APPLETS IN SECONDARY MATHEMATICS CLASSROOMS: AN ANALYSIS OF THEIR USE AND IMPACT

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Abstract

The incorporation of technology in secondary mathematics classrooms is not a novel idea and, in today’s ever-advancing society, the means to do so are seemingly endless. One of the ways in which secondary mathematics teachers incorporate technology within their classrooms is through the use of applets. Applets can be defined as interactive, computer-based applications that perform a specific task. Through a series of interviews, this thesis investigates the implications behind using applets in secondary mathematics. Specifically, the author examines whether or not mathematical content area and academic designation affect the ways in which applets are used. The included group of secondary mathematics teachers’ perceptions of applets and the ways in which their use affects student understanding, motivation, engagement and interest are examined as well. Findings show that applets are used mostly for instruction and practice in algebra and calculus classrooms, perhaps due to the broad range of topics in algebra and the existence of more abstract concepts in calculus. The majority of teachers in the group hold a favorable view towards the use of applets, mostly because of their dynamic, visual, and interactive capabilities. Finally, the findings indicate that teachers perceive using applets to have noticeable and beneficial effects on student engagement. Overall, the implications and insights developed from this study can be valuable to secondary mathematics educators and also open the door for further research.
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Introduction

I believe mathematics education is an art form. The vast assortment of mathematical subject matter rivals the various media available to create a work of art. The range of learners at the hands of mathematics educators can be likened to the various artistic surfaces, from canvas to clay. Akin to the artists themselves, mathematics educators must be familiar with their medium and their surface—they must be aware of what is needed and what is ideal for creating a refined work of art from a blank canvas or ball of clay. In the sense of mathematics educators, this requires understanding how students learn and how to apply this information. In a 2001 book edited by Kilpatrick, Swafford, and Findell, the authors argue, “mathematical proficiency…is necessary for anyone to learn mathematics successfully” (p. 116). They claim that being mathematically proficient involves the development of five “interwoven and interdependent” strands (p. 116). These strands are conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition.

According to Kilpatrick, Swafford, and Findell (2001) conceptual understanding is a qualitative strand involving the comprehension of mathematical concepts. On the other hand, procedural fluency includes the efficiency and accuracy of carrying out mathematical procedures. Strategic competence is the ability to generate and execute solution methods for mathematical problems. Adaptive reasoning encompasses both the thought processes that go into generating solutions and the ability to justify a solution or process. Finally, productive disposition includes the ability to see and understand how mathematics is applied in real-world contexts, as well as an appreciation of the subject matter. Once a student has developed
sufficiently in each of these strands, we can say they are mathematically proficient or that they have successfully learned a certain mathematical concept. However, this merely gives us an understanding of the ends and leaves the means to personal interpretation.

In other words we have an idea of what our finished product will look like—we have an idea of how to tell if a student has successfully learned a mathematical concept—but how do we reach that point? What tools and strategies should we use to help develop mathematical proficiency and facilitate learning? James Hiebert and Diana Wearne (2003) offer three strategies to help develop mathematical understanding. These include allowing mathematics to be problematic for students, focusing on methods, and telling students the right things at the right times (Hiebert & Wearne, 2003).

Allowing mathematics to be problematic involves challenging students and presenting them with problems that are just beyond their abilities. In other words, it involves pushing students a bit beyond their comfort zones and encouraging them to think in different ways. This will inevitably lead to students seeking more assistance, but we are advised to tell them the right things at the right time and not give too much away. This allows students to do more self-exploration and discover concepts independently. Finally, the authors suggest it is important to focus on methods as students embark on these challenging problems. Considering all the solution methods to a problem can expand students’ thinking and promote self-discovery (Hiebert & Wearne, 2003).

If ideal strategies for reaching understanding in mathematics include allowing the mathematics to be problematic, focusing on methods, and telling students the right things at the right time, we are left to consider the tools best suited for implementing these strategies. In today’s modern and ever-advancing society, one answer lies in technology.
The incorporation of technology in mathematics classrooms is not a novel idea. In 1986, British mathematician Sir Michael Atiyah wrote, “Whereas the eighteenth and nineteenth centuries witnessed the gradual replacement of manual labor by machines, the late twentieth-century is seeing the mechanization of intellectual activities” (p. 43). The validity of this assertion has only increased in the past 28 years, as technology is now a principle feature in almost every secondary mathematics classroom across the globe. The National Council of Teachers of Mathematics (NCTM) states that technology is essential because it enhances mathematics learning and supports effective teaching (NCTM, 2000).

