples used to illustrate concepts. Therefore real world connections may be a way to combat increase student attitudes and motivation towards physics.

1.2 Real World Connections

It has been found that students' positive expectations and beliefs strongly correlate with thier performance and probability of continuing their study of physics [3],[9], [6]. Students who enter into a course with more favourable beliefs are more likely to achieve higher learning as students' achievement expectations have found to actually be a more significant predictors of success than their prior teaching or even exposure to the field [3], [9]. Furthermore, the leading reason for increased interest in physics was found to be due to strengthening the connection between physics and the real world [10].

Although teachers may believe they are teaching about the real world when they teach physics, the context dependency of this leaning opens up yet another gap. The majority of students may believe that the field of physics is related to the real world, but they fail to extend this to their own lives and as a result believe that what they are learning in class has little or no relevance to their personal experience of the world [7]. This lack of relevance is not surprising when looking at traditional ways of teaching physics for example, the teaching of motion through blocks on frictionless ramps. This approach only enforces in students' minds the idea that these principles do not apply to objects they would encounter daily, as rarely are students going to be sliding blocks down ramps, let alone frictionless ones. Furthermore, by assigning problems that are solved by plugging numbers into a formula, the notion that physics is just about memorization is strengthened and reasoning out an appropriate answer or applying concepts to a situation not previously encountered becomes irrelevant [6], [1].

It is also extremely important to note that the bulk of physics teaching in introductory physics courses, whether that be in high school or first year university, is to non-physics students. At UBC for example, approximately 80-90% of the teaching of physics in the first year classes is to non-physicists. So naturally, studying teaching in this context has to take this into account. In 1971, Shonle claimed that physics teachers had been focusing too much on training professionals and had been unsuccessful at introducing physics to non-majors as the version of the course offered to them was simply a non-calculus version of the physics majors class [11]. Over 25 years later, this is still an issue as most non-physicists studying physics often fail to see the connection between physics principles and their discipline of interest. Instead of viewing physics courses as relevant knowledge needed to succeed in their education or careers, they see it as an accumulation of formulas and concepts, completely void of meaning and unworthy of interest [4], [12], [13]. This is a problem as students' failure to connect what is being taught in their physics class to their personal experience creates barriers to gaining understanding that grow increasingly difficult to break down [7]

Some have argued that if physics courses were changed to appeal to a wider range of students, some of the beauty of physics would be lost, and the subject would lose its prestige and the appeal of being a field with a reputation for being quite challenging. This research is not at all addressing this concern, but is instead seeking ways to enable more students to appreciate the beauty and power of physics as they see its application to their everyday lives and consequently are more willing to pursue studies in it, even if it's not central to their degree[8].

This is especially necessary now as society now faces critical global-scale issues that are technical in nature, such as climate change, genetically modified food, and energy sources. No longer are such issues academic problems, but they are now social problems that only a scientifically and technically literate person can make informed decisions about. Seeing that only those with knowledge and training can create solutions to these problems, it is imperative that these topics be explicitly introduced in elementary schools and nurtured in high schools and post secondary institutions. Furthermore, economics are becoming so heavily based in technology that having an understanding of basic physics and problem-solving skills will be an asset, if not a necessity, in any career path [6], [14], [5].

As a result of this, it is desirable that science educators combat students' lack of interest in physics by teaching with explicit connections between the course material and the real world around them. By inviting students to solve problems surrounding issues which impact their lives daily and shape their future, not only is physics learnt and attitudes improved, but it also becomes "fun" and "exciting" [4], [15], [5]. Through this, students will discover that the study of physics is more flexible than they imagined, relating to biology, chemistry, engineering, economics, medicine and physiology in a meaningful way [4], [16]. By making this connection explicit, the relationship between physics and society becomes much more obvious and students are able to make intelligent and informed decisions about current social issues such as energy generation, transportation, pollution, balancing human population with resources and climate change [17], [18], [14].

1.3 Methods to Make Real World Connections

In order to generate student interest, it is important to create scenarios which are relevant and contemporary. Students want to know what is going on in the world they interact with now, not what was applicable 30 or 50 years ago [19], [20]. Furthermore, it has been found that examples in which students can integrate their own experiences, or materials frequently encountered in their lives, with the specific concepts to be learnt are even more beneficial [21], [20]. But in light of this, there needs to be a balance between extremely relevant and relatable examples that include overly advanced concepts and the tendency to over simplify to make real world things easily understandable or particularly applicable to the concept they are trying to teach [19]. The goal is to captivate students' attention by raising questions in their minds about the subject matter and stimulating them to use both their prior knowledge and experience, and the physics concepts learnt in class, to seek out a possible solution or explanation [21].

In the early 1970s, some teachers took this approach and tried to make their students' education relevant by means of presenting them with materials that allowed them to grapple with the current problems faced in society [22], [18]. One teacher in particular led his students in the evaluation of the production, use and waste of a variety of energy sources, both in the short and long term, relating it to the per capita energy consumption and standard of living. He solely focused on the fundamental physics principles and ignored the temptation to delve too deeply into the engineering or ethical aspects. This was a solid example that taught classical physics and its importance to the days' technology, and by the end of the course students had shown the initiative to pursue studying the energy crisis further, and it actually increased the enrolment of students in the next term's physics class [22]. By taking this approach, teachers found test scores have been the same, if not better, but that students had learnt the material with more interest and enjoyment than those in a traditionally taught class [12].

Physics can be related to the real world in a variety of ways. Kinetics can be taught through various modes of transportation, and kinematics and momentum, instead of being taught via the concepts of billiard balls, can be taught through automobile accidents [4]. Energy and power can be taught through the study of alterative power sources, such as wind turbines or solar cells, and conservation of energy in the context of home heating and climate change. Fluid mechanics can be taught through the flow of rivers and streams, circulation of blood in arteries and veins, or the flights of insects and birds][23]. Mechanics through the structure of dams and thermodynamics through thermal pollution [19]. Other streams of physics are relevant to global social issues too, as arms control treaties are linked to geophysics knowledge and the cleaning up of pollution to chemical physics [24]. Also, almost all fields of physics can be related in some way to the fields of biology, medicine and the human body - for example forces, torque and the centre of mass can be taught through the scenario of minimizing the force on the injured hip of a skier [4].

This approach, although seemingly straight forward, is challenging to implement. First of all, while some instructors think that physics teaching should stick to laws and concepts, others think that physics appears abstract unless its application is emphasised and taught [19]. The latter teaching style has been found to motivate students more, as seen above, but it is also much harder to do and takes more time, covering less material in a year but hopefully promoting a deeper and more transferable understanding of the material [25]. Also, it has been found that Physics 11 and 12 courses are frequently taught by non-physicists who probably don't have the background to develop examples that demonstrate accurate physics and yet are relevant to the students. Therefore there is a need for resources that present teachers with accurate ways of relating physics to real world contexts that are understandable by non-physicists and easily incorporated into a classroom setting.

For the students, this approach of teaching physics in explicit connection to the real world can be intimidating at first as they often have difficulty relating concepts from different areas of physics, or science together[1], [4]. They are conditioned to traditional physics teaching and change is sometimes resisted as they may not understand what is required of them or how to succeed in this new approach [12]. But, by presenting information in a multidisciplinary way, it helps to make students more comfortable making connections between different concepts and applying what they know to other contexts.

In regards to the topics, while teachers see many physics concepts as relating directly to real-world contexts, students may not make the same connections [7]. More so, while teachers assume that students will find contemporary examples interesting, it has been found that few students are motivated to be interested in things they cannot understand [1]. Therefore, there is a need to make examples that both teachers and students find interesting and applicable, while also being presented in a way that the average student can understand. On top of this, teachers also have to choose topics that support and do not significantly alter the physics curriculum they are instructed to teach [16]. Therefore it is important to get feedback to see which topics are relevant and make real world connection explicit to students and also which topics fit well into the curriculum.

The University of British Columbia's (UBC) Physics Outreach Program's "Physics Teaching Resources for the 21st Century" website (http://C21.phas.ubc.ca) is the basis of this project. It is a collection of overviews, multiple choice questions, problem sets, and take-home experiments, designed for grades 8 - 12 and first year university classes, and created with the goal of helping to provide resources for instructors who want to connect physics to the real world. Since different audiences are captivated by different emphases, a variety of resources is provided so that a wide assortment of teachers and classrooms can benefit. Topics include renewable energy sources, energy use at home, transportation, climate, the human body and animals.

This project studied the barriers and benefits of teaching a physics curriculum that is connected to the real world by determining what teachers need to teach physics in real world contexts and by examining how this website addresses their needs. The aim was to provide recommendations for changes to the website based on findings. The use of this website was monitored and feedback was collected in order to make recommendations for improving not only the website, but also the development of resources of this kind. It is hoped that these recommendations will lead to serious improvement of the website, making it a widely used teaching resource, and that ideas for new projects and ways of improving how physics is taught will be generated. By doing this, it is anticipated that students will benefit from the use of these resources, as hopefully they will significantly increase their motivation and enhance their learning experience as they see the relevance of what they are studying to the world around them.

Chapter 2

Theory

Research in the social sciences can often be separated into four approaches: exploratory, descriptive, relational and explanatory. Exploratory research is used to gain familiarity with a subject, descriptive seeks to portray the subject accurately, relational seeks to describe relationships between variables and explanatory shows causal relationships and patterns [26]. In this project, the first three approaches were used: exploratory, to be introduced to the barriers and benefits of applying physics to the real world, descriptive to understand them and finally relational, to understand how to improve resources to address these barriers. Regardless of what research approach is used, research must be conducted systematically, with carefully detailed procedures so that results can be replicated [1].

Research is commonly separated into qualitative or quantitative approaches and more often than not, researchers choose methods most commonly associated with their field, avoiding alternative approaches. Quantitative researchers usually start with a hypothesis and seek to provide support for it by studying the measurable cause and effect of an external variable on this topic. On the other hand, qualitative researchers start with case studies and work toward a hypothesis, seeking out people's perceptions and their meanings by studying their feelings, opinions, and values [26]. Quantitative researchers accuse qualitative research of being too focused on abstract concepts such as thoughts, perceptions, attitudes and values, which are difficult to measure and thus open to interpretation, instead of utilizing concrete data that clearly provides support for or against a hypothesis. Conversely, qualitative researchers charge quantitative research of being too reliant on numbers, measurement tools and statistics, which do not take into account contextual detail and may miss the motivations or explanations underlying the response [26]. By using these methods simultaneously, a better description of the phenomenon of interest can be gathered, as information is obtained from a variety of perspectives. The drawback of this approach is that there is no set way to resolve incongruity between the findings of the different methods.

The methodology in this study will include qualitative data, obtained from surveys (open ended questions), interviews and focus groups, mixed with quantitative data from surveys.

