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Designing and Evaluating an Interactive eTextbook for RBE1001

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Designing and Evaluating an Interactive eTextbook for RBE1001

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Abstract

This paper will present the design and evaluation of an interactive eTextbook meant for Worcester Polytechnic Institute's robotic engineering class, RBE1001. Articles and other literature were used to research teaching methods, textbook writing, eTextbooks, and evaluation strategies, to develop and present the evaluation procedure, consisting of surveys, a focus group, and a quiz. Following that procedure, data were gathered from the current class and analyzed. The results were inconclusive due to insufficient data about usage of the eTextbook.

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Authorship Page

The following parts were specifically Joseph Gallagher's work:

- In Project Proposal
    - Literature Review
        - Potential of eTextbooks
        - Software
    - Methodology
- IRB application

The quiz was written by Bryce Jassmond and Professor Mike Ciaraldi with help from Brad Miller, Professor Ken Stafford, and

The rest was fully written by Bryce Jassmond.

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Executive Summary

RBE 1001, the introductory course in robotics engineering at Worcester Polytechnic Institute, has never had a textbook, unlike many courses. No textbooks were able to meet the needs and demands of the instructors. Professors Ken Stafford and Brad Miller decided to apply for a grant and advise an IQP to design, develop, and evaluate an eTextbook specifically tailored to the course. The IQP was specifically limited to design and evaluation. One primary goal was to assess the effect having an eTextbook would have on the course and the student's learning. The professors had additional interest in interactive elements, making a second primary goal to determine the effect they have on students' learning. An additional goal was to take the experience gained during the study and write a guide to help other professors write their own eTextbooks.

To accomplish these goals, a firm grasp of knowledge in the subject area needed to be obtained. Research was conducted into how textbooks are used by students, finding a study that observed behaviors such as how much time did they spend reading textbooks and for what purposes they read the textbook. The study's conclusions indicated that professors need to carefully consider their course's textbooks and how they guide students to use them, which led to research in teaching and learning styles. The first things studied were learning styles and how classes tend to operate, and then the use of the inverted teaching style and its implications. Next, how textbooks are designed and written was researched, revealing them to be much different than other literature. After all this research on paper textbooks, focus changed to studing the growth of the eTextbook format, how they came to be and where they are now. The potential of eTextbooks and how current advances in related technology can impact their abilities and uses was looked into. The software involved in eTextbook creation was studied, noting the capabilities and limitations of different tools and formats. After all of this research in the actual content, techniques for evaluations became the focus. Methods for determining which ones to use in a course were discovered, and

techniques for conducting studies to gather and analyze useful data for projects similar to this one were studied.

Using information from the research, a sample chapter of the eTextbook was developed. While the rest of it was to be written by an independent team, it was necessary to put the techniques learned into practice and make sure there was the minimum amount of content to base the study on. The content was largely based on lecture notes provided by the professors and created in Adobe Indesign. Interactive elements were incorporated as in-text links, slide shows, animated images, and an experimental simulation. The chapter was saved as an interactive PDF, which at the time was determined to be the most portable option with the least technical requirements, such as programming skills.

After the chapter was completed, work began on the evaluation plan and materials. The sample groups were determined to be instructors, past students, and current students. Surveys were written for each. One was for the past students to understand the course experience previous to having a textbook. Two were for the instructors, giving opportunity to evaluate the eTextbook's effect before and after its introduction to the course from the teaching perspective. And finally, three surveys were for the current classes' students, which would provide insight into how the eTextbook affected the students' learning throughout the course. Plans were also made to collect quiz grades to analyze the difference the eTextbook made and conduct focus groups to get better qualitative data than the surveys could offer.

Unfortunately, the project quickly fell behind schedule from a number of pitfalls. The eTextbook was never completed, leaving a miniscule amount of material for the study to use. There was also difficulty conducting the surveys due to low interest among the study groups. By the time the study period began in the final term of the year (D-term), it needed to be scaled back. The past students and instructor study groups were dropped, and the surveys were limited to only two, surveying the current students before and after they were exposed to the eTextbook. An eight-question quiz, with background

questions, was developed to compare learning with eTextbook support and learning without it.

The data collected from the focus group, the two surveys, and the quiz were then analyzed. It was determined the sample size was not large enough for statistical significance, so statistical analysis, which was originally desired, was not necessary. Additionally, there were a very small number of students who even viewed the eTextbook, causing the study to be inconclusive. The quiz showed many students achieved correct answers from studying lecture notes or from past experience, paralleling the students' popular response that they felt reading the eTextbook was unnecessary. Questions about how students use textbooks revealed that they would likely use the eTextbook much more if it were specifically required for the course.

It was concluded that, in order to achieve significant results, let alone statistically relevant ones, another study would need to be conducted with much more preparation and organization. The sample group(s) has to be larger and more responsive. The eTextbook would need to be fully complete and integrated into the course. The evaluation materials would need to be fully planned and scheduled, with secondary plans in the case of low response biases. With those, a follow-up study could be successful where this one was lacking.

Introduction

The robotics engineering program at WPI is relatively new. It aims to prepare and inspire future pioneers in the industry. The field is innovative and constantly evolving, so the courses must update their material to keep up. RBE 1001 is an entry-level course, giving many students their first formal experience with the field, but has been without a textbook since its onset. The instructors attempted to find one that fit their needs, but none were satisfactory because they were either unsuitable or would quickly become out of date. Deciding it was time for a change, they set up an IQP and applied for a grant to have an interactive eTextbook written and evaluated for the class.

The IQP is primarily concerned with the design and evaluation of the eTextbook by researching what would make it effective according to the teaching style (much consideration being taken in choosing an inverted format), researching methods of evaluating the resulting textbook, and conducting the determined evaluation. The goal was to determine whether or not the eTextbook assisted learning in this classroom environment that previously did not have a textbook and whether or not the interactive elements assisted learning as compared to textbooks without them.

To accomplish these goals, institute resources were utilized, such as the library, the Academic Technology Center staff, and professors, to assist in researching the various subject areas related to the project. Knowledge was gathered from studies, textbooks, news articles, and other forms of literature. This knowledge was used to write a chapter of the eTextbook and prepare surveys and a quiz to evaluate the performance and usefulness of its elements and as a whole in the classroom environment. Then, all the gathered data were analyzed and the results and observed trends were recorded. Lastly, the gathered material and the drawn conclusions were presented.

Literature Review/Background

Textbook Usage

Textbooks have long been used in the learning environment. Instructors assign reading and work from them, sometimes making them the cornerstone of their class, and students use them to study the material. Many students use them to learn subjects that have no formal classes. While these are well known, there is not much research on exactly how typical students use their textbooks. It turns out students do not really use them how most instructors expect.

A study conducted by DePaul University in the spring of 2008 surveyed students of finance classes in 3 different universities, and 264 usable surveys were received. A number of trends were discovered in the data indicating textbooks are not used in the way instructors expect. First, the majority of the students did not use the assigned textbook much or felt that it was not useful, over 50% of them reading it less than one hour a week and over 90% reading less than three. Despite this, the survey indicated that students felt that the instructor desired them to read more, and did perceive that reading the textbook was key to a good grade. It was also found students used the textbook more before exams and for assignments than for class preparation, 50% saying they rarely used it before class, and used it for assignment completion instead of deeper understanding. When given optional or unassigned material, 60% rarely attempted to read it. These trends show that something is lacking in textbooks or the way instructors use them.[1]

Further questions offered some insight into the previously stated trends. While quizzes and exams proved effective at motivating students to use their books, a majority stated they would prefer they be told exactly what is important before they read the material. A focus group after the survey revealed that a big part of it was the excessive material

[1] Berry, T., Cook, L., Hill, N., Steven, K. (2011). An Exploratory Analysis of Students' Use of the Textbook and Study Habits: Misperceptions and Barriers to Success. College Teaching, 59(1), 31-39.

available. Students don't often want to learn material that is not essential to the course, so a plethora of supplementing information is usually more detrimental than useful. The busy lives of the students, most taking classes and working simultaneously, causes them to only be concerned with the key information. These observations help show why students do not use their textbooks as much as perceived they should.[1 above]

The presented study shows that instructors need to exercise careful consideration when choosing textbooks and organizing courses. They need to outline a path for students to follow instead of expecting them to do so on their own. Doing so should help encourage better textbook usage, with the goal of augmenting their learning of course material.[1 above]

Unfortunately, outlining a path for students to follow is difficult. Not everyone learns the same way; some excel at learning in environments others struggle in. Instructors always need to keep this mind and try varying their coursework to accommodate as many students as they can. A new teaching style has the potential to encourage students to use their textbooks more: the inverted teaching style.

Inverted Teaching Style

Over the years, the general methods of learning have changed very little. Tools such as lectures, research material, and experiments are used to comprehend the world. Professors have experimented with many different combinations and formats of these to teach, but the diversity of the learning styles of students causes effective teaching to everyone to be difficult. A rising method, the inverted classroom, is designed to address this problem, using modern technology to assist in ways past tools could not.

The traditional classroom style is the most widely used, but often presents difficulty in satisfying every individual's needs. It typically consists scheduled lectures, assignments outside of the classroom, and various evaluations, such as quizzes or exams, to gauge the current status of learning. Variations may include learning tools such as experiments

and group projects. Various learning styles have been observed and categorized from this method. The Grasha-Reichmann questionnaire categorizes participants as dependent, independent, or collaborative, while the Keirsey-Bates categorization bases depends on the Myers-Briggs Type Indicator for four personality scales: Introvert vs. Extrovert (how individual relates to the world), Judging vs. Perceiving (how individual evaluates environment), Sensing vs. Intuitive (how individual processes information), and Thinking vs. Feeling (how individual makes decisions). Yet another categorization, attributed to David Kolb, subjects evaluated based on how they take in and process information are divided into four categories, which are assimilators, convergers, divergers, and accommodators. Assimilators and convergers take in abstract information better while divergers and accommodators take in concrete examples better, and assimilators and divergers process information better through observation while convergers and accommodators process better with experimentation. To accommodate these, professors often attempt to adjust how they present material to the students, which is difficult to do effectively and efficiently. The traditional classroom style worked much of the time, but there was clearly a need to improve upon these challenges.[2]

The inverted classroom style was developed to use modern learning and social tools to flip the way classes are designed. What is traditionally done in class, i.e. lectures, is now presented outside of class, and what is typically performed out of class, like assignments and projects, is worked through in class. Using multimedia presentations, students are expected to view lectures and material before arriving at assigned class periods. During the meeting periods, professors begin by asking if there are any questions, followed by small lectures on topics that students need more explanation about. Afterward, assignments and projects are conducted, allowing rising questions to be answered immediately.[2]

[2] Lage, M. T., Platt, G. J., Treglia, M. (2000, Winter). Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. Journal of Economic Education, 31(1), 30-43.

In trial classes performed at Miami University for an introductory economics course, the inverted style was positively accepted. Students and teachers perceived it to work better than traditional styles. Teachers observed that students seemed to work harder because they felt their learning relied more upon them and noted that students utilized group work and experiments more for references. They also noted that females especially tended to enjoy the inverted method. The majority of participants had only positive opinions about it.[2 above]

When comparing the two styles, the inverted is different from the traditional in several key ways, and seems to be superior. First, there is a lot more preparation for the course before it even begins. The inverted style commonly utilizes multimedia tools for preparing lectures and material for the students to view on their own. As a result, preparation costs for individual lectures for inverted classes are much less than what is necessary for a traditional class. Second, the inverted method accommodates all learning styles without the professor sacrificing excess class time. The format allows each student to learn from the method that suits him/her best. Thirdly, the inverted style utilizes tools like the Internet to its advantage, making various research materials easily accessible. Lastly, the inverted classroom seems to fix the gender imbalances present in the traditional classroom. Females enjoyed and participated more in the inverted setting. While very different, the benefits of the inverted style show it is better than the traditional.[2 above]

Traditional teaching methods have been used well for many years, but it is difficult to accommodate every learning style effectively using them. Inverted classroom teaching style is a rising method that attempts to fix the shortcomings of the traditional methods by using modern multi-media tools widely available. So far, the inverted method seems to be successful and is an effective educational format.

Textbooks used in traditional teaching formats typically have not been edited for an inverted format. The material presented is the same in both teaching methods, therefore re-evaluating the textbook has not been found necessary. The interactive eTextbook

that was evaluated, though, was written with an inverted classroom setting in mind. While much of the material was the same, subtle changes, such as the frequency of pre-recorded lectures, were evident. Even with these small changes, the interactive eTextbook was written using the basic principles of textbook design.

Textbook Design

Textbooks are fundamentally different from other types of literature. They are designed to teach a subject by being both informative and engaging. To accomplish this, careful planning and writing must be done when creating a textbook.

There are a number of key characteristics needed when writing a textbook. It must have simplistic and descriptive title that indicates the subject matter presented. It must be written in a way anybody can understand, devoid of jargon that is not explained. Writing must be formatted in a way that students can find information easily, such as using boxes and figures to separate key information. It should include summaries, such as chapter summaries, learning objectives, key terms, and end of chapter summaries to indicate and review important information that should be learned from reading. There should be references to additional material to expand learning, even though, as discussed in a previous section, they may not often be used. There should be activities and studies for students to perform to supplement reading, which will help accommodate the various learning styles as well as simply provide deeper understanding of the material. Organizational tools such as headings, cross-referencing, and glossaries should be utilized to assist readers in finding information easily. Illustrations are also important; graphs and figures help relay information better than simple text. All of these elements need to be considered carefully and included in a textbook.[3]

[3] Tips for Writing and Publishing a Textbook or Textbooks: How to Write and Publish a Better Book. (2010, October 14).

All of the above features are characteristic of a textbook. They have been used for a long time to write text to relay information to aspiring students. While fundamentally sound, certain elements are beginning to change with the emergence of modern technology. There is a continual shift to the digital medium, and interactive eTextbooks are now starting to grow more popular because of it.

Growth of eTextbooks

Physical text has been used for millennia, but with the new digital era, much of the physical work has been, or is being, digitally recorded. Obvious benefits are saved space and sturdiness, not being limited by the degradation or fragility of physical objects. Social media has also seen an exponential growth in the past decade. However, it is only recently that textbooks have been adapting to this digital age.

An infographic created by EducationOnline.net revealed many interesting statistics regarding the rise of eTextbooks. From 2008 to 2009, there was a 400% increase in eTextbook sales. In 2010, eTextbooks accounted for only 1% of sales in the US, but this year, the projected outcome is 5.5%, with a projected 18.8% by 2014. South Korea is currently investing $2 billion to make all textbooks digital by 2015, which was estimated to be about $10 billion if the US had similar program. These statistics show eTextbooks are a growing trend.[4]

Some other points show eTextbooks have an advantage in modern society. New textbooks accounted for nearly three-fourths of the $7.5 billion in textbook sales, using up a lot of resources. And eTextbooks have been found, on average, to be 53% less expensive than their physical counterparts, a large incentive to consumers. The digital medium also has notable benefits, such as note taking, paper writing, and researching capabilities on the same device as the eTextbook, which, due to ever-changing technology, is quickly becoming more and more portable. All of these show that eTextbooks are perfect for the evolving culture and will likely keep growing.[4]

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[4] Anson, A., (2011, September 16). Digital Textbook Statistics [Infographic].

Most of the current eTextbooks are simply digitized versions of their physical counterparts. There are a few applications given to allow them to mimic texts, such as page flipping animation and highlighting features. However, using modern advances, there is so much more potential for eTextbooks to make them more interactive and engaging than is possible in the physical realm.

Potential of eTextbooks

In comparison to other printed works, textbooks are a relatively niche market, primarily used only within academia. This led much of the early innovation within the eBook market being targeted towards other forms of printed materials, such as newspapers and novels. The results can be seen for example, in the design of early Amazon Kindles, which focused on features like compact size and readability without inducing eyestrain, at the cost of useful topical sorting features, effective graphical display, and even basic interactive features such as highlighting and annotating.[5]

However, recent advances in content creation software and touch screen based e-Readers have made eTextbooks a more attractive option.[6] In most works that have been converted to an electronic format, the text itself is what the eBook needs to deliver, such as in a novel or nonfiction work. In an eTextbook however, the text is merely a vehicle for delivering information, knowledge, and understanding to the reader. Since information, rather than text, is the ultimate focus, authors are free to expand upon the methods of presentation. They may use techniques and tools not previously possible to achieve their goal of teaching more effectively, making eTextbooks more favorable than traditional ones.

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[5] Bradshaw, T. (2010, March 15). No substitute for a paper read. Financial Times Limited.