In other words, technology is an integral part of mathematics education, used to foster mathematical proficiency and help develop understanding. Because mathematical technology encompasses such a wide range of devices and programs, the focus of this paper will be on a much smaller scale. Specifically, this paper will concentrate on applets, where and how they are used, teachers’ perception of them, and their implications in student understanding, engagement, and motivation in secondary mathematics education. I chose applets because the research base is small compared to other mathematical technologies such as graphing calculators, SMART Boards, and computer algebra system (CAS) software. Further, from my experiences, I have seen that applets are used much less frequently than these aforementioned technologies so I wanted to learn more about their use.
Literature Review

Applets: Where and How They’re Used

Drawing from existing research (Daheer 2009; Healy, Berger, Romero, Aberson, & Saw, 2002) an applet will be defined as an interactive, computer-based application that performs a specific task. Daheer (2009) specifies that applets “require a WWW browser or other application to run” and that they “[usually] treat a specific topic” (p. 383). However, the author argues that applets typically represent scientific concepts (Daheer, 2009). On the other hand, Healy et al. (2002) focuses most on the interactive capabilities of applets, referring to them as “computer applications designed for the Internet” and claiming they are “among the most powerful and sophisticated ways of achieving online interactivity” (p. 1).

Due to the extremely varied nature of mathematics, there are many ways in which, and environments in which, applets can be utilized in mathematics education. I will use terms—information conveyor, manipulation aide, dual processor, answer giver, representation generator, technology as a puzzle, and motivation provider—found in Zbiek (2002) to describe the purposes that I believe could be served by each of the applets discussed. As Zbiek (2002) writes in her paper, a piece of technology is used as an information conveyor when it provides illustrations and/or information to students while a manipulation aide is part of a larger process wherein work is delegated to the piece of technology. She defines technology being used as a dual processor when a tool is used to solve a problem or explore a concept in multiple different ways, an answer giver as a tool that provides the solution to a given problem, and considers technology being used as a representation generator when it is used to create a visual depiction of a concept, idea, or example. Finally, Zbiek (2002) considers a tool being technology as a puzzle when it
generates results that are puzzling or intriguing to students and a motivation provider as a tool when used to produce visual representations and illustrations that serve to “inspire a concept, process, problem, lecture or lab” (p. 4).

As for the environments, I will describe the use of applets in various mathematical settings. One of these settings is within a statistics course. Applets have long been used in statistic courses, mostly because of the integral role data analysis plays in statistics (Godino, Ruiz, Roa, Pareja, & Recio, 2003). Applets can be used as a means for students to record sets of data, present them in different ways (graphs, tables, spreadsheets), and calculate their critical features (mean, median, and mode) (Godino et al., 2003). There are existing applets that can perform all of these tasks, while others are limited to only one or two of these capabilities. In all cases, these applets allow for the “discernment of patterns in data” which can help foster student understanding (Forster, 2006, p. 148).

It is apparent that applets are used for the organization, presentation, and analysis of data in statistic courses. Therefore, when applets are used in statistics to help illustrate statistical features and present information in various ways, they can be considered as technology used as representation generators and information conveyers. It has also become evident that using applets in self-discovery activities and during independent practice may be more beneficial than trying to utilize them for instruction in a statistics course. If statistical applets are given an instructional use, it is best to incorporate them into a discussion-based environment in order to maximize their potential (Forster, 2006).

Applets also prove to be extremely useful in problem-solving environments. The dynamic and interactive nature of most applets allows students to make discoveries through computerized trial and error. This facilitates students in finding multiple solutions to a single problem, thus
enhancing their understanding and placing a larger emphasis on methodology (Lee & Hollebrands, 2006). Therefore when we see applets being used to provide multiple solution methods in problem-solving settings, we would classify their purpose as a dual processor. Further, using an applet in problem-solving scenarios is only a part of the larger process, yet the piece of technology is still doing work. Thus, problem-solving applets used this way can be classified as manipulation aides. Direct manipulation and immediate feedback are also helpful problem-solving capabilities that applets can provide to students and other forms of technology and traditional paper-and-pencil methods cannot. In this sense, applets are being used as answer givers when they provide the user with an answer to a problem, regardless of whether the problem is provided by the applet or another source. Further, while mathematical problems can be solved without applets, it has been found that applets make the solution process faster, easier, and more enjoyable because of their direct manipulation and immediate feedback capabilities (Daher, 2009).