Surveys, a source of quantitative and qualitative data, are usefu as one can inexpensively gather a lot of data quickly, the structured questions allow for easy data coding and analyzing, and they provide anonymity for the responder. Their drawback is that the researcher is limited to analyzing only what is physically written on the paper and no implied assumptions can be drawn. When writing questionnaires, it is imperative that all ambiguities and misunderstandings are anticipated so that the participants do not have to work to interpret the meanings of the questions. Each question should be related explicitly to a specific aspect of the objective of the study and the survey's lay out should be aesthetically pleasing. Surveys should be arranged as a conversation, beginning with the researcher introducing the project, moving into non-threatening questions, shifting slowly to more threatening questions, and finally concluding with asking for comments [26].

Surveys can be composed of a variety of questions. Open ended questions are exploratory and should always come first in a survey so that respondents give their opinions in their own words, without the other survey questions influencing their answers. The number of open ended questions should be limited, as responders do not want to answer a lot of these and the results are more difficult to analyze. One word responses should be avoided as respondents are reluctant to give specific answers. Closed questions, used for breadth over depth, are useful for comparing results from different surveys (given identical wording) and they are easier to quantify. Categorical responses, a type of closed question, asking responders to place themselves in a category, are generally easy to answer but it must be ensured that categories are exhaustive and mutually exclusive. Finally, assertion questions asking the extent to which the responder agrees or disagrees are useful, both when positively and negatively worded [26].

Focus groups, a source of qualitative data, are advantageous especially when entering into a new field, establishing issues of importance, or seeking to gain insights from those who have experience. They are beneficial as motives are made clear and do not have to be speculated and opinions can be highlighted and negotiated. If something isn't clear, clarification can be sought and positions easily articulated. When conducting a focus group, it is important to be aware of what you write down or appear to be interested in, so that you do not influence the participants into focusing their answers on what they think is the answer you want to hear. Therefore it is necessary to record focus groups and to later transcribe and analyze them. Also, the interviewer must ensure that all participants feel comfortable speaking and no one should be allowed to dominate the conversation, ensuring that the opinions of all participants are equally covered [26].

Another source of qualitative data, interviews, are useful for exploring respondents' thoughts and motives without having to speculate. Any confusion about particular questions can be clarified and researchers can probe deeper if a response does not fully answer their question. Also, recording interviews is beneficial as then the interviewer does not write down just phrases of interest, but they can analyse the entire conversation. Finally, participants in interviews are often willing to participate in panel studies, consisting of a series of interviews, to track opinions over time [26]. In this study, semi-structured interviews were conducted. These are interviews in which the interviewer has a general framework of topics to be discussed and questions to be asked, but new questions may be brought up during the interview in response to what the interviewee says.

There are two different ways of sampling populations, by probabilistic and non-probabilistic means. Probabilistic sampling requires a formal representation of the population of interest while non-probabilistic sampling uses strategically chosen samples of the population [26]. Probabilistic sampling was not used in this study as it would require that every physics teacher in the province has an equal chance of being chosen for the study. The average teacher's response is not a primary matter of interest, but rather the feedback from those teachers who are interested in using the site and have insight into how it could be improved. Such teachers need to have the knowledge and experience necessary to give feedback, the ability to reflect and articulate thier thoughts, the time and the willingness to participate [26]. Even in this strategically chosen sample, the background of each teacher involved was considered so that the teachers involved represent the total population of teachers as fairly as possible.

Finally, the validity of the results must be ensured so that there can be high confidence in the accuracy of the conclusions drawn. In quantitative research, validity is the degree to which the measurements relate to the variables they intended to quantify and that these results can be repeated. In qualitative research, validity is not that the same findings will be observed again, but rather that the results are consistent with the data collected. Volunteer bias occurs in studies in which participants volunteer to participate, as the willingness to participate says something about them. In this case, biases must be identified as well as how these biases affect the results [26].

Triangulation, used to validate results, is the idea that if the results obtained using a variety of methods all agree, then one can be fairly confident that these results are accurate. In this project, data will be collected in interviews, surveys and focus groups and will be used to triangulate the findings. Member checking will be used to obtain inter-rater reliability. This ensures consistency in interpretations when multiple people separately code data or analyze results. If two researchers, who code data separately, come to similar conclusions and then work together to produce a unified analysis of the results, the likelihood of that analysis being accurate increases.

Chapter 3

Experiment

3.1 Research Conducted

The project consisted of two workshops with Science 10, Physics 11 and 12 teachers and first year university physics instructors, in addition to a series of interviews. To recruit teachers for the workshop aimed at high school teachers, information about the workshop was faxed or emailed to all schools in BC which offer grades 10 - 12. In addition, information was sent to teachers who subscribe to the Physics Outreach newsletter and those who have participated in the Outreach Program's Professional Development workshops in the past. For the post secondary instructor workshop, one physics instructor from each institution in British Columbia was invited to participate, with the option to pass the invitation along to a colleague in the case that they were unable to attend.

3.2 High School Teacher Workshop

On October 23rd, 2009, a Professional Development workshop held by UBC Physics Outreach with the first 24 teachers who responded to the invitation. In the morning, Dr. Waltham and Dr. Kotlicki gave an overview of the goals and layout of the website and then taught two sessions using resources directly from the website. One was an experiment, from the "Energy Use at Home" section, involving the measuring and graphing of power loss when hot water was put in a Styrofoam container. Teachers were given infrared thermometers and oven thermometers and asked to compare the temperature inside the container with that on the surface of the container. The second session involved teaching a lecture on the harnessing of energy by wind turbines using the lecture notes on the website. In the afternoon, participant teachers were given an overview of other topics on the website by Dr. Moll and left to explore the site themselves for an hour or so. After this, they were surveyed on the importance of connecting physics to the real world, types of resources beneficial to teachers, the connection between the resources on the website and the curriculum, and the usefulness of the resources developed. Twenty four teachers completed surveys; however, the quantitative data from one of them had to be left out as that person's answers were inconsistent with each other. Of the teachers who filled out the surveys, 14 of them (58 percent) had been teaching for more than ten years. Also, the population consisted of teachers who taught a range of different courses, and in regards to location, although most of them were from various regions of the lower mainland, there were also a few from the interior and northern BC.

In these surveys, teachers were asked open ended questions including the following: What do you consider most important in physics teaching? What do you think is the goal of physics teaching? Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach? Which types of resources, from those provided on the site, are you likely to include / not include and why? Do you have any suggestions for additional topics or activities that can be included in the C21 resource?

Workshop participants were also asked to rank their opinions on the usefulness of different types of resources (overviews, lecture notes, multiple choice questions, problems sets and take-home experiments) on a scale from 1 to 5 where 1 is not useful and 5 is useful. In addition to this, they were asked some questions about possible resources the website could include in the future - such as instructional videos, social media, and the ability to rank, comment on or contribute to articles.

Finally they were asked to rank their opinions, on a Likert scale from 1 to 5 where 1 is strongly disagree and 5 is strongly agree, on a series of statements about the site and the resources. Statements included topics such as the importance and potential benefits of linking physics concepts to the real world, the benefits to using the resources in the classroom, the relevance and level appropriateness of the material, the navigation of the site and the likelihood of them using the website.

The three teachers from out of town, each of whom had been given funding to attend the workshop, were invited to attend a 45 minute focus group. This focus group was held early in the study, as was earlier stated to be one of the more advantageous times in which to run a focus group, in order to gain insight and establish an understanding of this field from those who have experience [26]. During the focus group, discussion was facilitated to probe deeper into what teachers believe is important when teaching physics, the issues associated with connecting the curriculum to the real world, and their initial responses to the resources provided. One teacher was from Prince George and teaches Physics 11 and 12, Science 9 and 10, electronics and computer information classes. Another, from just outside of Nelson, teaches Science 10, Physics 11 and 12, Chemistry 11 and 12, and Math 10 and 12. The third participant was from a small town north west of Prince George and teaches Math 8 - 10, Science 8 - 10, Physics 11 and Physics 12.

3.3 Post Secondary Instructor Workshop

On December 10th, 2009, a similar workshop was held with 14 post secondary instructors from around British Columbia. In the morning, Dr. Waltham and Dr. Kotlicki gave an overview of the motivation and background to the project followed by Dr. Moll introducing the participants to the various topics and resources on the site. Subsequently, participants worked in small groups to review and critique specific topics on the site. After a large group feedback discussion in the afternoon, they were invited to fill out a survey identical to the one given at the High School Teachers' Professional Development Workshop in October.

3.4 Interviews

In February, after having been given some time to incorporate these resources into their teaching, teachers who had attended the workshops were sent a follow up email informing them of the more recent changes to the site, asking them of how they have or plan to use the resources and inviting them to participate in an interview. Those instructors who participated in the workshops were first invited to participate, and four of the post secondary instructors but only one of the high school teachers volunteered for an interview. Because more participants were desired, two additional instructors, one high school and one post secondary, who had previously shown interest in the project, were also interviewed. The majority of interviews were conducted by phone and probed deeper into the goals of physics teaching, the instructor's impression of the website, the benefits and drawbacks of using the resources in their teaching and the appropriateness of the level of math and physics on the site. In addition to this, instructors were asked their opinion on both topics and types of resources (overviews, lecture notes, multiple choice questions, problem sets, and take-home experiments) on the website, including how easy they are to incorporate into classes, ways of improving them, and their experiences while using them.

3.5 Data and Analysis

After conducting surveys, interviews and a focus groups with instructors, the data obtained needed to be analyzed. The interviews and focus group were recorded and transcribed texts were produced. Analysis was done by examining the texts line by line, and highlighting relevant statements that provided answers to the various questions this project sought to answer.

Aside from interviews and focus groups, surveys were another method of acquiring data. In order to analyze the answers to the closed ended survey questions, the mean values of the responses were calculated. The open ended questions were coded by two researchers, Dr. Moll and myself. Coding is a type of data analysis method that consisted of first reading through the verbatim responses of each participant. From this, a list of ‘codes or common themes was created, into which the teachers’ responses could be appropriately categorized. These codes, or categories, had to be specific enough that not all the instructor’s responses fell into only one category, yet significantly broad so that there was not just one category per response. Also, it should be noted that one response can fall under multiple categories. After the codes were created by each researcher, they were compared so that both researchers agreed that they accurately represented the data. The researchers then individually placed the teachers’ responses from the survey questions into appropriate codes and counted how many responses fit into each category or ‘code’. These sums for each code from both researchers were then combined to produce a final coding scheme. As desired, at least 80% of the responses were coded identically, giving an inter-rater reliability of more than 80%. Finally, when analysis of all the data from surveys, interviews and focus groups was completed, the data from all sources were compared for similarities and differences.

3.6 Ethics

The ethics procedures for this project were followed as specified by the Social Sciences and Humanities Research Council (SSHRC) and UBC’s Behavioural Ethics Board. All participants were asked to give informed consent prior to participating in each of the activities after being told the purpose and usefulness of the study and the benefits and risks of participating in it. Participant confidentiality was maintained in the surveys by the participants remaining nameless, and in the interviews and focus groups by using pseudo names in the results. This nameless data will be kept secure in the UBC Physics Outreach Office and will be destroyed after 5 years. Computerized files are stored on a secured password protected computer.