[6] Baig, E. C. (2012, January 12). Apple joins the e-textbook party with iBooks, iBooks author apps. USA Today

eTextbooks possess the potential to enhance learning in ways traditional textbooks cannot. At its core, it must still be a textbook, being an effective text, and the material should be presented in one cohesive document. It shouldn't sacrifice qualities upheld for standard paper textbooks, but the digital medium allows it to be nonlinear and layered, offering supporting material where and when needed and can allow it to cater to diverse learning styles by offering supportive, interactive content. The digitization is much like when typewriters were pushed out for word processors because it granted many more capabilities for writing. eTextbooks may take advantage of the newest forms of media to deliver information in a way modern society may understand best. They are also flexible and low-cost to deliver because paper does not need to be used to produce copies; a near infinite number of copies may be made and distributed without needing a single drop of ink or taking up more space than a USB stick. As previously mentioned, they can cater to diverse learning styles; students who learn better individually through reading may simply read the book while those who require instruction may view recorded lectures, and still others who learn by interaction may be able to experiment with interactive media. Lastly, eTextbooks may be non-static, meaning they could be edited by instructors, keeping the material up-to-date as well as allowing sections of the book to be arranged to accommodate a particular lecturer's format. eTextbooks simply have so many potential advantages over traditional textbooks.

With these advantages, why have interactive eTextbooks not caught on yet? Simply put, there hasn't been enough time yet for them to catch on. Technology is constantly evolving, and tools to easily create and utilize eTextbooks have not yet matured. It would be safe to assume they will blossom in the near future.

For all of this potential to be utilized, tools to create the content need to allow it. Literature began from oral translation before writing tools allowed it to be written, then printing tools allowed it to be mass produced, and digital tools further enhanced the writing process. Now, new software tools offer the ability to further evolve writing with interactive content.

Software

One challenge in the development of interactive eTextbooks has been the availability of effective software packages targeted at their creation. As with the books themselves and eReaders, the introduction of interactivity to eBooks has lagged behind the creation of eBooks themselves. Much of the software currently available, such as 3Dissue[7] and Kindle Digital Publishing[8], target themselves at simply converting text documents into a format suitable for use on mobile eReader devices like the Amazon Kindle.

Changes in the interactive eBook field began to appear with the growing popularity of touch screen tablets, starting with the Apple iPad[9]. The easy to use, touch screen interface made interactivity a natural next step, and a large step forward was taken with the release of iBooks, Apple's proprietary eBook creation software. Unlike its predecessors, iBooks placed a focus on content creation and multimedia, rather than simply presenting text. However, iBooks remains proprietary not just as a development environment, but also in its export abilities. In order to fully take advantage of the tools provided by this software, the books must be exported to, purchased on, and read using the Apple iPad only.

There are a number of file formats that offer interactive components, all of which have their own benefits and limitations. The most common format is ePub, which is useful because it is accepted on most platforms and has word wrap, allowing pages to be adjusted to the reader, but it has very limited interactive capabilities[10]. iBooks is Apple's extension of the ePub format and has all of the interactive options desired, but only the iPad supports it, limiting the possible number of users. SWF is Flash-based and excels in graphic and animation[11], but is not optimal for text and has some support issues[12], as

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[7] 3D Issue. (n.d.).

[8] Kindle Publishing Programs (n.d.).

[9] McLean, P. (2010, March 10). Penguin betting big on interactive eBook content for Apple iPad.

[10] Castro, E. (2011). *EPUB Straight to the Point: Creating ebooks for the Apple iPad and other ereaders.* Berkeley: Peachpit Press

[11] Mischook, S. (n.d.). What is Flash, when and why to use it?. *Killersites.com*.

well as requiring a high degree of author effort. HTML historically has been used for websites, but new interactive tools added to HTML5 allow it to be used for other things, such as games, animations, and interactive eBooks. HTML5 is incredibly customizable as well as working on most platforms[13]. It is the best choice for those with significant development resources because it requires a great amount of work and custom building, making it difficult to use for those without many resources. Interactive PDF, also known as Dynamic PDF, is an extension of the normal PDF format that include many desired interactive features, as well as retaining its text features[14]. It is also well supported, working on most of the popular platforms. Disadvantages of it are no word wrap capability and some interactive limitations.[15] There are a number of other file formats, but they aren't as notable as those presented for reasons including support and interactive capabilities.

For this project, it was determined the best software option is Adobe Indesign and the best file format is Dynamic PDF. Together, they offer a high degree of platform support and interactive capabilities while being rather simple to use. The drawbacks of using them are significantly less than the other options; the inability to word wrap is of small concern when the interactive content support is so great, and while that interactive content may not work on mobile platforms, that problem does not hold as much weight as other criteria.

The software and file format enables the creation and distribution of content. Choosing the appropriate ones can make or break an endeavor. Once the correct options have been found and the material is produced, it needs to be evaluated.

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[12] Jobs, S. (2010, April). Thoughts on Flash. *Apple Inc.*

[13] Kyrnin, J. (n.d.). What's new in HTML5. *About.com.*

[14] 6 Awesome Examples of Multimedia PDFs. (2009, March 24).

[15] Indesign/Dynamic PDF Documents. (n.d.).

Evaluation

For this project, evaluation takes two distinct parts. For one part, the eTextbook needs to be evaluated using the same criteria an instructor would judge any other textbook. He/she needs to make sure it covers all the material in a format they like, including all the necessary sections and components. A form made by Crystal Springs Books (see Appendix A) is one example of a way to quantitatively evaluate them. The instructor can run through each criteria on the form and grade the textbook on a four-point Likert scale. The form is generic so the instructor may decide to simply follow it or give more weight to specific criteria. Simply put, the textbook should cover all the needed material in a way the instructor desires.[16]

With this project, the first part is simple. The eTextbook is being designed and written with direct input and feedback from an instructor of the course. It should inherently meet all of the needs, meaning further evaluation of its material would be unnecessary.

For the second part, as an experimental interactive eTextbook being used in a class for which no textbook has been used before, the evaluation is twofold; it needs to be studied for its value to the class as a textbook and for the merit of its interactive content. These can both be addressed through many of the same techniques, while there are a few that only assist with evaluating one.

Evaluation Tools

One of the best tools for evaluations like the one required by this study is the survey. They collect a large amount of data efficiently and can provide quantitative or qualitative information; quantitative data is numerical and easy to analyze, while qualitative data provides opinionated information from the participant that is sometimes more useful than quantitative data, but is harder to interpret. Questions must be written carefully so

[16] Textbook Evaluation Form (n.d.). Crystal Springs Books/Staff Development for Educators.

there is no ambiguity, and an appropriate scale (for quantitative questions) needs to be used to collect accurate information. For analysis, quantitative data may be summarized easily in visual representations (tables, charts, etc.), descriptive statistics (mean, median, mode), and/or inferential statistics (tests that show the probability the data is representative of the overall population). Qualitative data may be analyzed quantitatively, but needs to be considered carefully due to differences in the individual participants and their environments. Surveys are useful for evaluating the eTextbook as a textbook and evaluating the usefulness of its interactive content.[17]

A second useful tool is examinations. Most commonly in the form of homework problems, quizzes, and tests, these provide information about how well students are learning the information they are supposed to. Questions need to be chosen carefully so they are representative of the material evaluated and worded in an unambiguous way. Optimal times to conduct examinations are at the end of chapters or major sections of material. They may be analyzed in the same fashion as surveys. Examinations will be particularly useful in evaluating the merits of having the textbook in the class.[17]

A third tool is user observation. Case studies and interviews allow the researchers to directly observe how the users interact and use the product. They commonly include some quantitative and qualitative questions and data extraction through various means like surveys, questionnaires, task completion statistics, and other methods. Data collected through user observation could be useful for evaluating the eTextbook as a textbook, but is more useful for evaluating the interactive content. The data can be tedious to analyze because there is a lot of it; it is often important to record everything and anything possible, but this causes analysis to take more time than the collection of the data took.[17]

A fourth tool is the focus group. Similar to user observation, focus groups involve meeting with people to gain insight into their opinions, allowing a more “realistic”

[17] Stone, D., Jarrett, C., Woodroffe, M., Minocha, S. (2005). *User Interface Design and Evaluation.* San Francisco: Morgan Kaufmann Publishers

understanding of them. Focus groups provide qualitative data, but are as difficult to analyze as user observations because they also collect vast amounts of data. They must be planned carefully in a way to keep participants engaged and providing useful information in an easy-to-record manner while being open to unexpected conversation tangents. The group size and composition should be appropriate to the goal of the focus group and multiple versions should be conducted to allow comparisons. (Gallagher, J., personal communication, 2012)

These four tools are powerful data collection techniques. Each one has its advantages and disadvantages and is appropriate in different situations. Using more than one can provide extra information that was otherwise unobtainable. But they cannot be used arbitrarily; they need to be carefully planned into studies and analyzed appropriately.

Studies and Analysis

Knowing about evaluation tools is important, but knowing how to use them and the data they provide properly is just as important. Formal studies have a general template that should be more or less followed, and various analysis techniques, like the ones briefly touched upon earlier, are useful in different situations. Statistical analysis is a deep topic, so key parts will only be briefly touched upon.

This project uses sample studies to collect data on the opinions about the use of the eTextbook in the course from three sample populations. Sample surveys are a type of observational study, which are designed to obtain data from observed characteristics of sample units instead of imposing treatments on them. There are three main classes of observational studies. Prospective studies aim to show cause and effect (although in reality they never can) by recording information on characteristics hypothesized to be related. The data is collected over time and the characteristics are compared to establish association between them, or lack there of. Retrospective studies are similar to prospective studies, but they start with the result and look at factors hypothesized to have caused it. These studies are used instead of prospective ones when the studied

condition is rare and/or costly to follow over time. The last main class is the sample survey, which aims to establish characteristics of a population or subgroups of a population. They take a sample of a population to draw conclusions about the population as a whole. Because the project does not observe a condition occurring over time, or one that had occurred over time, the sample survey is appropriate.[18]

This study has three study groups. The first is the past students, who will be able to provide information about how the class was before using any text. The second and main group is the current students, who can provide data about the use of the eTextbook, both for its quality and the usefulness of having it in the class. The final group is the course instructors, who can give insight into how having the eTextbook has affected the class as compared to not having it because they will have experience with both situations, unlike the student groups. These three groups will provide sufficient data from which to draw conclusions.[18]

Various sampling methods may be used to assess a sample population, a subset of the target population that represents. A few are the simple random sampling, the probability sampling, and the stratified random sampling methods. In the simple random sampling, sample units are selected completely at random, often by assigning units a randomly generated number and selecting a desired number of the lowest assigned number units. The probability sampling method uses some predetermined chance mechanism to choose sample units. The stratified random sampling method divides units into strata, groups of units sharing some characteristic, and performs a simple random sample from each stratum. The method chosen is most like the probability sampling method; the entire RBE1001 current class was chosen, but the most recent past class was used to represent all classes before a textbook was introduced. The data from each of the sample groups was used to draw conclusions about the whole student and teacher population.[18]

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[18] Petruccelli, J.D., Nandram, B., Chen, M. (1999). *Applied Statistics for Engineers and Scientists.* Upper Saddle River, New Jersey: Prentice Hall Inc.

Unfortunately, each sample method comes with errors or biases, as they cannot perfectly represent the whole population. One is the non-sampling error, which comes from the inability to follow the sample plan correctly. A selection bias comes from selecting sample units that are unrepresentative of the target population or exclude some kinds of units. In human population studies, two extra biases are the non-response bias, when individuals refuse to cooperate or are unable to be contacted, resulting in smaller than planned and only represent the population willing to respond, and the response bias, when questions are phrased in a way that is difficult to understand or suggests a particular answer is desirable. With proper planning, these errors and biases may be minimized. This study carefully defined its sample groups and the questions in order to prevent non-sampling, selection, and response biases. To combat non-response bias, surveys and focus groups were offered multiple times in the hope enough people would answer. [18 above]

Once data is obtained, it needs to be analyzed. Raw data in tables are often hard to comprehend, so various models are used to visualize them, and each model is analyzed in a different way. This project desired to use histograms/bar graphs, scatter-plots, and box-and-whisker plots for statistical analysis. Histograms divide data into even intervals on the independent axis and, for each interval, raise a bar to the height of the dependent value, which is often the number of data lying within each interval. They can be used to assess stationarity (consistency of data over time) and data distribution. Scatter-plots have a point for each individual datum placed at its location according to the plot's axes; they can be used to assess stationarity, identifying specific variance, and assess data distribution. Box-and-whisker plots, or simply boxplots, are similar to a combination of the histogram and scatter-plot; they are based on the five-number summary, which consists of the median, first quartile (at least 25% of data lies below it), third quartile, lower adjacent value (the first quartile minus 1.5 times the interquartile range, which is the difference between the first and third quartile), and the upper adjacent value. The boxplot shows thick bars the width proportionate to the data lying within the range of the median, first quartile and median, and third quartile and median, thin bars with width proportionate to the range of data lying within the lower adjacent

value and first quartile and upper adjacent value and third quartile. All other data are represented by points. This allows boxplots to show data distribution and easily identify outliers. There are also few useful specific distribution models that may be represented by histograms, or sometimes scatter-plots. In brief, some include the binomial distribution model, uniform and normal probability density models, and the C+E (center plus error) model. All of these various models help visualize and analyze data in different ways.[18 above]

The data collected from the sample populations may be used to infer characteristics of the whole population. The prediction interval is the range of values a future datum is expected to lie within based on the current data. The confidence interval is the range of values that has a specific probability to contain a specific proportion of the population. These intervals contribute to the first statistical inference, estimation. A second type is hypothesis testing, which tests the validity of a scientific claim by testing a null hypothesis. If the result of the test statistic is small, typically less than 0.05, then the null hypothesis is rejected and the scientific claim is accepted, otherwise, there is not enough evidence to support rejecting the null hypothesis. These methods may enable statistically relevant conclusions to be drawn from the data.[18 above]

While the inference methods mentioned above work well for quantitative data, this project also has qualitative data, which must be treated a bit differently. The qualitative data needs to be quantified, which means manually viewing the data and interpreting it in a selected way, such as positive and negative opinions. Then, trend finding is a simple way to evaluate the data; meaning specific to the goals can be gleaned by finding patterns. Additionally, the statistical inference methods for normal quantified may be used for analysis. (Gallagher, J., personal communication, 2012)

This project utilizes many of these evaluation and analysis tools. Surveys, evaluations, and focus groups are used to collect data from the sample groups and are represented by histograms. Trend finding allowed the conclusions to then be drawn from the data. With these plans, the project was now ready to move forward.

Methodology

As discussed above, various resources were used for research. Primarily, sources were discovered through web searches or references from Wikipedia because they were the quickest information to find. Several books encountered in classes taken at WPI previously were used because they were relevant to design and evaluation techniques that were planned to be implemented. Several other books and internet sources were used that were suggested by Professor Chrys Demetry, for her evaluation and analysis experience, and Erin DeSilva, for her ongoing research into eBooks. All of these resources enabled thorough research to be conducted into the state of the eBooks and how to design and evaluate the eTextbook in our project.

After research, a plan for how to properly evaluate the eTextbook was devised. The study groups needed to be defined, and the participants were split into three sample groups. The first was students that had taken RBE1001 in the past. They had experienced taking class without a textbook available and could give insight into what effects that had on their learning and how they felt it could have been different if there was a textbook. It was determined the best choice was to study only the most recent classes because not only was the course fresh in their minds, but they also experienced the most updated version of the course without textbook influence. The second was students currently taking the class because they would have insight in how usage of the eTextbook affected their learning of the course material. This sample group obviously was limited to only the current class, sized about 50 students. The third sample group was the course instructors, both present and past. They would have knowledge about how teaching the course was like with and without a textbook present and observations into how its presence affected students. This group was limited because there were only seven professors who had ever taught the course. With these groups determined, plans on how to collect useful data from them could be devised.