Another applicable environment for applets is within a geometry course. The very nature of geometry offers plenty of opportunities in which applets can be utilized. Specifically, geometry places a heavy influence on shapes, their properties, and transformations within the Cartesian plane. Certain applets can be incorporated into a geometry lesson to provide visual representations of these ideas, illustrate dynamic changes, and test hypotheses. This specific use of applets would fall under the purpose of representation generator because the applet is being used to provide visual illustrations and representations. Margaret Niess (2006) offers insight into the use of applets in a geometry course:

[Geometry applets] provide students with wide-ranging opportunities for mathematical exploration and sense-making. With these tools students are encouraged to make
mathematical conjectures and use the dynamic capabilities to visualize an idea under a
wide variety of situations. (p. 4).

Applets can also be used to generate numerous examples and practice problems for students in a
geometry course. Altogether, this allows educators in geometry classes to utilize applets with an
instructional purpose as well as a means of practice (Daher, 2009). Using applets as a means of
practice involves the technology providing problems for the students and commands to solve the
problems. In this sense of allowing the user to use the technology to solve problems, the applets
are being used as answer givers.

One last environment, but not the last environment, in which applets can be used is a
calculus course. The most common applets used in calculus settings are typically divided into
two categories—teacher centered and student centered (M. Hohenwarter, J. Hohenwarter, Kreis,
& Lavicza, 2008). Teacher centered applets are used with instruction in mind. They are dynamic,
flexible teaching tools that can most certainly be classified as information conveyers because
they provide factual information to students. Further, Hohenwarter et al. (2008) argue that
teacher centered applets rely heavily on visual representations and illustrations. This means they
can be considered representation generators and might serve also as motivation providers.
Student centered applets, on the other hand, are more investigative in nature. They too include
dynamic aspects, but are incorporated more in an exploration activity rather than being a means
of conveying information (Hohenwarter et al., 2008). Thus, student centered applets are used to
obtain results that can puzzle or intrigue students. Because of this, they can be considered
technology as a puzzle.

Taking a macro perspective, a careful examination of the existing literature shows applets
can be used in just about any mathematical environment. Within these environments, the purpose
of applets can be classified into three categories: concept illustrating applets, computational applets, and assessment applets (Kamthan, 1999). Concept illustrating applets are most commonly used during instruction or self-discovery activities and take full advantage of their dynamic, interactive, and visual representation capabilities in order to illustrate a mathematical idea in a way not possible via other means (Kamthan, 1999). Therefore, concept illustrating applets are most commonly used as representation generators.

Computational applets focus more on the “capability of user-interactive visualization…to facilitate experimentation by manipulating various parameters” (Kamthan, 1999, p. 6). In this sense, applets used as manipulation aides or as technology as a puzzle could fall under the umbrella of computational applets. Finally, we have assessment applets. Assessment applets utilize the user-interactive and instant feedback capabilities of applets in order to provide formative and/or summative measures of student understanding. Therefore, applets used as answer givers or dual processors could be considered assessment applets.

Regardless of where and how applets are incorporated within a secondary mathematics environment, there is no denying their many purposes and uses. Existing research also shows a number of advantages of using applets, which will be presented in the following section.

The Benefits and Advantages of Using Applets in Secondary Mathematics

Concept illustrating applets

As stated above, concept illustrating applets are often used for instructional purposes. This is because the dynamic and visual nature of applets allows teachers to present information
that is difficult to convey in a more traditional manner (Kamthan, 1999). For example, imagine a teacher giving a lesson on quadratics. Part of the discussion involves the effects the coefficients $a$, $b$, and $c$ have on the graph of functions of the form $f(x) = ax^2 + bx + c$. Using the applet found at http://www.mathopenref.com/quadraticexplorer.html, the instructor, or even the students, can manipulate the sliders to see the effects of $a$, $b$, and $c$ in real time (see Figure 1). While the instructor could talk about the effects of these coefficients and accompany the discussion with static visuals drawn on a chalkboard, the ability to observe the phenomena in a dynamic environment makes an applet a much more effective lecture aide (Healy et al., 2002).

![Figure 1. Example images from the quadratic function explorer applet](image)

Another advantage of using concept illustrating applets in mathematics environments is their ability to present multiple representations of the same concept (Godino et al., 2003). Exposing students to multiple representations of a mathematical idea allows them to build connections amongst the representations, which can support their understanding (Webb, Boswinkel, & Dekker, 2008). For example, as Godino et al. (2003) showed, the statistics applet found at http://www.nctm.org/standards/content.aspx?id=25042 allows students to not only
record and analyze data, but also view it in a spreadsheet, scatterplot, and bar graph (see Figure 2). By providing these varied representations, the applet allows the student to see the same data presented in three different ways. From here, connections amongst the representations can be made and students can develop a greater understanding of certain statistical properties such as range, mean, median, mode, and correlation (Godino et al., 2003).