3.7 Validity

This project has validity as many steps were taken to ensure that results were accurate. Interviews were used to examine whether or not participants were interpreting our language, such as 'real world', in the same way as we had intended. Internal validity, defined as being how closely research findings match reality, is high since the reality being studied is experienced by the participants and so interpretations based on what they say are close to reality. Also, inter-rater reliability was used to ensure internal validity because by having at least two members of the research team interpreting and discussing the results, researcher's biases and misinterpretation are reduced. External validity is the ability to generalize the results. Generalizability, a limitation of qualitative methods, can be obtained by using random sampling. This is not beneficial in this study as we wanted to know, from those who would use it, how to improve the website, not the opinion of every teacher in the province on our project. Instead, it can be obtained by providing enough detail so that the reader can identify whether the findings apply to the situations they are interested in. Finally, triangulation, as seen in Figure 3.1 can be used to increase the confidence one has in the accuracy of the results. In this study, if data from the five sources (high school teachers survey, post secondary instructors survey, focus group, high school teacher interviews and post secondary instructor interviews) all explicitly provide evidence for the same claim, one can have high confidence this conclusion is correct.

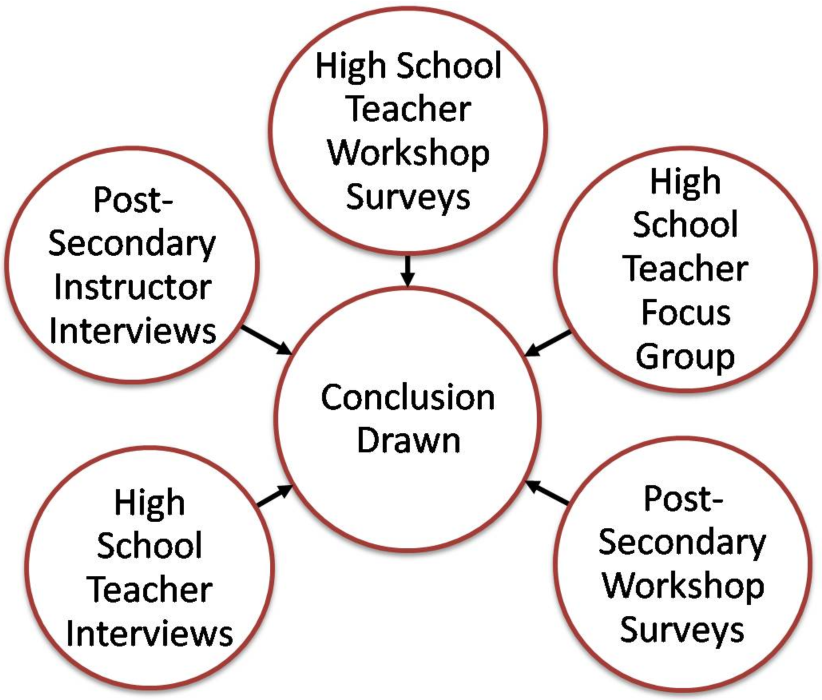

Figure 3.1: Triangulation increases the confidence one has in the accuracy of the results as if the data from all sources support the same claim, one can have high confidence that claim is accurate.

Chapter 4

What Is Important In Physics Teaching

First, this study sought to uncover what is important in physics teaching, or the goals that physics teachers strive to accomplish through teaching in their classes. This is essential, since in order for this website to be a source of effective teaching resources, it must be designed to address what teachers value. In order to determine what is important, this question was posed to high school teachers and instructors throughout surveys, a focus group, and interviews. Results from each of these data sources will be described.

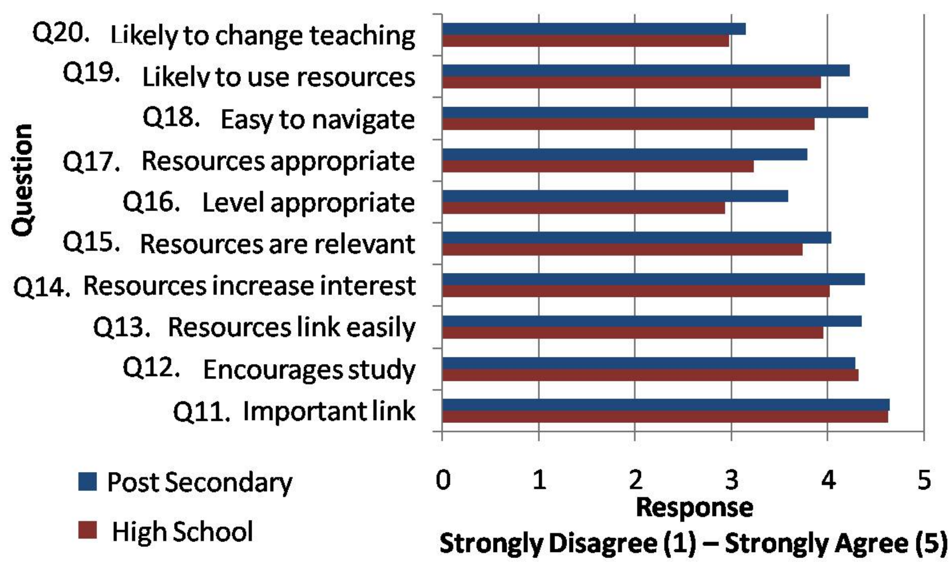

Figure 4.1: The high school teachers' and post secondary instructors' responses when asked to rank their opinion of a set of statements on a scale from 1 to 5 where 1 is strongly disagree and 5 is strongly agree (See Appendix A for survey questions).

4.1 High School Teacher Workshop Survey

The question of what is important in physics teaching was asked throughout the survey in a variety of forms. In the closed ended question portion of the survey, high school teachers were asked to rank their opinion, on a scale from 1 to 5 where 1 is strongly disagree and 5 is strongly agree, of the following statement: "Q10: I think it is important to link physics concepts to real world contexts and global issues such as energy consumption and climate change". The average response of the high school teachers (N=24) was a 4.6/5, as seen in Figure 4.1, somewhere between agree and strongly agree, indicating that linking physics to the real world was something they valued.

In the open ended section of the same survey, teachers were asked "what is most important in physics teaching?". The two most frequent responses were "conceptual understanding", which was mentioned by 12 of the 24 teachers, and "connection to real life" mentioned by 6 of the teachers. Example of responses about what is most important in physics teaching include "passing on sound understanding of concepts, making connections between concepts and practical 'real world' applications, generating interest and curiosity about our universe". Others also said it was "concepts and applying physics to the real world" or "understanding the basic concepts and making connections to real life" that was important. They were also asked "what are the goals of physics teaching?" to which 11 of the teachers responded by saying "conceptual understanding" and 9 said "connection to real life". As above, various teachers made comments such as: the goals are "relating physics to real life and solid conceptual understanding". From this it is evident that these two things, conceptual understanding and connection to the real world, are important as teachers individually responded to the questions with almost identical answers stating these two goals.

Finally, teachers were asked "What are your thoughts on connecting physics to the real world? (i.e. I'm already doing it, I would like to start doing it, it is not an important goal, it is too difficult)." Of the 24 teachers, 20 said that they are either "already doing it" or "would like to do more", 3 suggested ways and reasons for connecting it to the real world and only 1 teacher indicated that they thought the physics of real world contexts was too complex for his/her students to understand. So, over 80% of high school teachers already trying to teach physics in connection to the real world, and when asked about what is important, conceptual understanding and connection to the real world emerge as important goals.

4.2 High School Teacher Focus Group

At the focus group on the same day, when discussing the goals of physics teaching and what they consider important, the three teachers who participated said “I think the underlying physics principles or the concepts are the important things” and “I think the goal is to leave them with some understanding of the basic principles so they can relate them to everyday scenarios”. They also commented on the why they value connecting physics to the real world saying “to connect anything we’re trying to teach with the real world just makes it more relevant for them”. So again, the important things in physics teaching come forward as being concepts and connecting physics to the real world or relating it to everyday scenarios.

4.3 Post Secondary Instructor Workshop Survey

An identical survey to the High School Teacher Workshop Survey was given to the post secondary instructors and the results were similar. The instructors (N=14) were asked their opinion, on a scale from 1 to 5 where 1 is strongly disagree and 5 is strongly agree, of the statement “Q10: I think it is important to link physics concepts to real world contexts and global issues such as energy consumption and climate change”. The answer was the same as that of the high school teachers with the average response being 4.6/5, between agree and strongly agree, as seen in Figure 4.1.

These instructors were also asked about “their thoughts on connecting physics to the real world (i.e. I’m already doing it, I would like to start doing it, it is not an important goal, it is too difficult).” Out of the 14 instructors, 11 stated that they were either “already doing it” or “would like to do more”, 2 instead stated the importance of connecting physics to the real world and 1 instructor said that it was difficult but a practice that should be supported. Once more, the majority of instructors are aiming to teach their physics classes in connection to the real world.

When asked in the open ended section “what is most important in physics teaching” the most popular response, stated by 7 of the 14 instructors, was to “promote student engagement/interest”. Instructors said they valued “being able to engage students” and the “active engagement of students in class [by] showing the relevance of physics (your site will help a lot with this)". While this answer differs a bit from that of the high school teachers, as stated earlier, one of the leading ways to increase students' interest or engagement is by teaching physics in connection to the real world [10]. Therefore, the value of connecting physics to the real world is a means of increasing student interest.

Out of these 14 instructors, when asked explicitly "what is the goal of physics teaching?" 5 responded by saying that "connection to real world" was the goal and 7 responded by saying that the goal was developing "problem solving and thinking". For example, some responses stated that the goals of physics teaching are "relating physics to real life and [developing] real problem solving skills" and "producing people who can think and apply physical principles to solve real world problems". So connection to the real world as an important goal is again stated, but in addition, the goal of problem solving and thinking also emerged. This makes sense when comparing the venue of high school teaching to that of post secondary instruction. In high school, teachers require that their students understand the basic concepts while in university the instructors strive to have their students go beyond just understanding the concepts to being able to think and use the concepts to solve problems.

4.4 Interviews

Finally, the interview participants (N=7) were also asked to discuss what is important in physics teaching and what the goals of physics teaching are. A high school teacher responded by saying that at the grade 11 level "one of the goals of the program is to try and interest students in physics and get them excited in physics". Another said that not only was the goal "to introduce students to the concepts of physics" but also "to help develop students to analyze the information they receive - in the media for example - and to try and put some analysis into it instead of just believing it." So, this suggests that high school teachers are aiming to interest their students in physics, introduce physics concepts and help them apply what they have learnt to how they approach the world.