One of the project goals was to develop techniques for producing an eBook. A sample chapter allowed that methodology to be tested. InDesign was used to create an interactive PDF chapter about DC motors for the class. Topics were presented sequentially and many visuals were used to supplement the main text. In-text links, a slideshow, and an interactive simulation were included not only as supplements, but also as elements to base our interactive feature evaluations on. The exact process of constructing this chapter was handled by Joe Gallagher, who used online tutorials for InDesign and GameMaker for the simulation. A final benefit of developing a chapter independent of the other writers was it set a style for the eTextbook. The writers would be able to follow a similar design and format when writing the remainder of the eTextbook. (For the sample chapter, see Appendix F)

There were three main collection methods that were decided would be useful. The primary method was surveys, as they allowed simultaneous data gathering from an entire sample group. Six separate surveys were determined to be necessary for a proper evaluation. One survey would go to the past students, giving qualitative data on their experience. Two surveys would go to the instructors, one at the beginning of the current class and one at the end. These would provide all the qualitative data about how the eTextbook affected the class from a teaching perspective. Finally, three surveys would go to the current students, one before, one in the middle, and one at the end of the course. These would give preliminary information about the student's class experience and how the eTextbook affected them over the course of RBE1001. The second collection method was focus groups, which would provide qualitative data unobtainable through simple surveys. Two focus groups were planned to be conducted before and after the class. For each, ten to twenty participants were desired. In the first, each sample group needed to be present, each about a third of the group size. In the second, only instructors and current class students needed to participate, with the students comprising about ¾ of the group. These would provide information on preliminary and final impressions of the eTextbook and how it affected the class. The third gathering method was evaluation data, i.e. quizzes, exams, and course evaluations. While surveys and focus groups gave qualitative data, these could provide

concrete, quantitative data about how the eTextbook affected the students' learning. The instructors could also grant access all the grades and course evaluations from the past and present classes, which is ample material to work with. These collection methods were organized to span the current course, beginning with the preliminary surveys and focus group, ending with the final surveys, focus group, and course evaluations, and collecting quiz data throughout the course with a survey in the middle. This plan would give all the data necessary to conduct the study.

There were many obstacles encountered during the project that caused modifications to initial plans. First and foremost, the eTextbook has not been completed. The study was postponed one term to give the writers more time, which resulted in only a few chapters being finished. Scaling back the study was unnecessary yet because the material was enough to provide usable data, albeit less than anticipated. When the initial surveys were conducted, the problem of a low response rate from the sample groups was apparent. The past student response was satisfactory, but there was nearly no response from the instructors or the current students. To fix this, the current instructors granted the first few minutes of a class to explain the project and its purpose while giving students time to complete the survey. This proved very effective as responses were received from nearly the entire class. Unfortunately, the same method could not be done for instructors, and further efforts to remedy this were not conducted. For the focus group, there was similarly little interest to participate from the sample groups. After three reschedules and much advertisement, enough participants were gathered from each study group to conduct the focus group. The group proved to be successful and gave a great amount of extra insight into how students used textbooks and their opinions on the eBook format. After this, however, the project fell apart during the term. The first surveys and focus group occurred so late that it was almost halfway through, and the eTextbook was inadequately recommended, partly because it could not be explicitly assigned. These meant there would have been little to no observable effect from it. Additionally, one of the writers and helper to the project quit just past halfway through the term, causing the creation of additional material to suffer. These issues

caused most of the data collected to be unusable and the study was postponed until the final term while it was re-planned.

The study and its scope were redesigned according to how much material was present in the eTextbook and how much time was left for the project. First, the survey count was cut down to two. The preliminary survey results from the past students and the current students from the previous term were still relevant, but time did not allow much effort to be put towards including them in analysis. The same preliminary survey given to the previous class's students was given to the current class. The second survey was a combination of the middle and final surveys originally planned for the previous students. This was sent out to the current students after they had experienced all the class material that was present in the eTextbook. No surveys were conducted with the instructors because the current class was being taught by a single professor who had never taught the course before, giving no means to reliably compare the effect of the eTextbook's presence from the teaching point of view. No additional focus groups were conducted because there was insufficient time and limited useful data that could have been gained from them. Instead of collecting course evaluations, which would have been more qualitative data, or quizzes, which would have mostly been on material not covered by the eTextbook, the current instructor helped design an eight-question quiz covering concepts he had discussed up to the time it was to be given. Half of the questions were covered in the eTextbook and half were not. At the end of the quiz, several questions asked about the students' background in robotics, programming, and physics, as well as asked for the source of their answer for each of the eight questions. Together, this enabled the influence of the eTextbook on understanding the course material to be analyzed. This quiz was given after all the material that was in the eTextbook was covered and just before the final survey was sent out.

Statistical analysis on the data was originally planned. But after talking to Dr. Jeanne Hubelbank, a program evaluation and assessment consultant, the analysis was scaled back; she rarely used formal statistical analysis on her projects, especially pilot studies, and suggested not using it on this one. All of the data was plotted graphically, using

histograms and scatterplots, with included spreadsheets. Then, trends in the data were searched for, highlighting possible correlations. These are discussed the next section, along with the conclusions that were drawn in the section after that.

Results and Discussion/Analysis

To begin analysis, the data needed to be organized. The survey answers were automatically recorded in a spreadsheet on Google Drive, where the surveys were stored and hosted, and exported to Excel for further work (See Appendices C and D). The quiz results were input into Excel by hand (See Appendix E). The focus group notes were kept in rough form because they were purely qualitative, with no numbers associated with answers given (See Appendix B). With these done, the data could easily be worked with. For the full results of the focus group, surveys, and quiz, see Appendices B, C, D, and E.

Next, the data was summarized in useful ways. For each survey, the answers to each quantitative question were summed, and commonly stated themes from the qualitative answers were indicated. Similarly, the quiz answers and qualitative responses (generalized into basic categories) were tallied. Additionally, the sources students gave as the inspiration for their answers were divided into two categories, whether they answered correctly or not, and were summed up. This concluded summarizing the data for the purposes of this project.

The first important point to note about this study is the sample size and the statistical significance of it. Not only was the sample group small in comparison to the population of RBE1001 students, but the reply rate within the group also was too low. Using the formula to calculate a minimal sample size (ss) using a desired confidence level's Z value (z), percentage picking a choice (which was 50% for sample size calculations), and a desired confidence interval (c): $ss = ((z^2)*p*(1-p))/(c^2)$, it was determined that with a population of 42 (the current class), a sample size of at least 38 would be needed to have a 95% confidence level with a desired 5% confidence interval. With an actual

sample size of 31, the confidence interval was 9% for a 95% confidence level.[19] Keeping in mind data was not used from previous classes, the desired size was more than the number of responses received on the surveys, although tying the number of received quizzes. For this reason, the results are not statistically significant for the preferred confidence interval, and therefore do not afford themselves to the statistical analysis that was originally desired.

The primary goals were to determine whether or not the eTextbook assisted learning in this classroom environment that previously did not have a textbook and whether or not the interactive elements assisted learning as compared to textbooks without them. One of the aspects first looked at was whether or not students said they actually used the eTextbook.

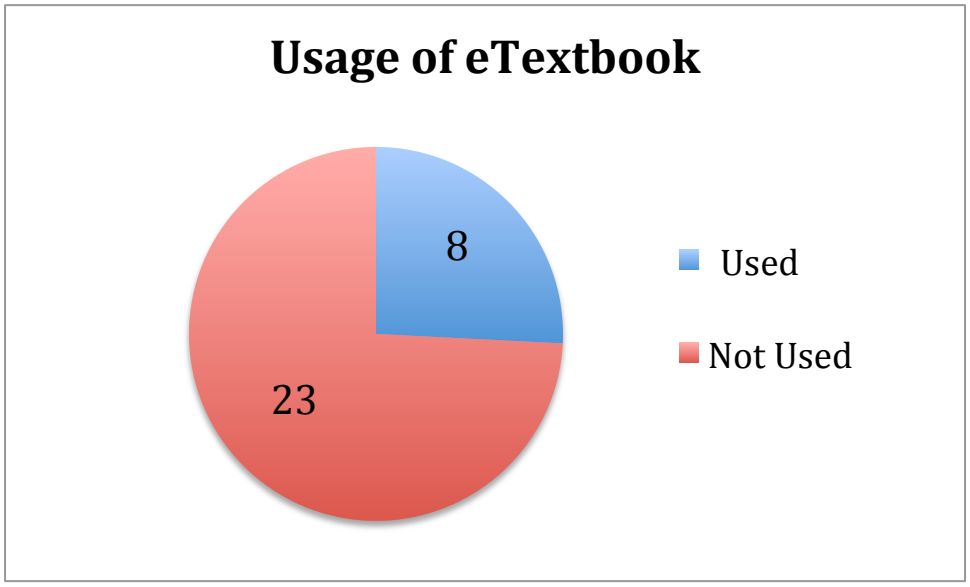

Figure 1 – Students' usage of the eTextbook

Figure 1 revealed only 8 out of the 31 students who answered even looked at the eTextbook, only about 1/4 of the respondents. The quiz similarly reflected this, with only one student claiming they used the eTextbook as inspiration for two of their answers.

[19] Sample Size Formulas For Our Sample Size Calculator. (2012). Retrieved from http://www.surveysystem.com/sample-size-formula.htm

This unfortunately meant comparison of whether or not the eTextbook had an effect would be very unreliable because it was scarcely utilized. As previously stated, at least 38 of the students to not only reply to the survey, but to also have used the eTextbook would have been needed for this analysis to be statistically significant for the desired confidence level and interval; the actual confidence interval at a 95% confidence level was 32%.

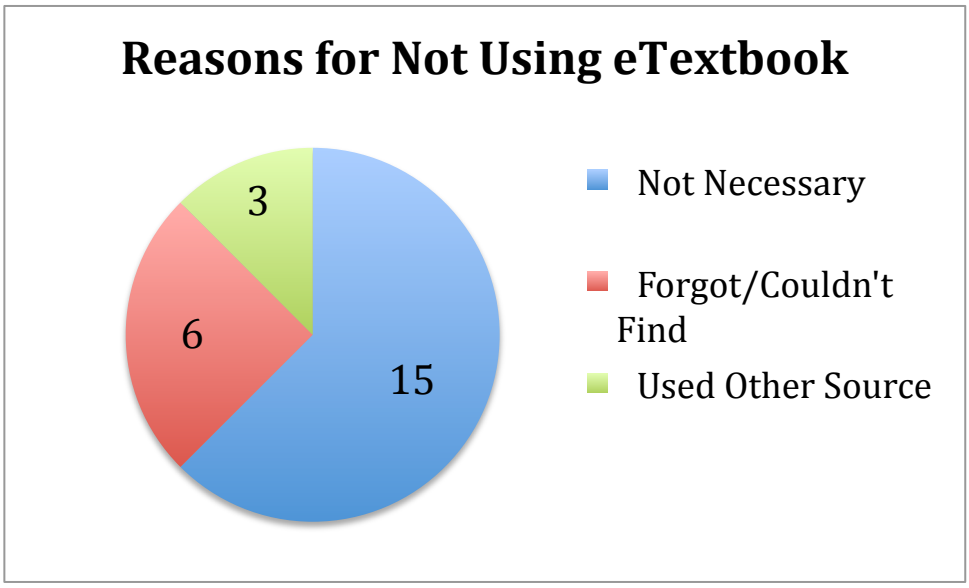

Figure 2 – Reasons for not using the eTextbook

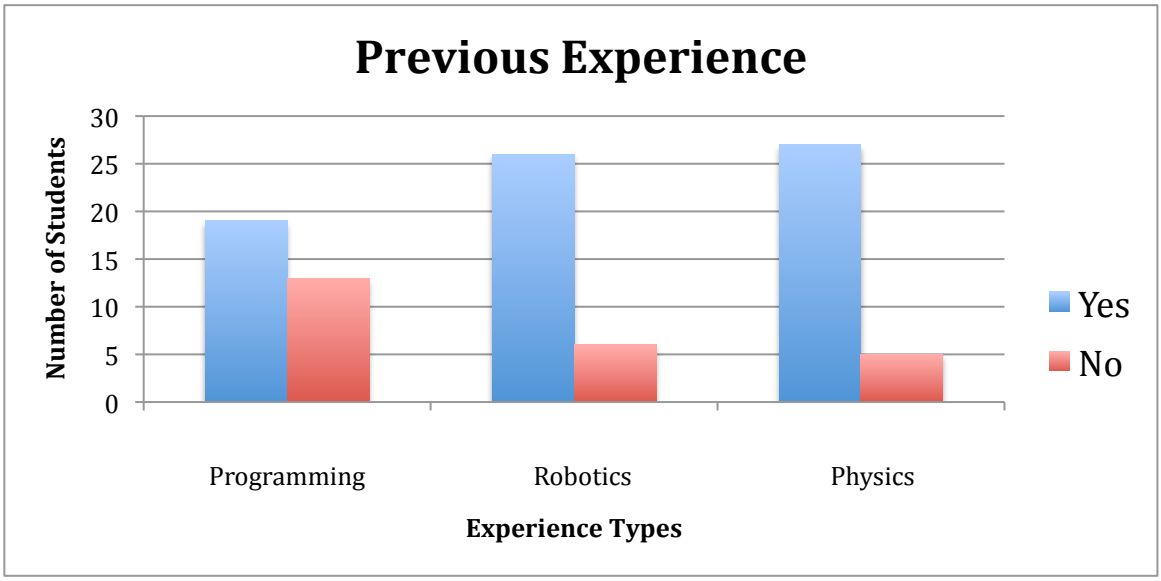

Figure 3 - The tally of students who began the course with or without previous experience

There were common reasons for why the eTextbook was not used, as shown in Figure 2. Fifteen students felt it was not necessary, some adding reasons such as limited time or feeling lecture material was adequate. Another reason may be the high number of students who came into the course with various forms of experience (Figure 3). Robotics experience tended to be participation in FIRST at high schools and courses taken at either Worcester Polytechnic Institute or high school. This parallels the results from the primary survey, which showed low levels of desire for a textbook (Figure 4) and learning from textbooks in other courses (Figure 5), and showed they only used textbooks when it was necessary (Figure 6). These also parallel the study discussed in the Textbook Usage section of the Literature Review. There were six students who claimed they forgot that the eTextbook existed or did not know where to find it, which indicated the eTextbook was not sufficiently integrated into the course. There were additionally three people that looked to sources other than the lectures or the eTextbook, which indicated the eTextbook did not appear to be useful enough to them; however, the small size of this response means it is not very reliable.

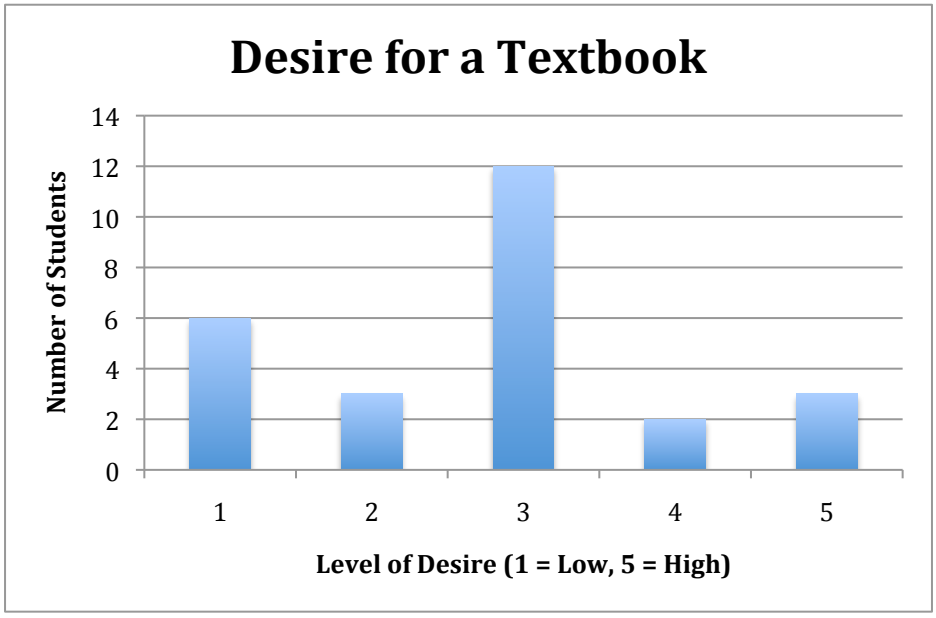

Figure 4 - Desire students expressed for a textbook in a course that lacked one, on a Likert scale of 1 through 5, with 5 being high