![Figure 2. Multiple representations of collecting and examining weather data](image)

In their paper, Healy et al. (2002) provide an exceptional summary on the advantages and benefits of using concept illustrating applets in mathematics education:

Applets are designed to make abstract principles concrete. Among the cognitive benefits of this teaching approach is that the graphic and interactive presentation format enhances semantic elaboration, leading to better long-term retention of the material. Teaching in this manner also allows students to take control of their learning process, which is the hallmark of constructivist learning theory. In addition, applets allow students to go beyond simply learning about a theory to actually seeing its applications, which improves both procedural and declarative forms of knowledge. (p. 1)


**Computational applets**

For starters, it has been found that when visual cues are incorporated into a computational applet, inferences can be easily made, thus leading to further understanding of a mathematical concept (Forster, 2006). For example, Forster (2006) discusses a least squares regression activity that incorporates the use of a computational applet. The applet both computed the least squares regression and provided three different visualizations of the least squares regression residuals (Figure 3). These illustrations allowed students to understand the concept of a least squares regression better than if the applet had only computed the least squares regression (Forster, 2006). However, this is not the only way in which computational applets can help improve mathematical understanding. The literature shows that students view computational applets as “fostering, facilitating, and clarifying” when used in self-exploration or a problem-solving environment (Daheer, 2009, p. 194).

![Figure 3. Three different visualizations of the least squares regression residuals](image)

Computational applets have also been found to be extremely adaptable (Eason & Heath, 2004). This allows for an almost universal application of computational applets in mathematics education. Specifically when computational applets are used to “enhance the learning experience,” it has been found that this allows students to better discover fundamental
mathematical concepts (Eason & Heath, 2004, p. 94). Overall, the adaptability, interactivity, and variety of computational applets make some of them an ideal classroom tool for improving students’ understanding.

Assessment applets

One of the most important aspects of assessment applets is their ability to provide direct and immediate feedback (Heck, Boon, Bokhove, & Koolstra, 2007). This feedback allows students to see, and subsequently correct, their mistakes immediately after making them. This can lead to students discovering multiple solution methods and different strategies for solving a mathematical problem (Heck et al., 2007).

The variety of feedback is yet another benefit of some assessment applets (Mawata, 1998). For example, some applets may simply tell the student that they got the problem wrong. This allows the student to try the problem again, but with little to no guidance. Other applets may provide hints or clues to lead students in the direction of the correct answer. Lastly, some applets may tell the students they obtained the wrong answer as well as why that answer is wrong and what the correct answer is (see Figure 4). These different types of feedback allow students to either develop their understanding through trial and error on their own or with the scaffolding of the applet (Mawata, 1998). For example, the feedback provided in Figure 4 assists the student in understanding why the angle is acute. In this particular instance, the user is told the correct answer as well as why it is the correct answer. This corrective and informative feedback can be much more beneficial for the student’s understanding than if the applet simply showed, “Incorrect. Please try again” (Mawata, 1998). Whatever the case may be, the variety of direct
and immediate feedback provided by assessment applets allows students a chance enhance their mathematical understanding.

The literature also shows that using applets for assessment allows for a much greater range of questions when compared to traditional paper-and-pencil forms of assessment, which can lead to an increase in students’ confidence (Kamthan, 1999). For example, by using an applet, it is possible to give students an assessment that requires them to answer various types of questions including multiple choice, short answer, identifying parts of a graph, comparing representations, and manipulating an illustration. Pairing these different types of questions with direct and immediate feedback can develop students’ proficiency in a number of areas, thus increasing their confidence (Kamthan, 1999).

Because of the possibility of increased confidence, it may be beneficial to use assessment applets as study tools to prepare students for examinations. This practice has been shown to be both a more effective and more enjoyable means of preparing for written exams (Heck et al., 2007). Further, it is argued that “digital assessments…add to the motivation and
performance of students in mathematics education” and most assessment applets can certainly be considered a form of digital assessment (Heck et al., 2007, p. 18). Therefore, assessment applets can help increase confidence, motivation, and performance amongst students. Without a doubt, the benefits and advantages of using assessment applets in secondary mathematics education are numerous.

In addition to the various benefits and advantages of using concept illustrating, computational, and assessment applets in secondary mathematics education, there are a few advantages that can be ideally attributed to all applets. For one, all applets can be accessed anywhere with an internet connection and a compatible device. Thus, applets that are used in class can be further utilized by students at home or at a local library. Secondly, almost every applet is tailored. This allows educators a plethora of applets to choose from for any given lesson. Finally, applets may be helpful in working with students with disabilities, a notion that could be useful for special education teachers (Suh & Moyer-Packenham, 2008; Daheer, 2009).