Post secondary instructors stated that the goals are for "students to emerge with a good understanding of concepts", for them to "be able to apply the concepts in physics to everyday situations" and to have taught "enough background knowledge and developed enough critical thinking skills to have an informed opinion of important issues like climate change". It seems that post secondary instructors value the understanding of concepts and the application of concepts to everyday situations, and also push it a bit farther and desire their teaching to have an impact on how their students view important issues.

4.5 Conclusions

When looking at the data from each of these sources, it becomes apparent that each source is providing support for the same claim - that what is important in physics teaching is conceptual understanding and connection to the real world. As earlier discussed, triangulation is the idea that if results obtained from a variety of methods all agree, then one can be fairly confident that these results are accurate. This agreement is evident through the fact that overall, the teacher and instructors agree/strongly agree that connecting physics to the real world is important and that the majority of them are either already teaching in a way that aims to make this connection explicit or trying to. Furthermore, when asked about the goals of physics in general and what is important, both groups of instructors, in both the open ended survey questions, the focus group, and the interviews, all stated that it was connection to the real world and conceptual understanding that is important. It also it supported that instructors are aiming to do more than just have their students understand the concepts, but they want them to be able to go beyond understanding to applying the concepts and using them to solve relevant problems. These findings also agree with those of Arion et al., who in 2000 claimed that the goals of physics education include teaching the ability to apply concepts to problems solving and the application of physics to real world situations [15].

From these findings, we can conclude that instructors value conceptual understanding and connections to real world. Therefore, since the C21 website seeks to provide resources for teaching physics concepts through real world contexts, it is evident that this project addresses what teachers value and consequently, the development and improvement of the website is a worthwhile direction to pursue.

Chapter 5

Resource Topics

Upon establishing that this project is worthwhile to pursue, as it addresses what physics teachers consider to be important in physics teaching, an analysis of the resources on the site, and in particular the real world contexts, must be conducted. The usefulness of the resources will be looked at in terms of ease of incorporation into classrooms, relevance the resources have to the students, and the extent to which the website will make physics more interesting to the students.

In regard to the resources in general, a few of the closed ended survey questions, addressed the perceived usefulness, relevance and interest generating ability of the resources. The instructors' opinions to these questions are seen in Q13, Q14 and Q15 in Figure 4.1. Instructors were asked to give their opinion, on a scale from 1 to 5, 1 being strongly disagree and 5 being strongly agree, of their opinion of the following statement "Q13: The resources provided on the website make it easier for me to link my teaching to real world issues." High school teachers responded with an average answer of 4.0/5(agree) and post secondary instructors with a 4.4/5 (between agree and strongly agree), revealing that teachers agree that these resources do provide an easy avenue for teaching physics in connection to real world issues. When asked about their opinion of "Q14: I believe the resources provided on the website will make physics more interesting to my students" the average high school teachers' answer was a 4.0/5 (agree) and the post secondary instructors' answer was 4.4/5 (between agree and strongly agree), indicating that they anticipate that these resources will make physics more interesting to their students. Finally, instructors were asked to rank their opinion of the statement "Q15: The contexts and issues presented in the resources are relevant to my students". High school teachers responded with a 3.7/5 (between neutral and agree) and post secondary instructors with a 4.0/5 (agree), showing that they did think that the resources would make physics more interesting for their students.

It can be seen in the three above questions that the average responses of the post secondary instructors were always slightly higher than those of the high school teachers but the differences are not statistically significant. The reason as to why there is this small difference can only be speculated upon, but it seems that post secondary instructors observe that their students will find physics more interesting and relevant by studying real world contexts than the high school teachers do. This could be due to the fact that post secondary students are more mature than high school students and so are somewhat more interested in examples revolving around global issues or perhaps as a result of the instructors backgrounds.

Specific sub-topics on the site have been evaluated by both the teachers and instructors. Subtopics include Renewable and Clean Energy, Energy Use At Home, Climate, Transportation and Biology. Table 5.1 shows a comparison of the instructors' opinions of the various resources topics using data from the surveys.

Topic	High School Teachers	Post Secondary Instructors
Renewable and Clean Energy	13/24	6/14
Energy Use At Home	10/24	0/14
Climate	7/24	1/14
Transportation	4/24	3/14
Biology	N/A	N/A

Table 5.1: Fraction of instructors who indicated the given topic when asked in the survey "Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach?".

5.1 Renewable and Clean Energy

Renewable and Clean Energy is a section of the website that contains examples relating to alternative energy sources. Currently, the only completed example in this section is on Wind Turbines, which looks at the total energy available in the wind, the power can be feasibly extracted using a wind turbine, the limitation of wind turbines and a comparison of the impact of wind energy to other sources of energy. This section seems to be the one most preferred by teachers. When asked in the surveys "Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach?" 13/24 of the high school teachers and 6/14 of the post secondary instructors, about half of each group, indicated that the topics in the energy section would be the one that would be most easily connected to the curriculum.

In the interview, this positive reaction continued as over half of the instructors referenced the energy section saying that it looked like the section contained “lots of useful stuff” which they cited as being good because, as one instructor said, “students often have a great difficulty understanding energy”. Instructors also commented that “energy use is very relevant and students seem to want to have more knowledge in that area” and that this section “showed how to attach more relevance to some of the things that are maybe happening in the classroom in terms that are ‘very everyday’ for the students.” It seems that expanding this section would be very beneficial to teachers since energy seems to be an area that students are interested in, from the teacher’s perspective, and it also ties in well to the concepts teachers are trying to teach. This should be a high priority for future developments of the site.

There were also many requests for this section to be expanded to include examples on solar and nuclear energy. Solar energy is a topic in the Science 10 curriculum and nuclear energy is covered in Science 10 and then more in depth in Physics 11, and so this should be kept in mind when developing these resources. In addition, instructors requested that we delve deeper into comparing our energy use to our standard of living, including the source of our energy, how much we use, and how this has changed compared to our energy use in the past.

The wind turbine example in particular was said to be “right on the money” and that it “matched almost identically to the IB curriculum”. One instructor in particular commented that the perspective presented here was “a very useful way to look at [energy and air friction]” and that it was a “particularly useful perspective” for looking at the kinetic energy of the air. The fact that the example contained realistic numbers about the dimensions of a turbine and how much energy it can harness led them to think that students would be able to connect with it since they could more easily visualize the equipment being discussed. When developing more topics, it would be wise to model them after the wind turbine page, since it was referenced more times than any other article or topic on the website. To do this, topics should be explicitly connected to the curriculum, present a real world context for teaching on a standard concept, and contain realistic data that students can easily relate to. There were also some requests for this topic to be expanded to compare wind turbines to other sources of energy - both in terms of efficiency, cost and environmental considerations.

5.2 Energy Use At Home

Energy Use At Home is a section of the website that contains examples on topics such as the issues surrounding heating and cooling of buildings, examining the benefit of turning off the heat when you go out, and comparing the power used during a shower to that used by a car. In the survey, when asked "Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach?" 10 of the 24 teachers indicated that the Energy Use at Home section related the most to the classes they teach. However, this topic was scarcely mentioned in the post secondary survey or any of the interviews, except to suggest that looking at the thermal conductivity of windows would be a good way to expand this topic. It was also said to be well connected to thermodynamics, and so looking at courses that include thermodynamics and developing resources aimed at their curriculum may be the way to progress this section. In addition, Energy Use at Home can be tied into the Renewable and Clean Energy section by relating our standard of living to the energy use in our homes, and looking at renewable energy sources that could realistically meet the demand for power.

5.3 Climate

The section on climate includes articles focused both on understanding the earth's climate and on addressing some of the most frequently encountered claims regarding climate change. When the high school teachers were asked in the survey, "Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach?" seven of the 24 teachers indicated that they thought the climate section was the most connected. Then, throughout the interviews, this topic frequently surfaced, being referred to as "a very hot area of interest" to students by several teachers independently. Instructors also commented that it was "really good because [it] relates exactly to one of the things that we do in IB [International Baccalaureate] program" in addition to being well suited for Science 10 or an introductory astronomy class. Despite this easy curriculum connection, some instructors also stated that "some calculations in there were a little bit beyond what [students] need to know". From these interviews, it becomes apparent that Science 10 and IB classrooms, as well as astronomy classrooms, are some of the places these resources are likely to be used. Because of this, the resources need to be directed at a level which is appropriate for grade 10 students, as well as those in higher levels. This is particularly true in regards to the Simple Earth Climate Model article, which is stated as having curriculum connections to Science 8 - 10 and Physics 11. From reading the article, it becomes obvious the physics and math is beyond what a student in grades 8 - 11 could understand and the approach is also well above their level. While as stated previously, the articles are written at the instructors' level, it may be beneficial to show instructors more explicitly how this material can be simplified and made applicable to the science 8 - 11 curricula.

5.4 Transportation

Transportation is a section which presents articles on cars, buses, bikes, and planes to present displacement, velocity, acceleration, energy, power, work, and efficiency concepts. Some of the examples include examining the fuel required to get a bus up to speed after it stops for a stop light, the benefit of having properly inflated tires, the connection between paper airplanes and the energy cost of air transport, and comparisons between bikes, gasoline cars and electric cars. When the instructors were asked "Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach?" only 4 of the 24 high school teachers and 3 of the 14 post secondary instructors indicated that transportation was easily connected. This was surprising as one would expect that since a lot of high school physics involves learning about displacement, velocity, acceleration, energy and such, it would follow that articles on these topics would be seen as being connected to what is being taught. Apparently this was not the case.

Instructors also made similar comments in the interviews, such as saying that "it's interesting but it doesn't directly relate necessarily to the curriculum so it's kind of difficult to justify spending a bunch of time on that sort of stuff". While it is understood that resources not connected to the curriculum are difficult to justify incorporating into the classroom, especially in a course pressed for time, it is surprising that teachers don't see these articles as being curriculum connected. On the other hand though, some teachers did say that they would use these articles, one instructor said "the stuff about cars, efficiency or rolling resistance - those would be fairly useful". Other instructors said the various articles "give good thoughts for the kids to think about" or that through these resources "kids gain something to chew on". Throughout the interviews, almost every article under the transportation section was said to be useful or to be of particular interest to their students, by separate teachers. The discrepancy between the low indicated interest and lack of curriculum connection and the prevalence of teachers naming specific resources is quite interesting.

Furthermore, instructors in the interview had many suggestions for how this section could be effectively expanded. One such example included comparing the cost of driving a gasoline fuelled car to the cost of buying food so a cyclist could ride a bike over the same distance. Others provided suggestions for linking the Transportation and Renewable and Clean Energy sections by looking at how much power would be needed if all drivers in BC converted to electric cars and how many wind turbines would be needed to supply that power. Finally, there were some requests for data to be available for a variety of cars so that students could personalize the examples to the car that they or their family drives.