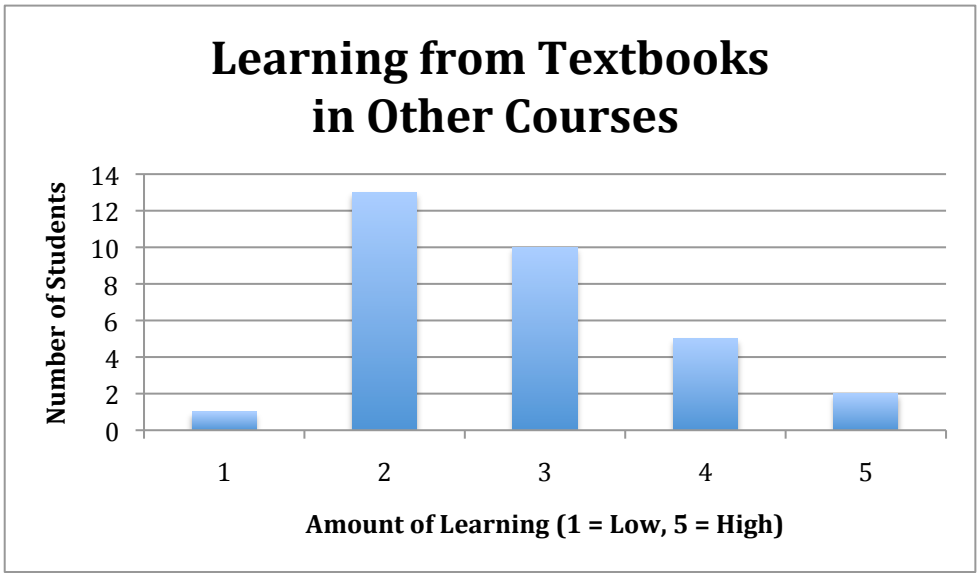

Figure 5 - The amount of learning students expressed obtaining from using textbooks, on a Likert scale from 1 through 5, with 5 being high

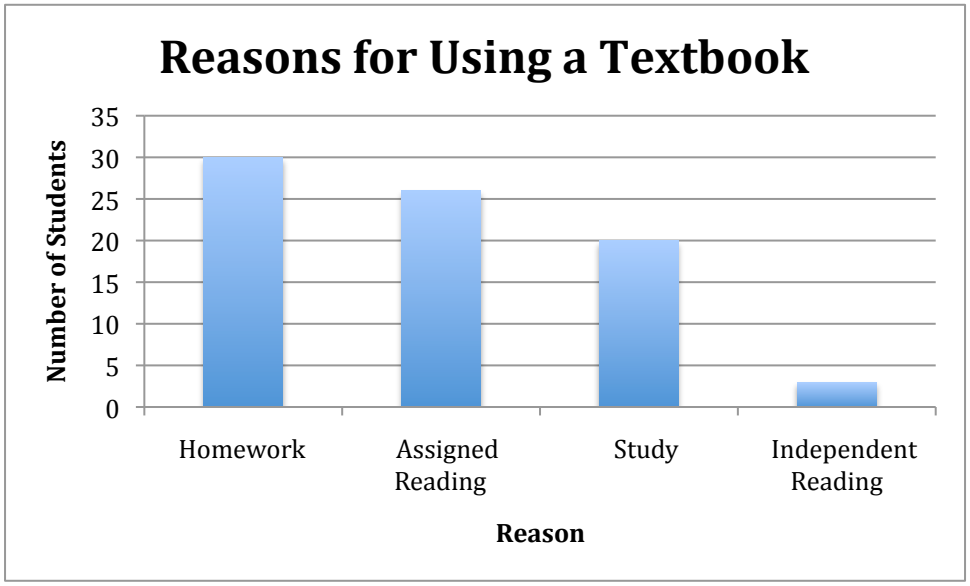

Figure 6 - The reasons students gave for using textbooks in previous courses

The reliance on lecture notes and past experience was even more evident in the quiz results (Figures 7 and 8). They were the two primary sources given for the answers, with guesses being the next most popular. Questions 2, 4, 5, and 6 were covered solely in lecture, while questions 1, 3, 7 and 8 were covered in both lectures and the eTextbook. Looking at the results, it is interesting to find that numbers 7 and 8 were the

questions most answered incorrectly, and an overwhelming majority guessed on them. The next question many answered wrong was number 2, which was only covered in lecture, and was also the one where most people used experience over any other source. These trends may suggest that if the eTextbook were more integral to the course, it would be used much more often and might be able to help students with questions such as the ones with which this group had trouble.

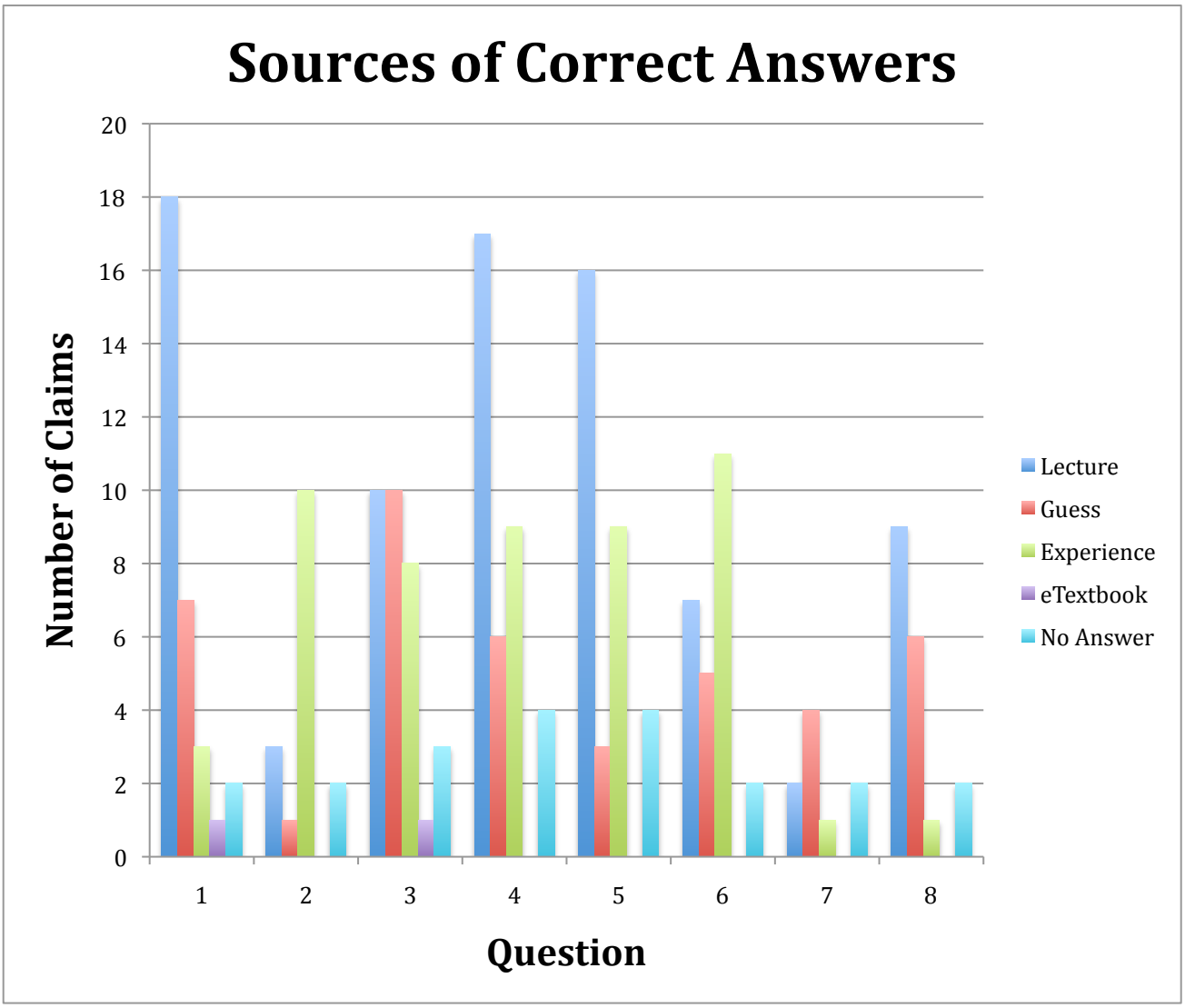

Figure 7 - The number of times particular sources students claimed was the inspiration for their answer were given when answering correctly for each question. Questions 2, 4, 5, and 6 were covered in lectures and questions 1, 3, 7, and 8 were covered both in lectures and the eTextbook

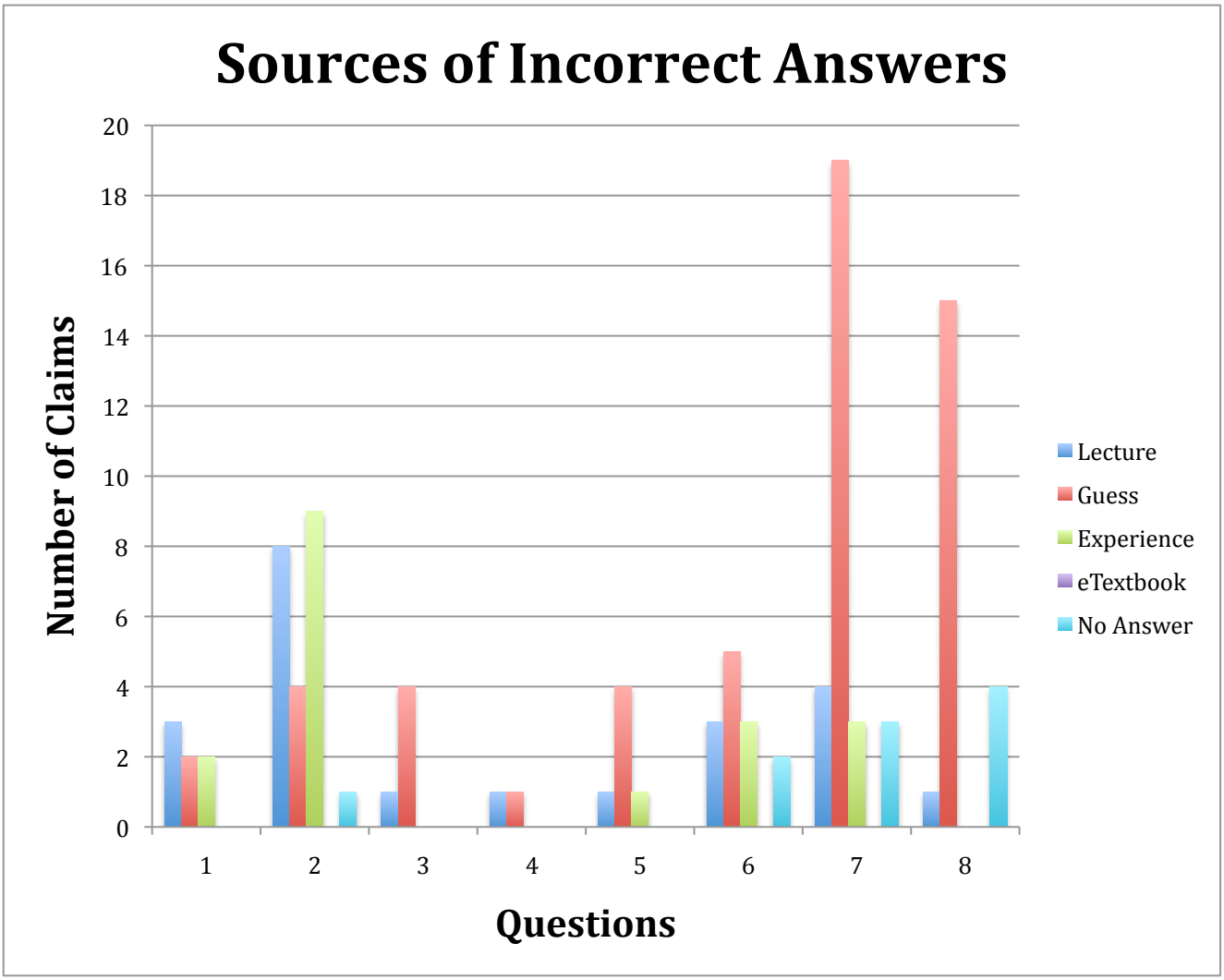

Figure 8 - The number of times particular sources students claimed was the inspiration for their answer were given when answering incorrectly for each question. Questions 2, 4, 5, and 6 were covered in lectures and questions 1, 3, 7, and 8 were covered both in lectures and the eTextbook

The second goal, evaluating the usefulness of interactive content, suffered from the small usage as well. Only half of those who used the eTextbook looked at the interactive content. Not only is this, again, not enough data to be statistically relevant, but it is also not even enough to try and find trends.

Even with the insufficient data toward the goals, the study did not only produce inconclusive results. There were signs that while the eTextbook was not used very much, it has the potential. The first survey revealed that students read textbooks rather

frequently in a given week (Figure 9), and liked past experiences with supplementary materials such as practice problems (Figure 10).

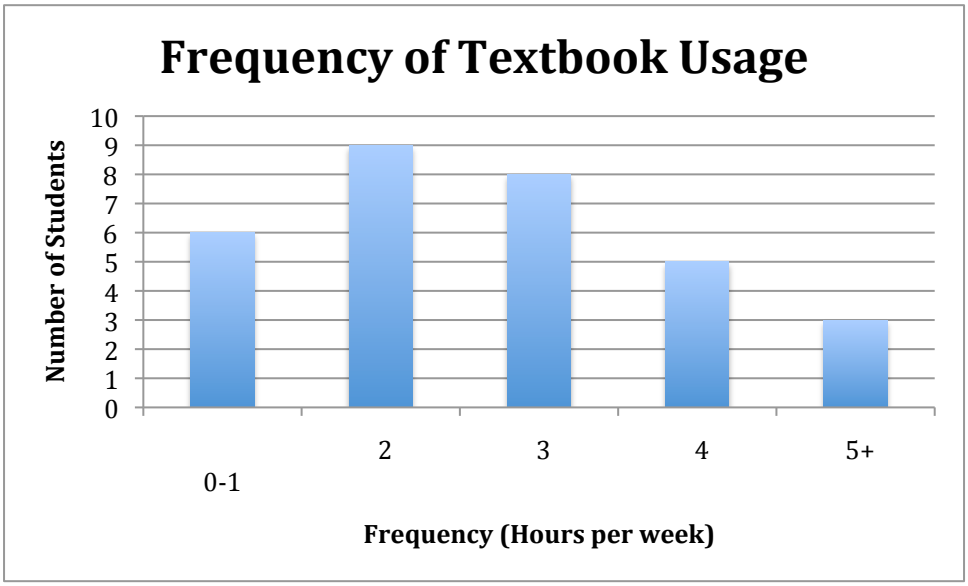

Figure 9 - Textbook usage in an average week in hours

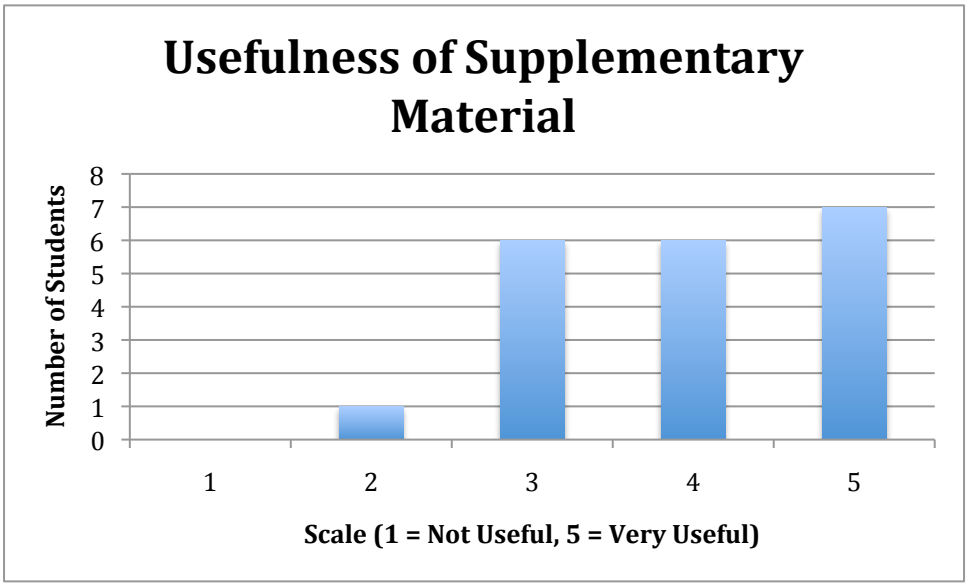

Figure 10 - The usefulness of supplementary materials provided with textbooks according to students who used them

Many had also had previous experience with eBooks, stating they enjoyed the portability, inexpensiveness, and ease of use. Main disadvantages included

dependence on technology, reading difficulty, and dependence on internet access. Similar findings came from the focus group, which had an observed halfway split on opinions about which form was better. Those who preferred eTextbooks cited the low costs and platform portability, as long as the content was tested. Those who preferred physical copies claimed they were easier to read and take notes in, as well as keep track of for future use. As hardware and software capabilities increase, some of these opinions may change in favor of digital versions, but only time can really tell.

This is the extent of the analysis performed for this study. It is not expected much more may be gleaned from the data due to the small amount of it. Even if not looking for statistical significance, at least 20 students having looked at the eTextbook would have been desirable; some trends could have been discovered from even that sample size.

Conclusions and Recommendations/Guide for Future Work

There are a limited number of conclusions that may be drawn from the gathered data. In respect to the main goals of the project, to evaluate the eTextbook's affect on learning in the class and the usefulness of interactive content, no conclusions could be made. There was simply not enough data to work with.

The quiz results and responses on the final survey suggest that the eTextbook was not incorporated into the class enough to generate interest. Most students stated they used textbooks only when it was assigned or required for work. If the text had been more complete instead of a compilation of a few chapters, been used for assigned readings as the subjects came up in lectures, and been used in an inverted classroom environment, as originally intended, there would be more incentive to use it.

The quiz results also suggested the eTextbook could benefit from paralleling the lectures, reinforcing the beliefs of the professors who applied for the study. Lecture notes were the most common source of correct answers. Additionally, the two questions which an overwhelming majority answered incorrectly by guessing were addressed in the eTextbook; this does not suggest reading it would have helped them answer the questions better, but it is a possibility.

There are a number of recommendations for future work that arose from this project.

First and foremost, the study needs to be repeated with more preparation into all aspects. The eTextbook should be complete, or near complete, before trying to evaluate it, and it needs to be planned into the course syllabus more. Optimally, the class would be conducted in an inverted classroom style, encouraging the eTextbook to be utilized to its fullest. The sample size used also needs to be carefully considered. It may be wise to perform the study several times with different classes in order to have a larger

population. Focus groups, surveys, and examinations need to be carefully and thoroughly planned and established early on to avoid the dilemma of low interest that, despite great efforts, was prevalent early in this project.

One of the ulterior goals of the project was to devise a guide for professors to design and write their own eTextbooks appropriate to their course. This has proven to be difficult because the study was inconclusive. Nonetheless, one thing is certain: the professor would need ample time and interest. Whether there are interactive features or not, the bulk of the eTextbook is still text, which takes a lot of time and effort to plan, write, and edit. If there was a dedicated team, it would be much easier to manage.

In conclusion, this project met many pitfalls. It started out strong, with great ambitions and extensive research. Data collection methods were carefully studied and planned. It fell apart because shortcomings were not planned for. The eTextbook was not completed as desired, the general participation was lower than expected, and delays in conducting the study, stretching about half a year more than initially intended, caused unanticipated scheduling issues. The data collection resulted in less data about eTextbook usage and interactive content than desired. All of these factors caused the study to be inconclusive. Nevertheless, it has set the groundwork for a follow-up study. Properly done, the next one will have more desirable results.

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Appendix A: Textbook Evaluation Form

Provided on the next few pages is the form provided by Crystal Springs Books and the Staff Development for Educators.

Textbook Evaluation Form

Introduction

The authors of *Differentiating Textbooks* have identified the elements that they believe are essential to a good textbook and their information has been compiled into this textbook evaluation form. Used as a general guideline, it will enable you to evaluate textbooks across curriculum areas using a measured, or quantitative, method. It is assumed that the textbooks being evaluated are intended for all learners.

Using a scale from 1 (poor) to 4 (excellent), you will rate each category based on its accompanying description. Occasionally, you may find that some do not apply to the subject area you are considering, and in such instances you would simply mark N/A (not applicable) rather than assign a numerical rating. After completing the form, tally your ratings, so you can quickly note which textbooks received the highest marks. You may want to keep the forms on file for future reference within a department, as they could be used to compare existing textbooks with possible replacements.

Book Title:	**Ratings**			
Author(s): **Publisher:**	1 (Poor)	2 (Fair)	3 (Good)	4 (Excellent)
Table of Contents: Material is presented in an order that makes sense for teaching. For example, a building approach is used with math and science subjects; new material is based on previously taught skills or already defined/discussed information.				
Glossary: Unfamiliar or specialized terms are well-defined and their pronunciations are included.				
Bibliography: List of books and other reference works used by author(s) is comprehensive and up to date. (Check publication dates to see if materials are current.)				
Recommended Reading: Includes works that enable the reader to pursue further information.				
Web Sites: Include direct links to pertinent information. (Randomly check a sampling of sites for current availability and to see if they indicate how recently they were updated.)				
Index: Index is thorough and easy to use, and consists of entries that are detailed and cross-referenced.				

Book Title:	Ratings			
Author(s): Publisher:	1 (Poor)	2 (Fair)	3 (Good)	4 (Excellent)
Writing Style: Writing is descriptive and thought-provoking, and fosters visualization, sparking the reader's imagination on many levels. Vocabulary consists of words that are both familiar and challenging, and words the reader may not know are clearly defined. Main ideas are explicit, not imbedded in the text.				
Headings/subheadings: Headings and subheadings support the content and preview what is coming so that the reader gets a clear idea about the section and can make predictions and read for purpose—helpful with before-reading activities. Wording is explicit rather than vague or ambiguous.				
Captions and labels: Captions and labels are accurate and informative, and supplement the text or main ideas in that part of the book.				
Sidebars: Sidebars augment the text by highlighting incidental or little-known information, or by expanding upon points or ideas mentioned in the text.				
Topic sentences and section/chapter previews: These communicate what is being discussed/developed in the paragraph or section/chapter; allow the reader to establish, identify, and absorb main ideas; and provide helpful information for before-reading activities.				
Section/Chapter Summaries: Key ideas and main points supporting the topic discussed in the section/chapter are clear and accurately restated.				
Extension Activities: Includes relevant activities offering sufficient practice so that the student can reinforce and retain what has been taught. Activities focus on different ways in which students might continue their study based on various learning styles.				
Page Layout: The text is complemented/supported by graphic elements (illustrations, photographs, maps, charts, etc.) that follow the less-is-more rule: they do not crowd the page or overwhelm the student with too much textual or visual information.				

Book Title:	Ratings			
Author(s): Publisher:	1 (Poor)	2 (Fair)	3 (Good)	4 (Excellent)
End-of-Section/Chapter Comprehension and Critical-Thinking Questions: The questions make connections between the learned content, allow the reader to reflect on main ideas, and extend critical thinking about past and future events. Questions also are multi-leveled, i.e., there are questions that the reader can answer by looking in a specific place in the text, some that require the reader to look in several places to find the answer, and others that require the reader to look for clues in what they have read and combine these with their prior knowledge. The number of questions included provides ample practice for students.				
Type Style, Line Length, and Leading: The point size of the type, length of the line of type, and space between each line all work together, producing a page that is not only visually appealing but also readable and accessible. (A line of text is usually easier to read if it does not span more than half the width of the page.)				
Graphic Elements (photographs, illustrations, maps, charts, etc.): Graphics are located with the text that they refer to rather than pages before or after it.				
Graphics are consistently identified with call outs, such as Figure 1, Figure 2, etc.				
Maps and charts include keys or legends that explain what the symbols mean.				
Each photograph includes a caption that succinctly identifies it and makes a direct connection between it and the text.				
At least half of the graphics are in color.				
Total Each Column				
			Grand Total	

Appendix B: Focus Group

Below is the rough agenda for the focus group and Bryce Jassmond's notes taken during it.

RBE1001 Preliminary Focus Group

Broad Questions:

1. What are your thoughts on textbooks? Usefulness? Their cost?
2. What are your thoughts on eBooks? Viable as textbooks?
3. Interactive elements in eBooks?

Present our eTextbook

1. Initial thoughts:

a. General opinion
b. What was done right
c. What was done wrong
d. What could be better

Feedback from surveys

- as needed
  - sold later
- keep what's needed
- pdfs
  - no page keeping
- Pdf > textbook
- paper book
  - use at home
- some more useful than others
  - homework
- interested in
  - read for fun/ahead
- visual
- progressing technologies
  - make more preferable
- cost is huge
- half-half paper vs. eBook
- device/platform dependency hard
- split view on paper vs. eTextbook
- content integrated into textbook
- content working is a must
- like features
  - side by side pages
- like reverse style

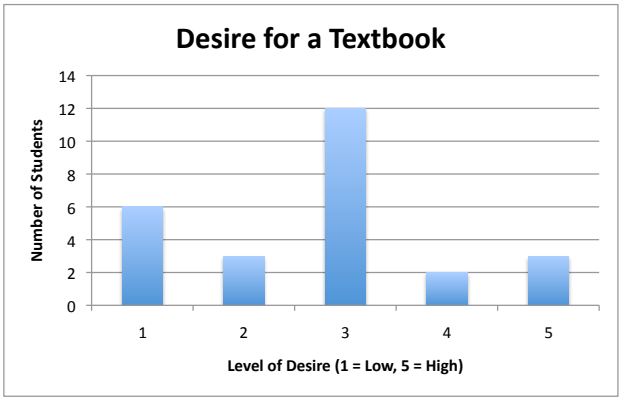
Appendix C: D Term Preliminary Survey Results

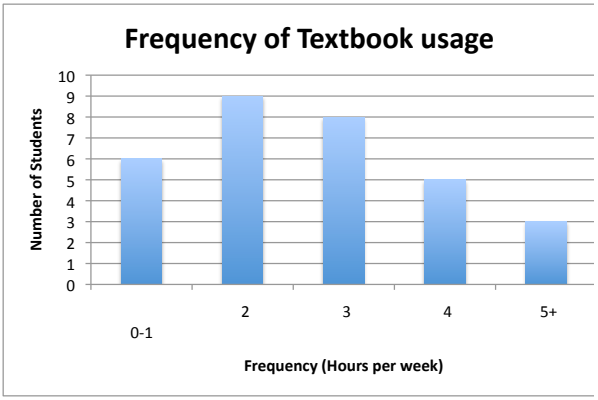
The next few pages show the questions and results of the preliminary survey given to the D Term students. The gray row shows the questions while each row afterward displays a different person's answers. After all of the answers, some totals are shown.

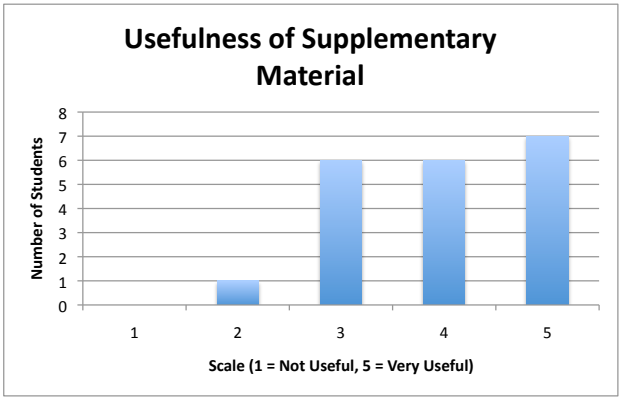
Have you ever had a class that did not use a textbook before?	Would you have wanted a textbook?	In a typical course, how often do you use the textbook?	In other courses, how did your learning from the textbook compare to learning from other sources (self-performed research, lecture, projects, etc.)	What do you usually use the textbook for? Check all that apply:	Have you ever used supplementary materials included with a standard textbook (online tools, CDs, etc.)	Please describe them/their content.
Yes	5	4	5	Homework questions, Assigned reading, Study for quizzes/exams	Yes	Online resources
No		4	4	Homework questions, Assigned reading, Study for quizzes/exams, encyclopedia	Yes	Mastering Physics, assigned homework, and had helpful suggested problems to help one along with the course.
Yes	2	2	2	Homework questions, Assigned reading	Yes	CDs
Yes	4	2	3	Study for quizzes/exams	No	
Yes	5	1	4	Homework questions, Study for quizzes/exams	No	
Yes	4	3	2	Homework questions, Assigned reading	Yes	Online articles research papers other scholars have completed
No		3	3	Homework questions, Assigned reading, Study for quizzes/exams	Yes	Other books I used in other classes on the same subject, MIT open courseware, The Great Courses
Yes	1	3	2	Homework questions, Assigned reading, Study for quizzes/exams	No	
Yes	3	4	4	Homework questions, Assigned reading	No	
Yes	3	2	4	Homework questions, Assigned reading, Study for quizzes/exams, Independent reading (out of interest/"for fun")	Yes	Wiley Plus online homework problems for physics.
Yes	3	2	1	Homework questions, Assigned reading, Study for quizzes/exams	No	
Yes	1	2	2	Homework questions, Independent reading (out of interest/"for fun")	No	
Yes	1	3	3	Homework questions, Assigned reading, Study for quizzes/exams	Yes	WileyPlus homework for Physics
Yes	3	3	4	Homework questions, Assigned reading, Study for quizzes/exams	Yes	I used online HW systems that provided additional questions and explanations, which really helped when I didn't understand lecture material.
Yes	1	4	3	Homework questions, Assigned reading	Yes	online videos and audio files necessary for homework questions in Spanish textbook
Yes	3	2	3	Homework questions, Study for quizzes/exams	Yes	

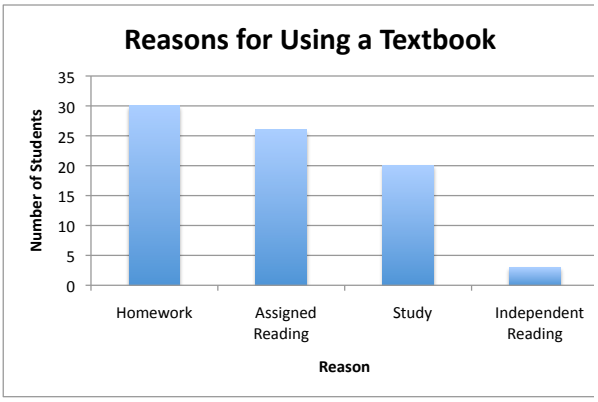
No		3	3	Homework questions, Assigned reading, Study for quizzes/exams	Yes	Online tutorials for a Spanish class.
Yes	1	1	2	Homework questions, Assigned reading, Study for quizzes/exams	Yes	WileyPLUS contained both the textbook and the practice problems.
Yes	3	1	2	Homework questions, Assigned reading, Study for quizzes/exams	Yes	online homework/studying tool
Yes	2	2	3	Homework questions, Assigned reading, Study for quizzes/exams	Yes	Online questions,
Yes	3	1	2	Homework questions, Study for quizzes/exams	No	
No		5	2	Homework questions, Assigned reading, Study for quizzes/exams	Yes	Usually there is a CD that comes with the textbook so i can have additional practice. or the textbook may recomend additional websites that i can use for practice
Yes	2	2	2	Homework questions, Assigned reading	Yes	links to websites found in the textbook
Yes	3	1	2	Homework questions, Assigned reading	No	
No		2	2	Homework questions, Assigned reading, Independent reading (out of interest/“for fun”)	No	
Yes	1	4	2	Homework questions, Assigned reading	Yes	I used wileyPlus for Physics, which had all the online assignments and grades on it.
Yes	5	5	5	Homework questions, Assigned reading, Study for quizzes/exams	Yes	When I took my Physics: Mechanics course, it used WileyPlus. It gave you the reading and you did the homework online and it gave you a certain number of tries to get the question right, and a walkthrough of how to solve the problem. It was really helpful and I did well in that course.