Overall, the data regarding the transportation section is quite surprising. The issue of the lack of perceived curriculum connection needs to be explored more deeply. In addition to this, ways of communicating to teachers how well other teachers found it to connect to the curriculum in the classes they teach should be looked at. Also, a few more topics could be added to this section relate it to some of the other sections on the site.

5.5 Biology

The section on Biology explains physics concepts through a variety of examples relating to the human body or animals. Examples include presenting optics through looking at eagles' eyesight, fluid dynamics through blood flow, and kinematics through nerve impulses. Since this site has been under development over the past year, at the time the surveys were completed, this section was quite bare, and so it was unmentioned through the surveys. After the surveys and prior to the participants being interviewed, more topics were added.

Throughout the interviews, many of the participants commented that they thought the biology examples would be useful in the courses they were teaching. This seemed to be especially true for those teaching first year non-calculus based physics courses at post secondary institutions. In these classes, the enrolment consists largely of biology or life science students who need physics credits for their degrees, and as one of the interviewees said, those physics instructors teaching it typically dont have a biology background. In this scenario, according to one instructor, "basically any resources of that nature are potentially very helpful". Instructors also cited the examples on blood pressure, nerve impulses, calorie counting and the cheetah's ability to run as those that would "connect most easily to the curriculum". This is not to say that these examples connect more than the other biology examples, as the dynamic nature of the site does not lend to us knowing which other topics were loaded when they viewed the examples, but it demonstrates that instructors do find these topics connecting to what they are teaching.

Concerns were raised by a few of the instructors interviewed, regarding the biology portion of the website. Their first concern was regarding the lack of material presently under the section and because of this they had problems commenting on the topic in general. Secondly, they worried about the real world context of the examples in regards to "talking about animals they will never actually deal with" or about the relevance of biology examples to those students not taking biology.

In light of this though, these instructors still had many suggestions for expanding this section including introducing topics on medicine and medical related devices and also on kinesiology or sports related contexts. By expanding this section in these directions, it is suggested that the Biology section will contain examples which appeal to a wider range of students. While fuel efficiency, for example, is applicable to the general population but perhaps not interesting to most, the application and relevance of biology examples will be more particular to the individual and perhaps more appealing to a variety of students. But, in order to really determine what is relevant and or considered to be related to the real world, the students' opinion should be sought.

5.6 Other Topics Suggestions

In addition to the feedback on the above sections of the website, many instructors indicated that they would be especially interested in the development of resources aimed at connecting the electricity and magnetism requirements of the Physics 12 curriculum to the real world. It seems that "students have a lot of difficulty with electricity and magnetism [...] because it's more abstract to them because of the nature of having to understand fields - the electric field, magnetic field". Instructors have indicated they struggle with explaining these concepts using examples the students can understand and so resources that fall under any of the above categories and relate to electromagnetism would be very useful. One suggested avenue for doing this was by adding an article to the transportation section looking at maglev trains.

5.7 Conclusions and Recommendations

Overall, all instructors identified topics under each section that they thought were not only useful and connected to the curriculum, but that their students would be interested in studying. Renewable and Clean Energy seemed to have the most interest and expanding this section should be a priority. In addition to this, instructors gave suggestions for expanding each of the other sections of the site as well, and all of them should be added to, including, in particular, a series of examples on electricity and magnetism. It is likely that teachers know their students better than the website developers do, since they are in much closer proximity to them, and so their speculations on what students can or cannot relate to should be strongly considered. Also, in regards to the climate section, it seems to be beneficial to modify the current articles to make them more geared towards the levels they instructors indicated they will most likely be used. Armed with the knowledge of what teachers prefer and which topics they would like to see developed, the designers of the site can now begin to sift through their ideas and begin the creation of new resources. The levels to which an article is explicitly connected should be kept in mind at all times throughout the writing process so that the articles can be easily incorporated into those class rooms.

It is also interesting that post secondary instructors predicted that their students will find physics more interesting and relevant by studying real world contexts than the high school teachers did. On the other hand though, the high school teachers found the topics generally connected more with their classes compared to the post secondary instructors' classes. In light of this, the developers should look to develop resources on topics more closely connected to post secondary classes, or to put more effort into emphasizing how these present resources can be easily incorporated there. Finally, instructors, as anticipated, were most likely to use those articles with explicit curriculum connections and so this should be remembered during the development of any additional resources.

Chapter 6

Resource Types

Next, the specific types of resources (overviews, lecture notes, multiple choice questions, problem sets and take-home experiments) must be evaluated in order to determine which resources are the most useful, how to improve specific types of resources, and where the greatest emphasis should be put in the further development of new resources.

In the survey, instructors were asked to rank their opinion, on a scale from 1 to 5 where 1 is strongly disagree and 5 is strongly agree, of the following statement: "Q19: I am likely to use the resources on the website (mini lessons, multiple choice questions, problem sets, and take-home experiments) to help me teach." The average response of high school teachers was 3.9/5 and that of the post secondary instructors was 4.2/5, both groups more-or-less agreeing that they were likely to use the resources (Figure 4.1). When asked in the open ended section of the survey "Which types of resources, from those provided on the website are you likely to include in your teaching and why?" 19/24 high school teachers and 14/14 post secondary instructors named a specific resource that they would use. Finally, in the same survey when asked "Which types of resources, from those provided on the website are you NOT likely to include in your teaching and why?"15/24 of the high school teachers and 8/14 post secondary instructors specified a resources that they would NOT use.

From this, it is apparent that while the majority of the teachers indicated that they would use a specific resource, half of them also indicated those they would not use. Therefore, demonstrating that while the resources developed so far are useful, instructors see ways to improve them, and so a study of what makes a resource useful to teachers is necessary. Table 6.1 shows a comparison of the instructors' opinions of the various resources using data from the surveys.

	High School Teachers			Post Secondary Instructors		
	Usefulness	Use	Not Use	Usefulness	Use	Not Use
Overviews	4.5/5	15/24	1/24	4.4/5	5/14	0/14
Lecture Notes	3.7/5	8/24	3/24	3.7/5	7/14	4/14
Multiple Choice	4.3/5	9/24	1/24	4.0/5	5/14	2/14
Problem Sets	4.2/5	6/24	2/24	4.1/5	8/14	2/14
Take-Home Experiment	4.4/5	15/24	4/24	3.9/5	7/14	2/14

Table 6.1: Instructors' opinions on resource types from three survey questions. 'Usefulness' is taken from instructors answers to "Please Rank the Usefulness of the [overviews] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful)' '. 'Will Use' is the amount of teachers to indicated the given resource when asked "Which types of resources, from those provided on the website are you likely to include in your teaching and why?' and 'Will Not Use' corresponds to "Which types of resources, from those provided on the website are you NOT likely to include in your teaching and why?"

6.1 Overviews

Overviews are articles on the website that present a topic or real world context, state the curriculum connections, goals and tools associated with the article, work through the solution to the problem presented, and finally provide links to other resources, related articles and relevant external sources. They are the core resource which contains all of the information regarding the topic and how to solve problems associate with it that are needed as background to the other types of associated resources (multiple choice, problem sets, and take-home experiments).

When high school teachers were asked in the survey to "Please Rank the Usefulness of the [overviews] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful)". The average response was 4.0/5, showing that teachers agreed that these resources were somewhat useful. Then, in the open ended section, when asked "Which types of resources, from those provided on the website are you likely to include in your teaching and why?" five of the 24 teachers indicated that they would specifically use overviews. These results were duplicated by the post secondary instructors who, when asked the identical questions, ranked their usefulness as being 4.4/5 (between somewhat useful and useful). When asked "Which types of resources, from those provided on the website, are you likely to include in your teaching and why?" 5 specified they would use overviews, making comments such as "overviews - guide to topic summary for me" and "overviews - a well written overview would give me a pedagogically sound order in which to present the relevant topics".

When both groups of instructors were asked "Which types of resources, from those provided on the website, are you NOT likely to include in your teaching and why?" none of the post secondary instructors mentioned overviews and only 1 of the high school teachers said overviews indicating they were "not clear about the main teachable point". From this, it seems that overviews are useful to teachers and while only a third or less of teachers indicated they would use them specifically, only one of the 28 teachers said they would not use them at all.

Overviews were also mentioned quite often through the interviews in regards to being useful as an outline for teaching or a source to draw information from, but some suggestions were also made. Many teachers indicated that they were useful particularly as an outline, making comments such as "I think they're good. They outline things a little bit." and they're "useful as a guide of how I approach the subject". They present teachers with a context to teach physics in connection to the real world and show how to work through towards a solution. Many teachers also found them as being good sources of information saying "I like the fact that there are overviews because all the information is there. I dont have to spend a tremendous amount of my time reinventing the wheel and looking up the stuff." In particular, teachers seemed to appreciate the links included on the page to each of the sources used in the designing of the overview. Instructors made comments such as "I like the bibliographies", "I like the links on your site to other sites, thats great!" and explained that "It helped me to prepare for a lesson or for a class. Having those resources to draw information from was great". It provides instructors with easy ways of finding other useful information on the topics presented, or a way of finding further explanations to what was presented.

There were also some suggestions on how to improve overviews, mainly in regards to specifying what level they were aimed at. One teacher commented that the overviews "seemed like a bit of a mishmash between stuff that is pitched at the student and stuff that's pitched at the instructor." There were also a handful of teachers who commented how useful it would be to their students. Again it should be emphasized that overviews are not intended to be directed at students, but rather towards instructors. Information should be understandable by students, but it covers the examples at a faster pace than what would be understandable by the average high school student.

On the whole, overviews seem to be a great guide to outlining topics, presenting background material, and working through the concepts - which is what they were intended to accomplish. Teachers seem to agree that they are useful and that they will use them. On top of this, instructors mentioned that they found the links to the external sources very useful, and so incorporating useful links should be continued in the future development of overviews. To improve overviews, the only suggestions were focused on ensuring they are clear and emphasizing who the intended audience is so that teachers understand that they are aimed to be used by teachers, not their students.

6.2 Lecture Notes

Lecture notes are presentations which transform all of the information covered in the overview into something that can be easily incorporated into an instructor's lecture. They are posted on the website in pdfs format and as PowerPoint presentations, which can be downloaded and immediately used. The latter allows for the instructors to edit and adapt the presentations as they see fit.

In the survey, instructors were asked to "Please Rank the Usefulness of the [lecture notes] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful.)" Both the high school teachers and the post secondary instructors responded with a mean answer of 3.7/5, indicating they were between useful with minor changes and somewhat useful. When high school teachers were asked "Which types of resources, from those provided on the website, are you likely to include in your teaching and why?" 8 of the 24 said they would use lecture notes. A higher fraction of the post secondary instructors, 7 out of the 14 instructors, indicated that they would use them, and made comments such as "I would use them as a guide" and "I would edit substantially to fit my style but I like having them as a start and to frame". It seems that while the lecture notes are useful, they also need to be edited by the teachers before being used in the classrooms. This makes sense, as each teacher has his/her own style of teaching and explaining material and so it is hard to design lecture notes for other teachers to use.

This trend was continued in the survey question that asked "Which types of resources, from those provided on the website, are you NOT likely to include in your teaching and why?" 3 of the 24 high school teachers said they would not use lecture notes, adding no additional comments, and 4 of the post secondary instructors said they would not use them, saying that they "would probably make my own lecture notes but they would be based around yours" and "I prefer to use the blackboard". Again, it seems to be style and teaching preference that limits the use of these resources.

In the interviews, the same themes continued. Instructors were quite positive about the lecture notes, saying "lecture notes were great" and "the lecture notes I found very helpful so far." Some of the teachers had already used them and said that it was easy to pull some of the slides into their own presentations, others had not yet had the chance to do that but said "I think it would be easy to make use of that as part of the presentation". Still other instructors indicated that they prefer to use other teaching styles but they could "see that they [lecture notes] would be useful".

Overall, it seems that teachers found the lecture notes to be a useful base, but that most of them would edit the lecture notes before incorporating them into their classrooms. As a result of this, lecture notes should be developed in such a way that allows them to be easily edited. This could include finding a version of power point that is the most consistent across other versions to maximize the amount of formatting that remains the same when the file is opened with a different version of PowerPoint. Also, by condensing the number of slides so that teachers have less to sort through and edit, it would probably also increase their usefulness.

6.3 Multiple Choice Questions

Multiple choice questions are designed to go alongside the information in the overviews to evaluate the extent to which students are following what is being taught. They are posted as both Power Point presentation files and pdfs and can be used in class to engage students and monitor their understanding.

When the high school teachers were asked to "Please Rank the Usefulness of the [multiple choice questions] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful)" the mean response was 4.3/5, indicating that the questions were somewhere between somewhat useful and useful. Later in the same survey, when asked about "Which types of resources, from those provided on the website, are you likely to include in your teaching and why?" 9 of the 24 teachers responded by saying multiple choice questions with comments such as, "multiple choice - interest generator". In the following question asking about "Which types of resources, from those provided on the website are you NOT likely to include in your teaching and why?" only one teacher responded by saying that they would not use multiple choice questions and cited time as being the reason why.

The responses were again replicated by the post secondary instructors. In the question regarding the ranking of the usefulness of the multiple choice questions, the mean response of the post secondary instructors was a 4.0/5, somewhat useful. When asked "Which types of resources, from those provided on the website, are you likely to include in your teaching and why?" 5 of the 14 instructors answered multiple choice questions making comments such as "multiple choice - in class conceptual / discussion" and "multiple choice questions - good for promoting active engagement and discussions in class". One participant also indicated that he/she would use the multiple choice questions but that they "want more - especially conceptual". Regarding "Which types of resources, from those provided on the website, are you NOT likely to include in your teaching and why?" 2 of the instructors said that they would not use multiple choices, saying also that there was "no time" or for unspecified reasons.

The interviews dove more deeply into how multiple choice questions would be used and how to improve them. Concerning how, and why, they would be used, instructors made comments such as "I would use the multiple choice stuff as a way of starting them off. Stimulating their thinking.", "I would probably use them in class. Part of an in class discussion" and "I thought they were pretty good. It's another way of getting kids engaged quickly." Instructors have found that using multiple choice questions in class stimulates students' thinking, generates discussion and engages the students. It also gives the instructor an idea about how much the students understand about what is being taught. But again, another separate instructor indicated that the multiple choice questions "seemed very based on factual recall as opposed to real conceptual understanding or reasoning. So those didn't seem especially useful to me."

So, again, the various sources of data collection all point to the same conclusions. Multiple choice questions are useful, especially for initiating discussions, generating interest, and increasing student engagement in class. However, they would be more useful if they included more conceptual based questions and less factual recall. The website developers should try to increase the number of conceptual questions in the multiple choice resources currently on the site, and should focus much more strongly on conceptual over factual content in the future.

6.4 Problem Sets

Problem sets consist of a series of long answer questions that further exploit the real world contexts and allow students to solve problems which may apply more obviously to their experiences than standard textbook questions. Again, they are posted as both Word documents and as pdfs so that they can be used as is, or modified as the teacher desires. In addition to this, all of the solutions are posted, as well as, in some cases, a spreadsheet showing how the answers change with respect to various parameters.

When the high school teachers were asked to "Please Rank the Usefulness of the [problem sets] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful.)" the average response was a 4.2/5, between somewhat useful and useful. 25% of the teachers, 6/24, indicated that problem sets were resources they were likely to use when asked "Which types of resources, from those provided on the website are you likely to include in your teaching and why?" One teacher mentioned they would use "the climate and energy problem sets - because they apply to 'real life' problems" showing the appreciation for the real world aspect of it. When asked about "Which types of resources, from those provided on the website are you NOT likely to include in your teaching and why?" 2/24 of the high school teachers said they would not use problem sets, one of them saying "unfortunately we dont have a lot of extra time to delve in quite so much detail as you have gone."

The post secondary instructors, when asked to "Please Rank the Usefulness of the [problem sets] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful.)" responded with a mean response of 4.1/5, just above somewhat useful. Over half of these instructors (8/14), when asked "Which types of resources, from those provided on the website are you likely to include in your teaching and why?" indicated that they would use the problem sets. They specified that they would use them as "weekly hand-ins and exam questions", "for class and exams" and for "assignments and even part of tests with various changes for security reasons". But, similar to above, when asked

"Which types of resources, from those provided on the website are you NOT likely to include in your teaching and why?" 2 out of the 14 instructors said they would not use problem sets due to style preferences or a lack of time.

Throughout the interviews, teachers indicated that they liked problem sets as they, for example, "do a good job of using/taking advantage of the context". Also teachers appreciated that solutions were posted because, as one instructor put it, "For someone who knows the physics it's good to double check. And then there are many teachers, especially [those] teaching younger grades who do not have physics background". But yet again, one teacher commented that it would just be something else that they have to mark. This reflects yet again on teachers preferred styles as those who use problem sets appreciate the questions on the website while those who do not want to mark assignments, do not see them as useful.

Problem sets were found to be somewhat useful by teachers as somewhere between 1/3 to 1/2 of participants specified they would use them and appreciated how they took advantage of the real world context they were connected to. Most teachers planned to use them as weekly assignment questions or as exam questions. No recurring suggestions were given in regards to how to improve them.

6.5 Take-Home Experiments

The last type of resource currently on the site is take-home experiments. These are experiments which directly connect to the real world context presented in the overview and are posed as more of an open ended problem to solve, not as a step by step recipe of how to accomplish something. A sample write-up is also posted with each experiment so that teachers can see an example of how the developers conducted the experiment. Sample data is provided in case there is not enough class time for students to actually do the experiments themselves, but the instructors would like to do the related calculations using the posted data. Both the instructions and the write-ups are posted as word files and pdfs so that teachers can modify them if desired.

When the high school teachers were asked to "Please Rank the Usefulness of [take-home experiments] on the website to your teaching. (1 - Not Useful. 2 - Useful with Major Changes. 3 - Useful with Minor Changes. 4 - Somewhat Useful. 5 - Useful.)" the average response was a 4.4/5, between somewhat useful and useful. In addition to this, when posed with the question "Which types of resources, from those provided on the website, are you likely to include in your teaching and why?" 15 of the 24 teachers said that said that they would use take-home experiments. They made comments such as "take-home experiments suit a lab with limited resources", "take-home experiments - activities and hands on is always great" and "the experiments intrigue me but they must be doable in fairly short time frames and not be beyond what is doable by the average student". The response to the complementary question, "Which types of resources, from those provided on the website, are you NOT likely to include in your teaching and why?" also revealed that 4 of the teachers may not use them: "I may not use some of the labs because of the time involved and the equipment" and "I will probably be more likely to use the take-home experiments as demos rather than the student centred labs due to time constraints in the course." But, in both cases, it was not that they didn't like the experiments, but rather that they did not fit well into the class time or the equipment they had.

Post secondary instructors seemed to be slightly less excited about these resources and only ranked their usefulness as being a 3.9/5, between useful with minor changes and somewhat useful. When asked "Which types of resources, from those provided on the website, are you likely to include in your teaching and why?" 7/14 instructors said they would use take-home experiments and made comments such as "great idea but needs to be more interesting to a younger audience" and "I would only use these with a select few keen students". In regards to "Which types of resources, from those provided on the website, are you NOT likely to include in your teaching and why?" two instructors responded by saying that they would not fit into the style of the courses they teach, one saying they were "impractical to deliver at a university level". This was fascinating. The high school teachers seemed to regard the take-home experiments as being useful and great for their students, but the post secondary instructors thought that the level was too high for the average student and was only useful to keen students.

The interviews indicated that instructors from both high school and a post secondary institution had used take-home experiments in their classrooms. As one instructor put it, "doing hands on problems is a better way to be going with most of the students we have". Another instructor found that "I asked them if anyone wanted to try it and I had a couple of students who wanted to try it - something I would probably do again". But, others claim the opposite is true, one saying that "The middle of the road students or the lower end students, I don't think they would really benefit from them. The reason is I don't think there would be the incentive to actually engage in the activity with thought." So, it seems like this kind of learning would fit well in certain classroom environments and not others.

The interview participants also raised some ideas on how these resources could be improved. Firstly, some of the experiments require a video camera and other things which may not be found in the average household. Also, many of the instructors indicated that they would "enhance some of the instructions a little bit for student use" and have suggested that they experiments include more step by step instructions. This is something that the developers of the website need to consider, as the initial plan was to provide more open ended labs which encourage students to design an appropriate procedure. Finally, one instructor recommended creating a series of miniature take-home experiments - "something that you could easily do at home that would take 5 minutes and you could see something".

Take-home experiments seemed to be a fairly useful resource. In the further development of these resources, more thought needs to be put into how easily they would be able to be done by high school students. This could be in regards to the concepts covered in them, the way the instructions are presented, and the equipment required to successfully accomplish the task.

6.6 Additional Resource Suggestions

In addition to the resources already on the site, instructors were asked to rank a series of additional resource ideas including instructional videos, social media, the ability to make comments or rank articles, networking with other teachers , and allowing teachers to contribute articles. Participants were posed with the question "Please rank the usefulness of the different types of resources available on the website to your teaching. (1 - Not Useful. 2 - Somewhat Useful. 3 - Useful)" and responses are as seen in Table 6.2. High school teachers ranked instructional videos the highest (2.9/3), social media the lowest (1.8/3) and the commenting, networking and contributing as being somewhat useful at 2.3/3, 2.5/3 and 2.5/3 respectively. Post secondary instructors ranked the suggestions in a slightly different order with commenting at 2.7/3, instructional videos and teachers contributions at 2.6/3, networking at 2.4/3 and social media at 1.7/3.