Yes		3	5	3	Homework questions, Assigned reading	No	
Yes		3	3	3	Homework questions, Assigned reading, Study for quizzes/exams	Yes	Cd's which include studyguides for the topics discussed in class
Yes		3	1	2	Homework questions, Assigned reading, Study for quizzes/exams	No	
Yes		3	3	3	Homework questions, Assigned reading	Yes	Animations for physics - electric fields, etc.
Yes:	1,2,3,4,5:				Homework?	Yes:	Popular topics:
	26	6	6	1		30	20 Online Resources
No:		3	9	13	Assigned reading?	No:	Homework problems
	5	12	8	10		26	11
		2	5	5	Studying?		
		3	3	2		20	
					Independent?		
	31	26	31	31		3	31





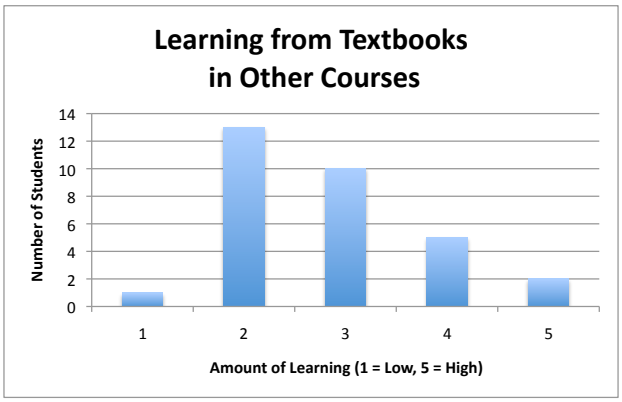




How useful were they?	Have you ever used an eBook before?	What advantages did it have compared to using a physical book?	What disadvantages did it have compared to using a physical book?	Were there any interactive elements?	If yes, please describe them.
3	Yes	If you save pages as PDF you can take notes on the book	No physical copy meant I read it less	No	
4	No				
4	Yes	Easier to carry	Not much	No	
	No				
	Yes	It was much easier to carry around. Didn't cost an arm and a leg	Not easy to write in.	No	
5	Yes	Can use tools such as ctrl+F and carry it on my phone	could not write on it	No	
5	Yes	I weighed considerably less.	When my laptop battery died or I had no internet connection.	No	
	No				
	No				
2	No				
	Yes	It is very easy to read on my iPad mini.	I like having a physical copy of the book.	No	
	Yes	It is cheaper, greener, and more portable.	You have to charge your tablet or laptop.	No	
5	Yes	It is right there on your computer, so it saves the hassle of carrying a textbook	Nothing beats having a solid, real life book, that you can hold onto, flip the pages, and dont tire your eyes out from the screen.	No	
4	No				
4	No				
3	Yes	not heavy less money	not paper	No	

3	Yes	Cheaper, lighter, fewer things to carry around.	Had to pull out laptop every time, needed internet.	No		
3	Yes	I didn't have to carry it around.	I didn't like it as much.	Yes	Practice problems and quizzes.	
3	Yes	I could search for keywords in the text.	it required using the computer for the entirety of my needing the book.	Yes	Links to other education resources.	
4	Yes	It was easier to find the content that I was looking for if I ever went back to look up a specific thing.	It was a lot more difficult to stay focused on reading it.	No		
	Yes	Not big to take up space. Also if its free thats super awesome. Mainly the free thing is the key.	NONE	No		
5	Yes	I idnt need a huge textbook.	It takes longer to raead text on a screen than it does on paper. this is an actual statistics. People read 205 slower on screens than from paper.	Yes	maybe a few games, or additional questions or something.	
4	Yes	less weight in my backpack, easy access, ctrl f	the need for internet connection	Yes	practice problems	
	Yes	Don't have to carry it everywhere. Easy to search things up in the book.	Need internet access	Yes	Flash cards, highlighters	
	Yes	No book to carry and the eBook for CS was online for free.	Needing to use laptop to see text and sometimes internet required.	Yes	Noting that it was during high school, senior year, the history books had a read aloud option on the online text. (But pressing the icon in the hard copy of the book didn't work for obvious reasons)	
5	Yes	If I had only used the eBook and not bought the physical copy as well (I didn't know about the eBook before the course), I would have saved a good 200 dollars. I could also access all the material from the course from my laptop, which is much easier to lug around places than a huge textbook. I could also access it from anywhere I wanted.	The particular website I was using had the book and the assignment on the same site, and didn't allow multiple tabs of the site, so instead of going back and forth between eBook and homework, I usually just used the physical book. It's easier to compare notes when you have a physical book and an online assignment.	No		
5	No					

	Yes	easier search	readability	No	
		i carried less books to class, library ETC..	sometime changing through the pages, or looking up the index is		
	3 Yes	i can use it easily in class	hard	No	
		You do not need to bring a textbook around. You can print	It is harder to read of a computer screen		
	Yes	pages out.	then an actual book.	No	
	5 Yes	Portability.	Harder to read.	No	
1,2,3,4,5:	Yes:	Popular topics:	Popular topics:	Yes:	Popular topics:
	0	23 Portable	Difficult to read		6 Practice problems
	1 No:	Cheap	Internet Access	No:	
	6	8 Search	Dependent on tech		17
	6				
	7				
	20	31			23



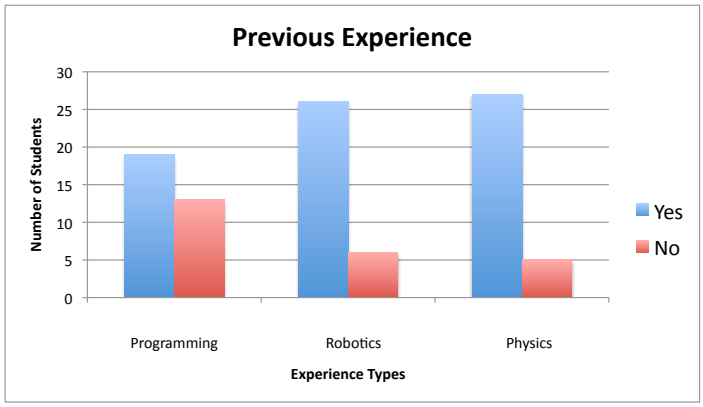
Appendix D: D Term Final Survey Results

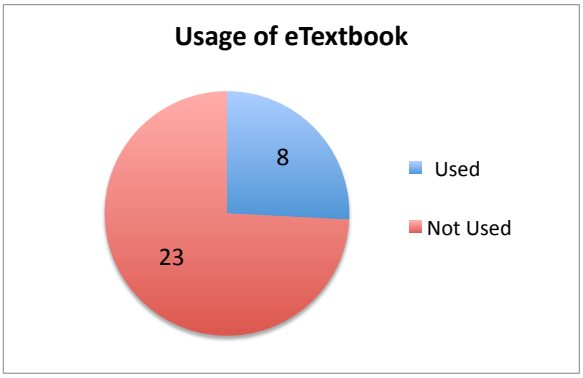
The next few pages show the questions and results of the final survey given to the D Term students. The gray row shows the questions while each row afterward displays a different person's answers. After all of the answers, some totals are shown.

Did you have any robotics experience prior to this course? If so, please briefly describe your experience(s) below. Mention significant cases such as classes, clubs, or personal projects.	Robotics experience	Did you have any programming experience prior to this course? If so, please briefly describe your experience(s) below. Mention significant cases such as classes, clubs, or personal projects.	Programming experience	Have you taken an AP- or college-level physics course?	Did you use the eTextbook?	For what reasons did you not use it?	How often have you used the eTextbook?
Yes	3 years of First Robotics, high school senior capstone, frontiers summer program.	Yes	3 years programming for First Robotics, high school senior capstone, frontiers, CS 1101, CS 2303	Yes	No	Don't really need it?	
Yes	11th grade robotics class, FIRST robotics.	No	CS 1101, BASICStamp programming in high school robotics.	Yes	No	I've never felt the need to utilize it.	
No		Yes	CS 1101 I dont think this really helps for it was in a completely different language and loops and variables and functions were all completely different.	Yes	Yes		2
Yes	Counselor at Tufts CEEO Lego Robotics Summer Camp 2 Years.	Yes	CS 1101	Yes	No	I didn't know we were supposed to.	
No		Yes	I programmed on my TI-84 plus calculator in high school, and I took CS 1101 during C Term.	Yes	Yes		2
No		Yes	I took a CS 1101 and am currently taking CS 2102.	Yes	No	I haven't gotten around to it.	
Yes	I was on my high school's FIRST robotics team, however I was not a heavily active member.	No		Yes	No	I haven't actively taken the time to look at it. I've had a lot of little things in all three of my classes to do and I don't read textbooks for help very often (this is not generally the best course of action).	
No		Yes	CS1101	No	Yes		1
Yes	Frontiers	Yes	Cs 1101	Yes	Yes		1
No		Yes	CS 1101	Yes	No	forgot and i got help from people instead of books	
No		No		Yes	No	I don't have time to do homework for all my classes and read the eTextbook.	
No		Yes	CS 1101	No	No	I don't think it will help me. And no idea how to access it	
Yes	I did First Lego League for three years in middle school and FRC for 4 years in high school.	Yes	I have taken CS1101 and in middle school used Lab View	Yes	No	i did not have it available to me/ i don't know what it is	
Yes	I took a summer pre college course in artificial intelligence.	Yes	CS1101, CS2102 other various work on programming on my own. Also the artificial intelligence class had a large programming portion.	Yes	No	Have not found it necessary/helpful	
Yes	Frontiers	Yes	Personal projects AP CS (high school) CS 1101	Yes	No	I knew most of the information	

No		Yes	Have took several CS classes in the past that required programming. Was also part of the Computer Club at Massbay, which had a programming team that went on competitions.	No	No	Found the information I was unclear about online at different website. Forgot that the eTextbook existed	
No		Yes	Yes. As I am a cs major I have taken several cs classes at wpi. As well as having a cs related internship and programming in NY spare time.	Yes	No	I didn't find that much of a need to use it	
Yes	FIRST robotics	Yes	CS 1101, use of Visual Molecular Dynamics (VMD and NAMD) modeling programs	Yes	No	I completely forgot that it was there	
No		No		Yes	No	I did not have time to read the eTextbook. Ain't nobody got time for that!	
Yes	Vex robotics national champion 2012 Competitor 2009-2012	Yes	AP computer science and wpi intro to computer science	Yes	No	I don't know where to find it	
No		Yes	A cs class in high school, CS 1101, CS 2102, CS 2303	Yes	No	I haven't had a reason.	
No		Yes	CS1101 with DrRacket	Yes	No	I did not know of its existence.	
Yes	High school Intro to Robotics course taught using the LEGO NXT kits.	Yes	High school Intro to Programming taught in BASIC, personal experimentation in high school with TI-83+ BASIC, WPI: CS1101, CS2102	Yes	No	Haven't run into a need for it yet. Lecture notes have been sufficient for everything I need.	
Yes	High school senior - robotics course FIRST - all four years of high school	Yes	programming since I was 8 years old on games, etc. published Android apps (Java) working for WPI information security (mostly Python) plenty of CS courses programming the backend of various websites more than I can list	Yes	No	I skimmed through the start and found that there was adequate material in the lecture presentations and handouts to understand what I need to do well on the exams. I have experience programming Arduino, so I didn't feel the need to use the textbook.	
Yes	FTC and Robotics class in high school	Yes	Robotics from high school, CS1101	Yes			
Yes	im really just a hobbyist. the only thing ive done with robots is follow instructions for the tetrix kits and robotics kits. I didnt do FIRST and im not familiar at all with programming. Its not until RBE 1001 that im beginning to think like a real programmer.	No		Yes	Yes		2
Yes	FRC -- 2 yrs	Yes	AP CS, Indp. Stud. CS, CS 1102, CS 2022, CS 2223	No	No	Used Wikipedia/Google instead	
Yes	Two years of FIRST Robotics	Yes	CS 1101	No	Yes		1

Yes	6 years FIRST Robotics Competition. 1 year mentor FIRST LEGO League. Developed, documented and manufactured educational robotics kit for school and individual use. personal Mindstorms and RobotC projects	Yes	C++ including Arduino and FIRST; Motorola assembler, HTML & CSS, some PHP	Yes	Yes							1
Yes	created FIRST FTC team/club	Yes	same as above	Yes	No	expensive and not used in the class						
No		Yes	Racket	Yes	No	I did not have a need to read it and I didn't want to waste my time.						
Yes	FIRST robotics, designed and built two large robots, one for playing the 2012 challenge and one for playing the 2013 challenge. taught me how to think of many different solutions to problems, taught me how to build, as in what materials and why.	No		Yes	Yes							2
Yes:	19	Yes:	26	Yes:	27	Yes:	8	Popular topics:		1,2,3,4,5:		
No:	13	No:	6	No:	5	No:	23	Not necessary	15			4
								Forgot/couldn't find it	6			4
								Used other source(s)	3			0
Total:	32	Total:	32	Total:	32	Total:	31			Total:		8



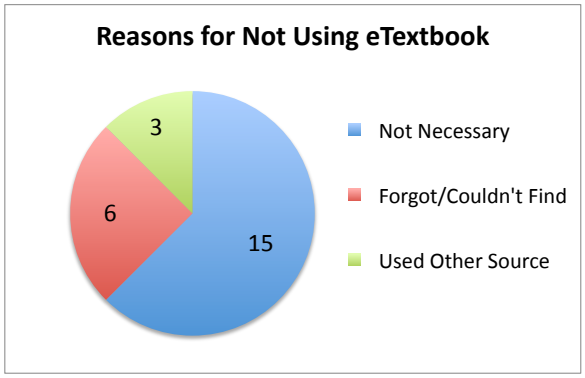


What did you use it for? Check all that apply:	How would you rate the book's level?	How helpful has having a textbook been for understanding of the course material?	How useful was this eTextbook as compared to textbooks you've had in other classes?	Which elements of the book have been useful to you? Check all that apply:	How often was the eTextbook able to answer questions you had about the subject material?	Did using the eTextbook make you feel more prepared for class?	Is the textbook an adequate resource for learning material which has not been presented in lectures?
Homework questions, Study for quizzes/exams, Independent reading (out of interest/"for fun")	3	3	3	Main text	3	2	No
Homework questions, Study for quizzes/exams	3	4	4	Main text, Interactive elements, End of chapter quizzes	4	4	Yes
Assigned reading	3	2	4	Main text	3	3	No
Study for quizzes/exams	2	2	2		2	2	No

Homework questions	3	3	1 Main text, In-text links	3	4	No
Assigned reading, Independent reading (out of interest/"for fun")	3	3	3 Interactive elements, In-text links	3	3	No

Assigned reading	2	3	2 Main text	4	4 Yes

Homework questions		3	4	3 Main text		3	3		
Homework?	1,2,3,4,5:	1,2,3,4,5:	1,2,3,4,5:	Main text?	1,2,3,4,5:	1,2,3,4,5:	Yes:		
	4	0	0	1	7	0	0	2	
Assigned reading?		2	2	2 Interactive?		1	2 No:		
	3	6	4	3	2	5	3	5	
Studying?		0	2	2 Quizzes?		2	3		
	3	0	0	0	1	0	0		
Independent?	Total:	Total:	Total:	Links?	Total:	Total:	Total:		
	2	8	8	8	2	8	8	7	



Compared with experience from other courses, how did your learning from the eTextbook compare to learning from other sources (self-performed research, lecture, projects, etc.)	If you could convert textbooks for your other classes to this eTextbook format, would you?	Have you used the interactive features?	Learning material not yet covered in the class or the text?	Reinforcing your understanding of the text?	Aiding completion of homework and quizzes?	Understanding finer details or special cases?	Learning material beyond the course syllabus?
	2 Yes	No					
	3 Yes	Yes	4	5	4	4	4
	3 Yes	No					
	1 Yes	No					

1 Yes	Yes	3	3	3	1	3
2 No	Yes	3	4	2	3	3

	2 No	Yes		3	4	2	4	3

	3 No	No						
1,2,3,4,5:	Yes:	Yes:	1,2,3,4,5:	1,2,3,4,5:	1,2,3,4,5:	1,2,3,4,5:	1,2,3,4,5:	
	2	5	4	0	0	0	1	0
	3 No:	No:		0	0	2	0	0
	3	3	4	3	1	1	1	3
	0			1	2	1	2	1
	0			0	1	0	0	0
Total:	Total:	Total:	Total:	Total:	Total:	Total:	Total:	
	8	8	8	4	4	4	4	4

What do you like about the eTextbook?	What don't you like about the eTextbook?	What were the two most useful elements of the eTextbook and for what reasons?	What were any annoyances or drawbacks of the eTextbook as compared to a traditional paper text?	How do you think the eTextbook may be improved?
Its online and i didnt have to pay for it. also doesnt take up physical space	chapters werent released fast enough	its a text book... i guess the material	not really	none
It is easy to follow, it doesn't weigh anything, ctrl + F	It is not complete.	ctrl + F, so that I could always find what I was looking for relatively quickly, and ease of access; I always have my computer with me. I don't always carry all of my books with me.	I don't always have internet access, my computer can run out of battery.	
It's on the computer!		On the computer! And I don't know.		

I like that its free	Its not finished.	It was good for the programming section	i need a textbook that directly relates to the class. if we go over opamps there should be a chapter that explains everything about opamps.	finish the textbook. directly correlate it to the course

It was relatively clear and useful.	Its bulky and the links are annoying, especially if the textbook is open in a browser, where (because its a PDF) you can't open in a new tab. Needs a better modulus description.	Text and non interactive diagrams; interactive parts are difficult to use.	It was linked poorly (noted before).	It needs better integration with the class, and it needs to be cut down in length.
gave me a quick idea of how to program.		easy access. clear explanations		more examples.
Popular topics: Easy to use Free	Popular topics: Incomplete	Popular topics: Easy to use Good information	Popular topics:	Popular topics: Finish book

Appendix E: D Term Quiz Results

The next few pages show the questions and results of the quiz given to the D Term students.

First is the two-part quiz, written by Prof. Mike Ciaraldi and Bryce Jassmond. The first part contains the eight concept questions covering material the students had learned to the date of the quiz. Questions 1, 3, 7, and 8 were all covered in lectures and in the eTextbook while questions 2, 4, 5, and 6 were only covered in lectures, allowing comparison. The second part contains background questions, asking minimal information about what experience students had prior to the class and what they based their answers on, with the goal of determining the eTextbook's influence.

After, the quiz results are shown. Each row includes the correctness of each student's answer to the quiz questions, the total of eTextbook-based versus non-eTextbook-based correct answers, and their answers to the background questions. For Excel functions, the questions needed to be listed out of order, so after totaling the count for each category and averaging the scored, they were re-ordered them for the results to be displayed sequentially. Finally, the sources given when students answered questions correctly and incorrectly were tallied and displayed in two graphs.

Choose a code number to remember: _____ May 1, 2013

RBE1001 Concept Quiz

This quiz was designed to evaluate student progress thus far and to collect concrete data about the effectiveness and usage of the eTextbook as part of an IQP. You will not receive a grade from it, but if you wish to receive the quiz portion back, please select a code number and write it at the top. Remember it for when Prof. Ciaraldi returns the quizzes. Both parts are completely voluntary.

Part I

Instructions: The part of the quiz consists of 8 multiple choice concept questions based on material covered up to this date. Circle the letter of your answer for each question. This should take you no longer than 15–20 minutes.

---

1) The Arduino can send a PWM signal to a Vex motor with a pulse width ranging from 1000 to 2000 μ sec. If we send a pulse with a width of 1500 μ sec., the motor will:

    a. Stop/Remain Motionless
    b. Run at 100% speed in a direction
    c. Run at 50% speed in a direction
    d. Start smoking

2) For a robot stationary on a ramp, the force of friction is _____ the normal force times the coefficient of friction.

    a. Equal to (=)
    b. Greater than or equal to (>=)
    c. Less than or equal to (<=)
    d. Not correlated with

3) What is the difference between digital and analog input for Arduino?

    a. Analog input voltage is either 0 or 5V while digital input may be any discrete number between 0 and 5V
    b. Digital input voltage is either 0 or 5V while analog input may be any discrete number between 0 and 5V
    c. Arduino can read analog inputs but cannot read digital inputs
    d. Arduino can read digital inputs but cannot read analog inputs

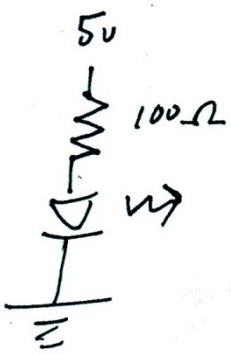
4) When should you write the header comment of a function?

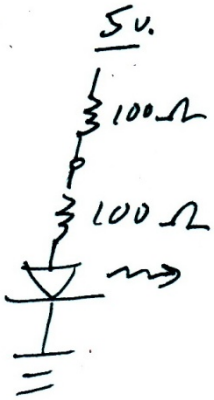
    a. Before you write the function because it forces you to plan out the function and allows others to know how to use it before it is even written.
    b. While you are writing the function because you now have an idea of how the function operates.
    c. After the function is complete because you now know what the function does, while you could not predict that while working on it.
    d. Never, it is unnecessary and ultimately a waste of time.

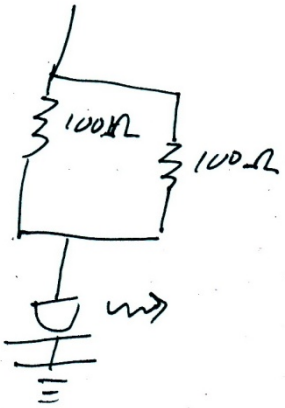
5) Using gears in a transmission, it is possible to:

    a. Increase mechanical power
    b. Increase mechanical torque
    c. Increase mechanical efficiency
    d. None of the above

6) In which circuit would the LED shine brightest?

a. 

b. 

c. 

d. All would shine at the same brightness

7) Which of the following fully specified robot operations requires the most powerful motors?

    a. Raising a load that weighs twice the robot's weight
    b. Pushing an identical, equal-weight robot across the field
    c. Driving the robot at 1 fps up a 30 degree slope
    d. Lifting your robot vertically at 1 fps

8) What is the purpose of a pullup resistor for a switch, whether it is built-in or the pin mode for and Arduino digital input is set to INPUT_PULLUP?

   a. To ensure a valid signal when the switch is open
   b. To limit the amount of current flowing through the switch
   c. To provide power to the switch
   d. None of the above

Part II

Instructions: Please take the time to answer the following questions. They will help us understand how you arrived at your answers and correlate accuracy with the presence of the eTextbook.

---

1. Have you ever had a class in robotics, participated in a robotics club such as FIRST, worked with robots in a workshop or summer camp, or worked with robots as a personal project prior to RBE1001?

   Yes **No**

2. Have you ever had a class with programming, participated in a programming, programmed in a workshop or summer camp, or programmed as a personal project prior to RBE1001?

   Yes **No**

3. Have you ever had an AP- or college-level physics class?

   Yes **No**

For each question in Part I, please list the source you based your answer from (lecture notes, eTextbook reading, eTextbook link/interactive element, educated or random guess, etc.).

1. Source: _____
2. Source: _____
3. Source: _____
4. Source: _____
5. Source: _____
6. Source: _____
7. Source: _____
8. Source: _____

RBE1001 Concept Quiz: Answers

---

1. A
2. C
3. B
4. A
5. B
6. C
7. D
8. A

Questions not covered by eTextbook				Questions covered by eTextbook						
#2 Correct	#4 Correct	#5 Correct	#6 Correct	#1 Correct	#3 Correct	#7 Correct	#8 Correct	# Non-ET Cor	# ET-Cor	Robotics?
n	n	y	n	y	n	y	n	1	2	y
y	y	y	y	y	y	n	y	4	3	y
n	y	n	n	n	n	n	n	1	0	y
y	y	y	n	n	y	y	y	3	3	y
y	y	y	y	y	y	n	n	4	2	y
n	y	y	n	y	y	n	n	2	2	y
n	y	n	y	y	y	n	n	2	2	n
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n	y	y	y	y	y	n	y	3	3	y
n	y	y	y	y	y	n	y	3	3	y
y	y	y	y	y	y	n	y	4	3	y

Correct:								Mean:		Yes:
16	36	32	25	31	33	9	18	2.86842105	2.39473684	23
Incorrect:								Median:		No:
22	2	6	13	7	5	29	20	3	2	15
								Mode:		
								4	2	

Ordering for Charts

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Correct:							
31	16	33	36	32	25	9	18
Incorrect:							
7	22	5	2	6	13	29	20

Source of Correct

Lecture:							
18	3	10	17	16	7	2	9
Guess:							
7	1	10	6	3	5	4	6
Experience:							
3	10	8	9	9	11	1	1
eTextbook:							
1	0	1	0	0	0	0	0
None:							
2	2	3	4	4	2	2	2

Source of Incorrect

Lecture:							
3	8	1	1	1	3	4	1
Guess:							
2	4	4	1	4	5	19	15
Experience:							
2	9	0	0	1	3	3	0
eTextbook:							
0	0	0	0	0	0	0	0
None:							
0	1	0	0	0	2	3	4

Programming?	Physics?	Source1	Source2	Source3	Source4	Source5	Source6	Source7	Source8
n	y	lecture	exp	lecture	lecture	lecture	exp	lecture	none
y	y	exp	exp	peer	guess	exp	exp	guess	lecture
n	n	lecture	lecture	guess	exp	exp	lecture	lecture	lecture
y	y	exp	exp	exp	none	none	none	none	none
y	n	lecture	exp	guess	lecture	exp	lecture	guess	guess
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y	y	lecture	exp	guess	lecture	guess	exp	guess	guess
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n	y	lecture	exp	guess	exp	exp	exp	guess	guess
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n	y	lecture	guess	lecture	lecture	lecture	guess	guess	guess
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y	y	exp	exp	exp	exp	exp	exp	none	none
y	y	guess	guess	guess	guess	guess	guess	guess	guess
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y	y	eTextbook	lecture	eTextbook	lecture	lecture	lecture	guess	guess
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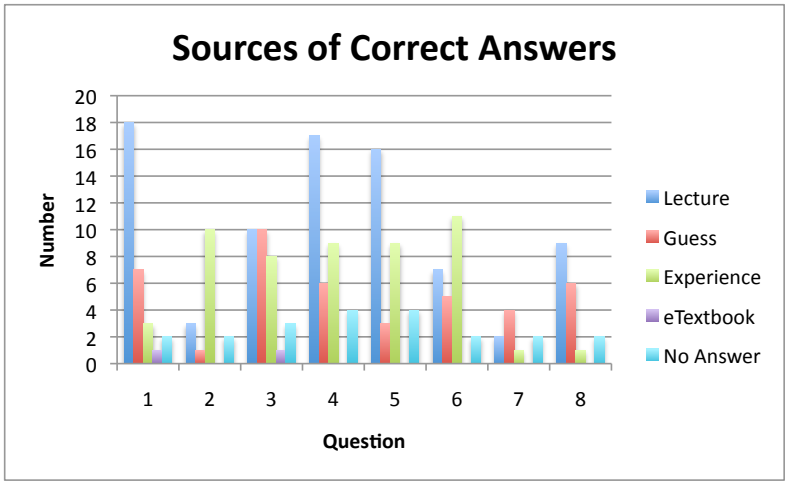
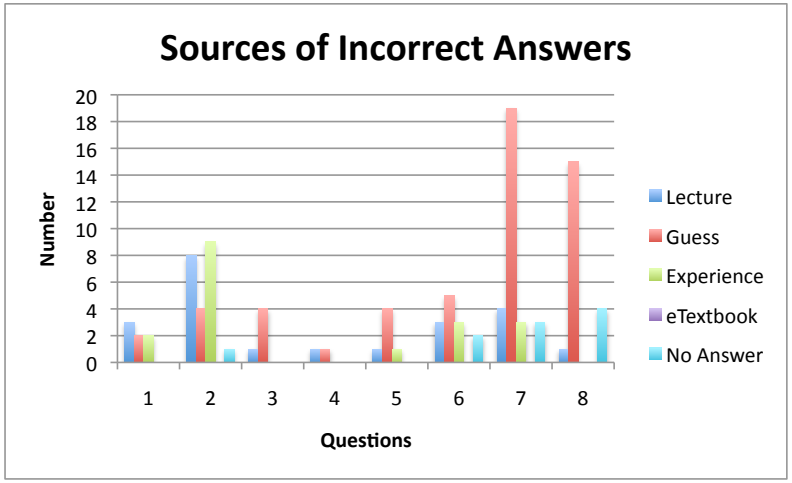
y	y	lecture	exp	exp	exp	lecture	exp	guess	guess
y	y	exp	exp	exp	exp	exp	exp	exp	guess

		Lecture:							
28	32	21	11	11	18	17	10	6	10
		Guess:							
10	6	9	5	14	7	7	10	23	21
		Experience:							
		5	19	8	9	10	14	4	1
		eTextbook:							
		1	0	1	0	0	0	0	0
		None:							
		2	3	3	4	4	4	5	6





Appendix F: eTextbook Sample Chapter

The following pages contain the sample chapter of the eTextbook produced by the project team for this study. Not all interactive features are operational in this file. As of now, a full version may be found at http://rbe1001.wpi.edu/chapter3/chapter3.pdf

Chapter 7:

DC Motors and Transmissions

Electric motors are one of the most common types of actuators found in robotics. Using them effectively will allow your robot to take action based on the direction given by its sensors and programming. Although there are many types of electric motors, this section will focus on the mechanics, mathematics, and proper use of DC permanent magnet, brushed motors. Commonly referred to as PMDC motors, they are a popular choice due to their small size and cost, and the fact that unlike many DC motors, powering them is as simple as connecting a constant voltage to the motor.

7.1: Basic Definitions and Concepts

A motor is an imperfect transducer . Motors are used to convert electrical power into mechanical power, in this case, a torque applied to the motor's output shaft . However, motors will also inevitably transform some of the given electrical power into thermal energy, heating up the motor instead of producing useful work.

Both power input and output can be measured in any unit of power, typically Watts. Power is the rate at which work is done. In mechanical terms, high power implies that not only is a load being moved with a great deal of speed, but continuing to move the load demands a great deal of force of a system. In terms of a rotating motor, power is calculated using the formula:

$$P = T * \omega * \text{Scale Factor}$$

For more on relationships between power, torque, and speed, return to transmissions.

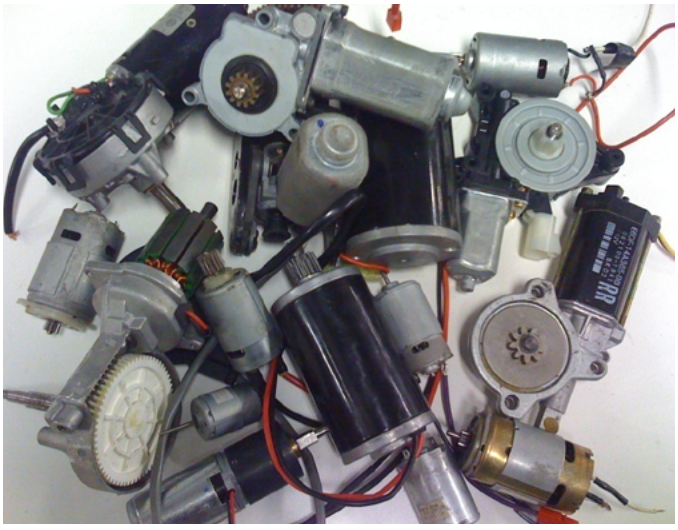


Figure 1: A number of sizes of Permanent Magnet DC motors.

Where T is the torque being output by the motor, ω is the angular velocity of the output, and the Scale Factor is used to correct for varied units. Some common scale factors are listed in the table here.

A key point to remember is that torque and velocity are equally important in the power formula. You could have X torque and Y speed, or Y torque and X speed, and get the exact same amount of power. If you ever had zero speed or zero torque, there would be no power.

Electrical power, also measured in Watts, is calculated using the formula P=IV, where I is electrical current in Amperes, and V is the motor's voltage. For example, a CIM motor that is drawing 40 amps while connected to a 12 volt supply is using 480 Watts of electrical power.

Motors are typically rated according to the mechanical power that they can output. If at the same time as this CIM motor draws 480 Watts of electrical power, it is spinning at 3800RPM and outputting 6.15 in*lbs of torque, it is outputting 275 Watts of power, based on the conversion factor for in*lbs and RPM to Watts found here.

Obviously a signifigant amount of power was lost in this process. Dividing power output by power input produces an important value for all motors called efficiency. Typically presented as a percent, efficiency tells you how much of the electrical power being input to the motor is actually being converted to useful mechanical power. The remaining power, in this case 205 Watts, is wasted as heat.

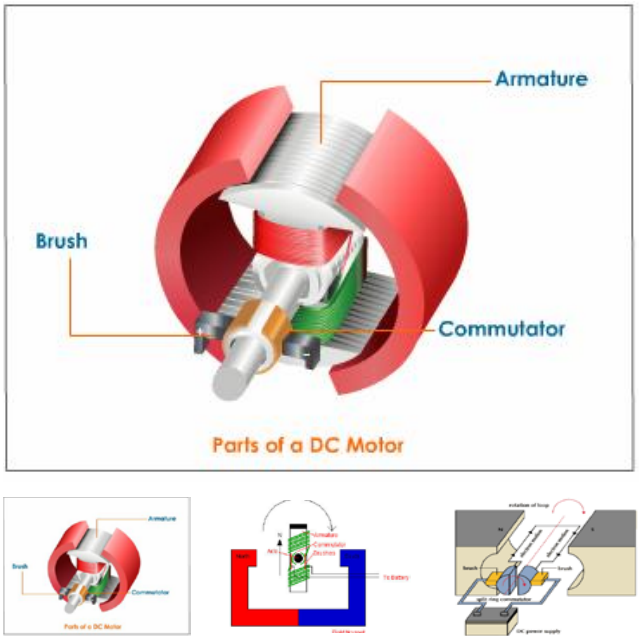


Figure 2: Three different visualizations of the inner workings of a PMDC motor

7.2: Internal Workings of a PMDC Motor

All electric motors use electromagnets to generate forces within the motor, creating rotation. In a PMDC motor, these electromagnets react with a pair of permanent magnets, created from naturally ferromagnetic materials, treated to permanently maintain their magnetic field.