Social media does not seem to be well liked by teachers and so it is not advised to incorporate these capabilities into the website yet. On the other hand, instructional videos and the ability to comment on and rank articles were seen to be useful and so this would be a recommended

Additional Resource	High School Teachers	Post Secondary Instructors
Instructional videos	2.9	2.6
Social media	1.8	1.7
Ability to comment	2.3	2.7
Ability to network	2.5	2.4
Ability to contribute ideas	2.5	2.6

Table 6.2: Reponses when instructors were asked in the survey to "Please rank the usefulness of the different types of resources available on the website to your teaching. (1 - Not Useful. 2 - Somewhat Useful. 3 - Useful)".

direction in which to expand the site. In regards to including contributions from other teachers, many teachers seemed to indicate in the commenting section of the survey that they appreciated the fact it's made by the UBC Physics and Astronomy department and so it is reliable. If the developers of the site wanted to include resources designed by other instructors, it is recommended that they first be reviewed by the developers at UBC to ensure the high degree of trustworthiness is maintained.

6.7 Conclusions and Recommendations

The current resources included on the website seem to all be useful to high school teachers and post secondary instructors, but suggestions have been presented to improve some of them. Most notably, multiple choice questions need to be expanded to involve more conceptual questions and less factual recall questions. Also, the website needs to stress who the intended audience of the overviews is so that both the site designers and those using the resources can be on the same page. Instructors have indicated that they will edit most of the resources available to meet the needs of their students and their preferred style of teaching. In light of this, the developers of the resources should seek to create resources in the most transferable format so that the changes that occur when opening resources on different computers are minimized. Finally, instructors have indicated which additional resources they would find useful, and so the website developers needs to choose which suggestions they will use and start pursuing these options - a task already in progress.

Chapter 7

Barriers

Finally, this study sought to uncover the barriers of using these resources to teach physics in connection to the real world in order that these barriers can be addressed in the further development of the website. The most common barriers or aspects to address to improve the development of the site include time, and the math and physics level appropriateness.

7.1 Time

Time is one of the barriers that teachers face when trying to teach their physics curriculum in connection to the real world, regardless of whether they are using the resources on the website. It is impossible to say how prevalent this issue is, as it was mentioned more in certain modes of data collection than in others, but regardless, it is a topic that resource developers need to be aware of.

When high school teachers were asked in the survey "Which types of resources are you likely to use in your teaching and why?" two of the teachers responded saying "I [would] like to include everything but time is a big factor in class so I might end up excluding some depending on the needs of my students" and "I may not use some of the labs because of the time involved". This raises the issue of class time, the fact that teachers only have a fixed amount of time with their students each week and it is impossible to squeeze a large number of different activities into those hours. This response was repeated in the post secondary instructors survey of the same question where two of the 14 instructors responded by saying they would not use certain resources because there is "no time" or "students won't have enough time to spend on the experiments".

So, restricted class time is a limitation of which resource developers need to be aware. Resources need to be developed to be used in a reasonable amount of time. This may include creating contexts or real world examples that can be explained in a 50 minute class or less and limiting the lecture notes to what a teacher could comfortably cover in the same time. Also, take-home experiments could be created to be done in a 50 minute class, or to be done in a few hours, for instance to be incorporated into a lab course or completed at home.

The high school focus group first raised the issue of the time restriction enforced upon teachers by the curriculum when one mentioned that the use of resources "depends on the curriculum. You can't just bring in wiring of houses because its an interesting topic". In interviews, instructors also supported this idea by making comments including "the more stuff you put in [to the curriculum] the more stuff you have to figure out how to get rid of" and "if you really like [a resource] you have to find some way to squeeze it in and hope not too much stuff gets lost in terms of what you need to get covered". It seemed to be a general consensus that "the number of topics [teachers] need to cover are far too many and the time in which [they] have to cover it just makes it difficult to incorporate some of [these resources]".

In light of this, the requirement that the resources all be explicitly connected to the curriculum is strengthened. It quickly becomes apparent that unless the resource provides a useful way of teaching a topic specified in the curriculum to the students, it will not get used. Topics cannot just be interesting, they need to be worthy of replacing something else that was previously taught in the course. Therefore, the website developers should aim to choose future topics that are explicitly included in the curriculum and enable teachers to better help their students understand what is required. The same thing holds true for the multiple choice questions, problem sets and take-home experiments. Unless they reinforce a concept students are required to know, they are not likely to be used.

On a positive note though, instructors have confirmed that using these resources is beneficial as one said using them "certainly reduces in general my workload". No longer do teachers need to spend hours researching topics, pondering relevant real world connections or designing experiments and questions, but instead they can download resources and use them in their classes. In order to reinforce this benefit, the resources should be developed in such a way that minimizes the need for further editing by the teachers, for example the need for level adjusting, leaving teachers just to adapt the resources to fit their preferred style of teaching.

7.2 Level Appropriateness

Some of the instructors also indicated that level appropriateness was a barrier that made it harder to incorporate the resources on this website into their teaching. Level appropriateness is the degree to which the level of difficulty of the resources is suitable to the level of the students it is designed to be used with. The high school teachers were asked in the survey to state their opinion, on a scale from 1 to 5 where 1 is strongly disagree and 5 is strongly agree, of the following statement: "The physics and math concepts are appropriate for the grade levels they are geared at". The mean response was 2.9/5, indicating that the collective opinion was approximately neutral, but showing that many of the teachers disagreed with the above statement. In the post secondary instructor survey, the instructors' average response to the same statement was a 3.6/5, between neutral and agree. It makes sense that the high school teachers would see the resources as less level appropriate than the post secondary instructors seeing as they are teaching a lower level of physics but using similar resources, but this issue must be looked into further as both responses are lower than the developers would like.

When the high school teachers were asked "What types of resources are you not likely to use in your teaching and why?" in the open ended portion of the survey, 5 of the 24 teachers responded by saying that level appropriateness was a reason for not using these resources. Teachers made comments such as "[they're] not aimed at grades 11 or 12 but I can always adapt" and "some of the work gets too detailed for high school". Two of the 14 post secondary instructors also listed level appropriateness as being a reason why they would not use the resources, making comments such as "[the resources] need to be more interesting to a younger audience" and "I would have to massage them to fit both mine and the kids comfort level". Again, pointing to the level of some of the resources being higher than what some of the instructors feel their students would be capable of understanding.

The focus group allowed for the level appropriateness of these resources in a high school setting to be explored deeper. When asked their opinions of the level appropriateness of the resources, the teachers first responded with comments such as "some of the language is high" or "it would take a bit of work to go through the site and prepare a lesson at the students' level". When they were probed deeper as to what about the level of the resources were too high, the main reason seemed be the disconnect between math and physics in the eyes of their students. As one teacher said “math and physics are viewed to my students as two separate things. They are not seen as one and the same thing. They know how to do the math. But when they start grabbing onto formulas they lose all track of what the big picture is because they’re separate.”

This problem is sometimes enhanced when teaching physics in connection to the real world because when you start trying to explain the physics of real world situations, there are often multiple concepts which must be all tied together and solving the question becomes much more rigorous. One instructor commented that in real world examples, “physics is really simple and obvious until you try to quantify it and then it becomes almost impossible”. This is one of the reasons why teachers often teach using examples from “the imaginary physics land”, where friction can be ignored in almost all situations and other simplifications can be used as well. It is in these examples that problems are more doable for their students to solve as the process of converting a word problem to a quantitative way of solving it is more straight forward. It seemed to be the consensus of the group that, as stated by one participant “as soon as you start talking about too many things at once [students] get overwhelmed” and so there is the tendency for teachers to limit questions to one concept.

But, at the same time, these instructors did agree that while real world examples may be a source of confusion, they also increase interest at the same time. So, how can resources be created that are realistic and take into account the multiple physics concepts applicable to a given real world situation while, at the same time, being understandable to students who get lost as soon as you try to turn a word problem into a calculation? One suggestion was to keep a qualitative component in the question by asking students to look at the answer they have found and comment on how fast or slow that number is or if it is a realistic answer given the question. Another way is by using more of these examples so that students get used to the process of utilising more than one concept to come across a solution. But, when designing resources for high school teachers, it seems from this focus group, that removing extraneous concepts would make them more understandable by the students.

Finally, the interviews shed some more light on the issue of level appropriateness. It was here that conflicting opinions within the same group of teachers presented itself. In interviews with high school teachers, comments were made such as “yes, the physics concepts are level appropriate” and “math concepts were appropriate for the most part”. But, these same teachers also made comments such as “some calculations in there were a bit beyond what they needed to know" and "students would get lost in some of the math [...] as they are able to do and what they are supposed to be able to do are two different things". Their comments seem to say that the resources are both level appropriate and yet beyond that the students are capable of doing.

These conflicting opinions are also evident in the interviews with post secondary instructors. Most teachers said the resources were "certainly appropriate for first year physics" and "the levels of the problems I see are entirely appropriate" but one mentioned that the "level appropriateness for the students was too high, but for an instructor it was a good level". This raises another question, are the instructors judging the level appropriateness to be to what they can understand, or to what they think their students can understand?

Overall, the level appropriateness of these resources is accurate according to some teachers and yet not appropriate to others. It may be the resource level might be correct in theory, matching what the curriculum specifies students should be able to do, but not necessarily what students can actually do. Or it may be that different teachers had looked at different resources, some which were more appropriate than others, or that the differing degree of opinion was due to the ability of the specific group of students each instructor is teaching. More research needs to be done on this aspect of the site on the following: whose level is the appropriateness of the resources being judged according to (teachers or students), are specific topics or resources level appropriate while others are not, and does the demographics of students play into teachers regarding the site as being at an appropriate level or not. Only after further research, including actually studying the students ability to understand the resources, can a claim about the level appropriateness of this site be made.

Chapter 8

Conclusion

This project first aimed to study the barriers and benefits of teaching a physics curriculum with explicit connection to real world contexts, and then looked to compile recommendations of how to improve the C21 website based on instructors' feedback. This was done by first determining what teachers value in physics teaching, and then examining how this site, most specifically the topics and types of resources on it, helps them to accomplish their goals. To evaluate this, data was gathered from high school teachers and post secondary instructors using a variety of methods including survey, interviews and a focus group. By comparing the data from all of these sources, it was found that two of the most important things in physics teaching are conceptual understanding and connection to the real world. This agrees with what Arion et al. found in 2000 where they concluded that the goals of physics education include teaching the ability to apply concepts to problem solving and the application of physics to real world situations [15]. This project aims to provide teachers with resources which explain concepts using real world contexts, and since these goals are in line with what teachers value, it is a worthwhile direction to pursue.