A Permanent Magnet DC motor is divided into two main parts, the stationary stator, and the rotating armature. The permanent magnets are placed on opposite ends of the stator, with opposite poles facing inwards. In between these magnets lies the armature, mounted on bearings and connected to the output shaft of the motor. The armature consists of a metal core, typically iron, which will readily take on magnetic properties. The armature is wrapped in one or more copper coils. This combination serves as a powerful electromagnet when current is passed through the coils.

Imagine for a second energizing this electromagnet. The armature will take on the properties of a permanent magnet. Forces will be generated at each end of the armature, caused by attraction to one end of the stator, and opposing the other. This creates a couple moment , forcing the armature to turn. However, as can be seen in the slideshow, the armature will quickly reach a stable equilibrium position, where the forces do not generate a moment, and any disturbance in either direction will result in the armature being pulled back to this stationary position.

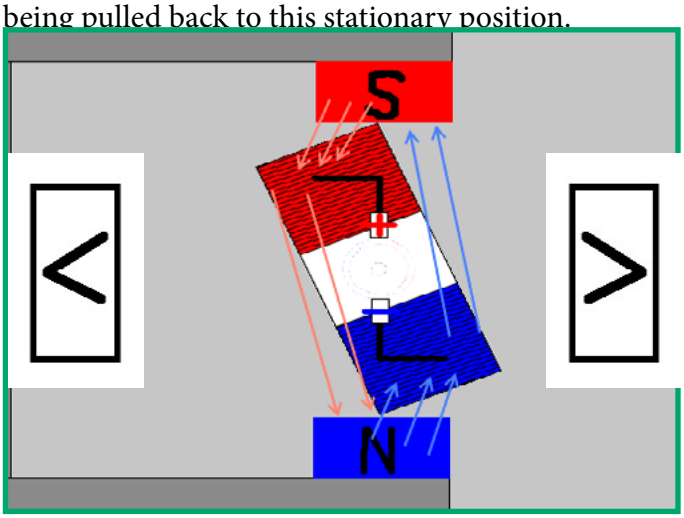
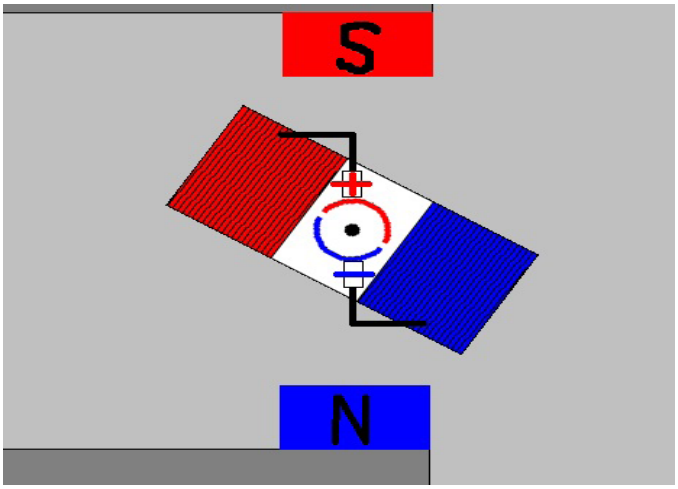


Figure 3: The armature is torqued by both permanent magnets

This problem is solved by a set of components called the Commutator and brushes. The commutator is typically represented as a pair of half-circle copper rings, with a small gap or piece of insulation between them. The brushes are metal strips or blocks which run along the outside surface of the commutator. The commutator rotates with the armature, and the brushes remain fixed to the stator. The coils of the armature are electrically connected to the commutator rings. Current is passed through the brushes, which is then transmitted to the armature though their contact with the commutator.

However, each time the commutator makes a half-rotation, the rings switch which brush they were in contact with (see this animated here). This has the effect of flipping the current flow in the armature. Inverting the direction of current also inverts the magnetic field generated by the armature. In the motor, the commutator is arranged such that this flip occurs just as the motor reaches the equilibrium position described above. But now, flipping the current will pull the armature through another 180 degrees of rotation. This cycle continues every half rotation, allowing the motor to continually rotate.



(*Click image to activate animation*)

Most motors have a slightly more complex inner structure. Instead of a simple two-pole armature and two segment commutator, larger motors in particular often have a commutator divided into many segments. This allows the magnetic field to switch its orientation many times throughout a single rotation, optimizing the application of force to the armature.

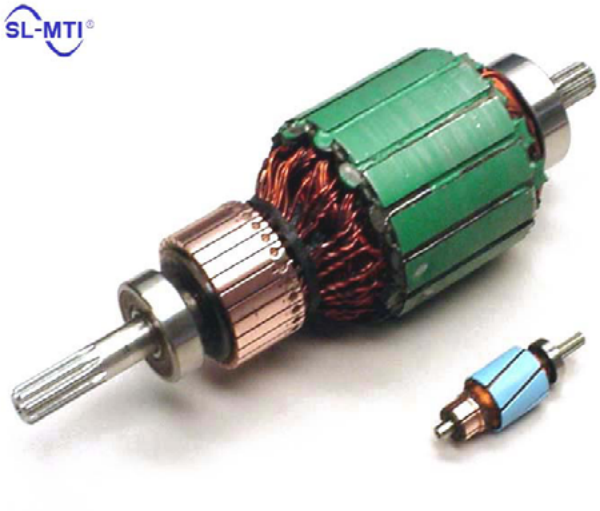


Figure 4: A few more realistic DC armatures, with multi-segment commutators. The brushes and permanent magnets are arrainged such that the magnetic force is always nearly perpendicular to the armature lever arm.

7.3: Basic Concepts Behind Motor Curves

In section 7.1, we discussed the nature of motors as a power transducer. Now, we'll look more in detail at how to get the most out of a PMDC motor.

Let's start with a straightforward concept. As the load which a motor must lift increases, the motor will slow down. Eventually, the load could reach such a high level that the motor completely stops, or stalls. However, the motor will struggle against this condition, and output the most torque it possibly can to attempt to break out of the stall. This maximum torque value is known as stall torque.

What happens on the other end of the spectrum, if the motor is allowed to free spin? This time, speed will be at its maximum. But torque, far from being constant, is effectively zero. The motor only needs to output enough torque to overcome wind resistance and internal friction, and as a result, no usable torque is produced at the shaft. In between, we will see the same pattern occur, speed being reduced as torque increases, and vice versa. Up until it reaches stall, the motor will only output enough torque to overcome external forces and rotate at a constant speed.

This relationship between torque and speed can be graphed. Since the external torque a motor will have to move is typically known, torque is usually used as the independent variable, with speed on the Y axis as the dependent varable. A typical torque-speed graph can be found in Figure 5. In a DC motor, the relationship is always linear. Other types of motors have a more complex relationship between output torque and output speed.

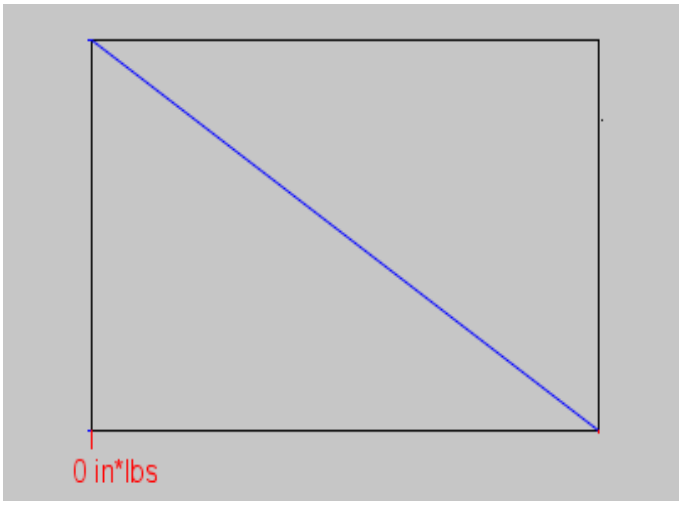


Figure 5: The inversely proportional relationship between speed and torque. The far left of the graph is free speed, the far right is stall

Other properties of electric motors discussed in section 7.1 vary with torque as well. A graph showing the speed, power, current draw, and efficiency of a motor as they relate to a changing output torque is known as a motor curve. An entire motor curve can be derived through four data points: free speed, free speed, current draw, stall torque, and stall current draw.

Based on your knowledge of mechanical power, transmissions, and the effect that increased load has on torque, try playing with the tool found here. Then, read about the details of motor curves, for further insight on the topic.

7.4: Building a Motor Curve

Using this data, we can set up our motor curve (shown in figure 6). Start with the X axis for torque, which will go from zero (at free speed) to the measured stall torque. Speed can be graphed next, a downwards linear curve moving from the measured free speed on the left, to zero at stall on the right.

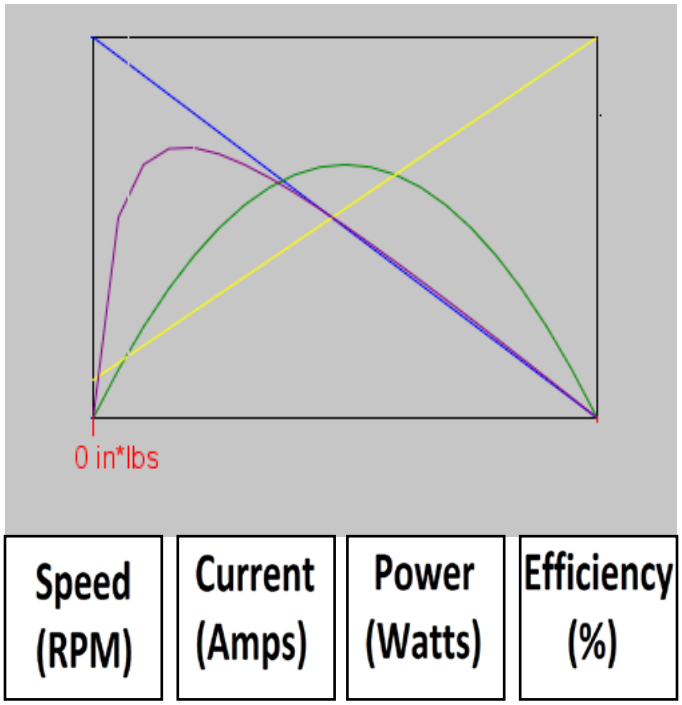


Figure 6: Complete motor curve. Click the frames below to isolate each part of the curve.

Current also shares a linear relationship with torque. The current measured at free speed should have been close to, but not quite, zero. This reflects the small amount of power required to overcome internal resistance of the motor. A much larger value should have been seen at stall. Draw a straight line between these two values.

Power comes next, and as discussed in section 7.1, is the product of torque, speed, and a scaling factor. Since torque is zero on one end of the graph, and speed is zero on the other, power will also approach zero at each end. Multiplying the functions for torque and speed together will create an inverted parabola, with a peak at exactly 50% torque.

Finally, efficiency can be graphed. It is calculated using the formula $Power_{OUT}/Power_{IN}$. Plugging in the formula P=IV for power in, multiplying the linear equation for current by the motor's voltage, and using the previously derived mechanical power formula, efficiency's curve can be graphed. It will typically appear as a skewed curve, with a peak at roughly 25% torque.

7.5: Interpreting a Motor Curve

A motor curve has four critical points on it: Free speed, peak efficiency, peak power, and stall. As has been discussed, free speed and stall are not particularly useful. Even though a motor is physically capable of putting out its free speed, it doesn't do you any good, because there is no torque, and therefore no power being produced there. And don't count on a motor to lift a load at it's stall torque, because it will do so with zero speed. Stall is actually a particularly dangerous position, because even though the motor is operating at 0% efficiency, it is drawing a tremendous amount of current, and therefore, using a huge amount of electrical power. Besides wasting power, this can be dangerous, because this power has to go somewhere. It is burned up in the form of heat, which can easily damage a motor. This is especially hazardous to smaller air cooled motors, which can smoke within seconds of being stalled.

Motors are often designed to operate near either peak power or peak efficiency. At peak efficiency, the greatest percentage of electrical power input to the motor is being converted into usable mechanical power. This is useful in an application where sustaining battery power is a high priority. At peak power, the motor is doing the most mechanical work it is capable of. If a robot is required to lift a specified load, operating the motor at peak power will lift this load the fastest.

Any level of power below peak power can be achieved in two ways: with high speed and low torque, or low speed and high torque. Generally, it is preferable to stay on the high speed, low torque side of the motor curve. This is because of efficiency, and it's skewed curve. Operating on this side of the curve will generally give you higher efficiency, and will always draw less current. And drawing less current reduces the likelihood of damaging your motor

7.6: Using Transmissions to Choose Where a Motor Operates

There was a lot of talk in the last section about choosing at what torque to operate a motor. How is this done?

The first, and most obvious way to do this, is by changing the load the motor lifts. Say you have a 1 foot long pivoting arm, that needs to lift 5 pounds. But your motor can only output four foot*pounds, even at stall. Reducing the weight being lifted down to two pounds would work, but this isn't always possible.

The better way to alter the torque that a motor "feels" is through using transmissions. Transmissions are another type of transducer, which alter the torque and speed characteristics of a device. Transmissions are represented using ratios. For example, a transmission with a 2.5:1 ratio will multiply the torque output by a motor by 2.5, while dividing the speed it outputs by 2.5. This means that a motor that previously output 2 foot*pounds of torque at peak power, now can output 5 foot*pounds, while still performing at peak power.

In order to determine the transmission ratio you need to use, use this formula:

Ratio = Desired Torque on Motor Curve * Transmittion Efficiency : Required torque

Included in Figure 7 is a tool which should help you get the feel for how transmissions affect a motor, and visualize how a motor behaves at different points on the motor curve. Experiment with different ratios and weights to develop an understanding of how they change the system's behavior.

This tool will also give you a targeted wattage to aim for. This is a typical design problem in many systems; the total mechanical wattage needed will be known, and the designer must set up the system in order to generate the correct amout of watts from the motor. If the desired wattage is below the motor's peak power, a larger motor must be used.

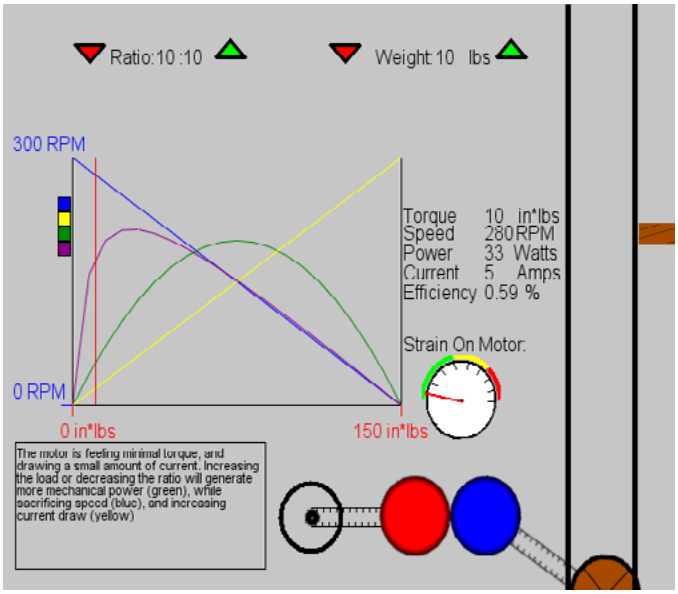


Figure 7: Click to activate the external motor curve simulation.

7.7: Formulae Used

Motor Power=T * ω * Scale Factor

Electrical Power = I*V

Motor Efficiency = $\text{Power}_{\text{OUT}}/\text{Power}_{\text{IN}}$

Ratio = Desired Torque on Motor Curve * Transmission efficiency : Required torque

7.8: Concept Check Questions

1. A battery powered handheld vacuum gets clogged with a piece of paper. The motor can be heard to suddenly increas in speed. How does this affect the motor's current draw?

Increase

Decrease

No Change

2. Changing a motor's voltage also affects performance. Cutting a motor's voltage in half will also reduce the motor's stall torque and free speed by half. If the motor's original peak power was P, what is its new peak power?