Upon establishing that the project addresses what teachers consider to be important, recommendations on ways to improve the website, and teaching resources of this kind, were compiled. Overall, the instructors found the topics on the site to be both useful and interesting, but they had suggestions for how to expand and improve them. First of all, the Renewable and Clean Energy section was found to be the most curriculum connected section, and so the website developers should first aim to expand this section, maybe to include sections on solar and nuclear energy as was suggested by various instructors. Also, instructors indicated that the level of some of these resources were much higher than the courses they were said to connect with. In light of this, it would be recommendable to adjust the level of some of the resources, in particular some of those in the climate section, to match the courses they connect most explicitly with. Suggestions were proposed for additional topics to add to each of the sections, providing the developers a list of topics in which to sift through and consider adding to the website.

In regards to the types of resources on the website, they were all found to be useful, but again, there is room for improvement. One of the main reasons for not using a specific type of resource seemed to be that the instructor simply preferred another style of teaching. Nothing can be done to address this, but improvements can be made to increase the usefulness and ease of incorporating the resources into the classrooms of those who would like to use them. First of all, instructors were found to appreciate the fact that the resources were editable, and so resources should be designed in such a way that maximizes the ease in which they can be edited. This includes minimizing the formatting changes that occurs when a document is opened using various operating systems and versions of programs. More specifically, the multiple choice questions were said to be more beneficial if they contained more conceptual questions and less factual recall, and so focusing on this when designing questions is necessary. In regards to the take-home experiments, instructors have requested that the experiments be designed to be accomplished using less specialized equipment, such as video cameras. They have also requested more step-by-step instructions for accomplishing the desired task. Since the developers aimed for these experiments to be more open ended and exploratory, the changing of this format into something more detailed should be considered.

Also, through this study, some of the barriers of connecting physics in relation to the real world emerged - mainly time constraints and the level appropriateness of the materials. In regards to time, the developers of the site need to be aware of both the class time, the amount of time teachers have with their students each week, and curriculum time, the amount of topics teachers are required to cover over the duration of the course. This agrees with other research that states that teaching physics in connection to the real world is difficult because it takes more class time. By using this approach, teachers have to balance their obligation to cover what is specified by the physics curriculum, while also making the class relevant to their students lives [16], [25]. Because of this, resources should be designed with explicit curriculum connections and the level appropriateness should match the level of the courses they align with.

While it was first necessary to study the instructors' opinions of the site, in order to establish that it is a teaching resource that teachers would indeed use, it now necessary to investigate the students' opinions of the site, including the topics and types of resources on it. This is especially important in regards to level appropriateness of the resources and relevance of the topics, since teachers can only speculate on what they believe their students think in regards to these things.

These findings provide a framework for the resources on the C21 website to be updated and expanded upon in the most beneficial way - both in regards to topics and resource types. It is hoped that by keeping these issues in mind and implementing these recommendations, that the resources on the website will be improved to closer match what teachers desire, making it a more widely used teaching resource. By continuing the development and improvement of this website, it is anticipated that students will benefit from the use of these resources in their classes. Hopefully, these resources will significantly increase students motivation and enhance their learning experience as they see the relevance of what they are studying to the world around them.

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Appendix A

Survey and Consent Form

The following pages contain the survey given to participants who attended the High School Teachers Workshop and the Post Secondary Instructors Workshop and the consent form which was signed by all participants.

Physics Teaching in 21st Century
Teaching Resource and Workshop – Feedback Questionnaire

GENERAL INFORMATION

1. In which city & province is your school located?

   ____

2. Which subjects/levels do you currently teach? (please circle your response)
   a. Science 10
   b. Physics 11
   c. Physics 12
   d. University (please specify subject name and year): ________________________
   e. Other (please specify subject name and grade): __________________________

3. How many years have you been teaching? (please circle your response)
   a. $\leq$1 year
   b. 2-3 years
   c. 4-5 years
   d. 6-9 years
   e. $\geq$ 10 years

WEBSITE CONTENT

4. What do you consider most important in physics teaching?

5. What do you think is the goal of physics teaching (i.e. preparation for further study, increasing students' interest in physics, relating physics to real life, developing solid conceptual understanding, solving challenging problems mathematically…)?

6. What are your thoughts on connecting physics to real world problems? (i.e. I'm already doing it, I would like to start doing it, it is not an important goal, it is too difficult…)

7. Which topics covered by the C21 website do you think can be most easily connected to the curriculum in the courses you teach?

8. Which type of resources, from those provided on the website (overviews, lecture notes, problem sets, take home experiments, multiple-choice questions), are you likely to include in your teaching and why?

9. Which types of resources are you not likely to include in your teaching and why?

10. Do you have any suggestions for additional topics or activities that can be included in the C21 resource?

	(Check the box that applies)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11.	I think it is important to link physics concepts to real world contexts and global issues such as energy consumption and climate change.	☐	☐	☐	☐	☐
12.	I think that linking physics to real world contexts will encourage more students to study physics.	☐	☐	☐	☐	☐
13.	The resources provided on the website make it easier for me to link my teaching to real world issues.	☐	☐	☐	☐	☐
14.	I believe the resources provided on the website will make physics more interesting to my students.	☐	☐	☐	☐	☐
15.	The contexts and issues presented in the resources are relevant to my students.	☐	☐	☐	☐	☐
16.	The physics and mathematical concepts are appropriate for the grade levels they are geared at.	☐	☐	☐	☐	☐
17.	The resources (e.g. problem sets and experiments) are appropriate for the grade levels they are geared at.	☐	☐	☐	☐	☐
18.	I was able to easily navigate and find resources on the site.	☐	☐	☐	☐	☐
19.	I am likely to use the resources on the website (mini lessons, multiple choice questions, problem sets, & take-home experiments) to help me teach.	☐	☐	☐	☐	☐
20.	I am likely to make substantial changes to the way I teach physics based on the resources on the website.	☐	☐	☐	☐	☐

21. Please rank the usefulness of the different types of resources available on the website to your teaching,

	(Check the box which applies)	Not Useful	Useful with Major Changes	Useful with Minor Changes	Somewhat Useful	Useful
A)	Overviews	☐	☐	☐	☐	☐
B)	Lecture Notes	☐	☐	☐	☐	☐
C)	Multiple Choice Questions	☐	☐	☐	☐	☐
D)	Worked Problem Sets	☐	☐	☐	☐	☐
E)	Take Home Experiments	☐	☐	☐	☐	☐

Comments on types of resources:

22. Please rank the usefulness of the following ideas as future additions to the website:

	(Check the box which applies)	Not Useful	Somewhat Useful	Useful
A)	Instructional videos (i.e YouTube	☐	☐	☐
B)	Social media (twitter, rss feeds)	☐	☐	☐
C)	Ability to comment on, discuss or rank activities.	☐	☐	☐
D)	Ability to network with other teachers using the site.	☐	☐	☐
E)	Ability to contribute teaching activities or ideas for activities.	☐	☐	☐

Any other ideas?

WORKSHOP CONTENT & DESIGN

(Check the box which applies)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. This workshop clarified the aims and objectives of the C21 project and its website.	☐	☐	☐	☐	☐
2. My feedback for the C21 website was well received during the workshop.	☐	☐	☐	☐	☐
3. Instructions for using the C21 website were clearly presented during the workshop.	☐	☐	☐	☐	☐
4. I learned valuable information from this workshop that can be applied to my work.	☐	☐	☐	☐	☐
5. The pace of this workshop was appropriate.	☐	☐	☐	☐	☐
6. Pre-workshop communications (advertising, registration, providing information in advance of the workshop) were well organized.	☐	☐	☐	☐	☐

7. What did you like the most about the workshop?

8. What suggestions do you have for improving future workshops of this kind?

(End of questionnaire)

THE UNIVERSITY OF BRITISH COLUMBIA
Department of Physics and Astronomy
6224 Agricultural Road
Vancouver, B.C. Canada V6T 1Z1

Tel: (604) 822-3853
Fax: (604) 833-5324

Teacher Participant Consent Form for
"Making Physical Science Teaching Relevant to the Real World"

Principal Investigator*:
Dr. Chris Waltham, contact phone number: 604-822-5712, Email: cew@phas.ubc.ca

Co-Investigator(s)*:
Dr. Andrzej Kotlicki, contact phone number: 604-822-3645, Email: kotlicki@phas.ubc.ca; Theresa Liao, contact phone number: 604-822-0596, Email: theresa@phas.ubc.ca.
Rachel Moll, contact phone number: 604-822-2302, Email: rfmoll@gmail.com
Brittany Tymos, contact phone number: 604-822-3675, Email: btymos@interchange.ubc.ca

* All investigators are members of the Department of Physics & Astronomy, University of British Columbia.

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Purpose:
Physics is a core subject that deals with many real life issues – reusable energy, climate change, and medical advancement. Yet it has been a challenge to link physics with these important questions; most high school and university physics materials do not contain lessons and problem sets directly related to realistic situations. With this in mind, we set out to develop an extensive online database with teaching materials containing real-world physics examples and problems. The website will be open to all and contains mini lessons, questions, demonstrations and take-home experiments. To ensure that the website maintains relevance and to survey user experiences for improvement, we will organize a workshop and conduct focus groups to collect feedback from teachers who have used the pilot website.

Study Procedures:
Research participants (teachers) will participate in one or more of the following sessions:

1. Preliminary teacher focus group: Teachers can attend a 30-45 min focus group where they will be asked to comment on what is important in physics teaching and their initial experience with using the website (on the organization of the website as well as content of the teaching materials available).

2. Website user workshop (1 day): participants will attend a workshop on:
    a. Goals and objectives of the project
    b. How to access and utilize the materials available on the website

At the end of the workshop, participants will be asked to complete a questionnaire (0.5 hour). The questionnaire will focus on whether they plan to utilize materials on the website, whether linking physics teaching with realistic issues (environmental and sustainability issues) will encourage their students to study physics, and any additional feedback regarding the workshop and the website.

3. Follow up teacher focus group: Teachers who are interested in using the website and providing in depth feedback will participate in a follow up focus group after they have tested some of the materials from the resource. During the feedback session, teachers will be asked to provide specific comments on their experience using the website (on the organization of the website as well as content of the teaching materials available). At the end of the feedback discussion, focus group teachers will fill out a questionnaire to provide general feedback regarding the website.

Potential Risks: No known potential risk

Potential Benefits: Teacher participants will have a better understanding of the goals and objectives of the project and be more aware of how linking physics with real life issues can encourage physics learning. They will also have the opportunity to use this tool to assist their teaching in class.

Confidentiality:
No names will be collected on the documents used in this study. Study documents will be kept in a locked filing cabinet for 5 years at the Principal Investigator's office. Subjects will not be identified by name in any reports of the completed study. Results of this study will be stored in a secured computer with restricted access (password). Please note that only limited confidentiality can be offered in focus groups, as we cannot control what other participants do with the information discussed.

Contact for information about the study:
If you have any questions or desire further information with respect to this study, you may contact Dr. Chris Waltham or Theresa Liao, Communications Coordinator for the Department of Physics & Astronomy at 604-822-0596 or email communications@phas.ubc.ca.

Consent:
Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time. Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to participate in this study.

____
Your name (please print)

____
Your signature Date

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