**Research Questions**

After examining the existing literature, it is clear a few unanswered questions remain. It is unclear as to whether or not the mathematical environment in which applets are being used influences the use(s) of the applets. In other words, the first research question guiding this study is, “Do different mathematical content areas warrant different uses of applets?” The literature briefly touches upon this notion, but there is much more to be discovered. Further, it is left unclear as to whether or not different academic designations (e.g. special education (SPLED), grade level, honors, advanced placement (AP)) influence the way applets are utilized in
secondary mathematics classrooms. Therefore, the second research question guiding this study is, “Do different academic designations warrant different uses of applets?” This study also looks to determine teachers’ perceptions towards applets as well as towards the influence applets have on student understanding, motivation, and engagement. Thus, the final research questions to be considered are, “What are secondary mathematics teachers’ perceptions of applets? Do they perceive applets having any effects on student understanding, motivation, and engagement?”

These questions are important because they can be beneficial to both students and teachers. For example, if my research illustrates the perception that applets are used more as a means of formative assessment in SPLED classrooms, and that this use improves upon traditional methods of assessment, then teachers of students with disabilities can adopt these practices. In other words, the current research could act as a reference for teachers. The current research can also provide us with useful information for students. For instance, if applets are used mostly as representation generators in geometry classes and further studies indicate this is better for students’ understanding than traditional representations, then geometry teachers can use applets as an instructional tool to better facilitate their students’ learning. In order to investigate the answers to these research questions, the methods needed to complete this research must first be considered.
Methods

Materials

The primary means of data collection was a phone interview. Each interview lasted about 20 to 30 minutes. To conduct each interview, I followed an interview protocol (see Appendix A). The interview protocol acted, in essence, as a script to guide each interview. The protocol included an introduction, background questions, and questions regarding the participant’s use of applets. I prepared the background questions in order to better understand the characteristics of the participants and I designed the questions regarding the use of applets in such a way that they could be answered regardless of whether or not the participant uses or has used applets. These questions were meant to gather information on each participant’s use of applets as well as any noticeable effects on student understanding, motivation, and engagement. No other interview protocols or research studies were referenced in the construction of the interview protocol.

Recruitment

In order to begin recruiting participants for my study, I contacted Penn State Mathematics Education faculty members who could help put me in touch with secondary mathematics teachers. This led to me collaborating with my Honors Advisor as well as three student teaching supervisors. These supervisors are responsible for coordinating student teaching placements in the Philadelphia, Pittsburgh, and Central Pennsylvania Regions. Each supervisor, responsible for
one of the aforementioned regions, provided me with the names and e-mail addresses of several secondary mathematics teachers who they believed might be interested in participating in my research. I contacted each teacher once or twice via e-mail, asking if they were in fact interested in participating in a research study on the use of applets in secondary mathematics classrooms. Due to the varied times in which I received these names and e-mail addresses, I contacted potential participants in two separate rounds.

I sent the same recruitment e-mail to each potential participant in round one (see Appendix B). The e-mail briefly described the study and what would be expected of them should they choose to participate. In the first round, I sent e-mails to 26 teachers, eight of whom responded. Of the eight who responded, six agreed to participate in the study and two opted out. In the second round, I sent the same recruitment e-mail to 38 new teachers. I also sent follow-up e-mails from an alternate e-mail address to the 18 teachers from round one who did not respond. The follow-up e-mails were the same as the original recruitment e-mails, but with an added note saying that it was my second time contacting them. I sent these follow-up e-mails from an alternate address in case e-mails from the original address were automatically spammed or deleted. After round two, 22 of the 38 teachers responded, 17 agreed to participate and five opted out of the study. None of the teachers from round one responded to the follow-up e-mail. Similarly, the 16 teachers from round two who did not respond to the original e-mail also did not respond to a follow-up e-mail. In total, I contacted 64 different secondary mathematics teachers, of which 23 replied to the original e-mail and agreed to participate in the study, seven replied to the original e-mail but opted out of the study, and 34 never responded. Needless to say, a large number of potential participants never responded to any of the e-mails. Due to time constraints, I
chose to move on and use a group of 23 secondary mathematics teachers. A concise summary of the recruitment process can be seen below in Table 1.

### Table 1

<table>
<thead>
<tr>
<th>Round</th>
<th># of Teachers Contacted</th>
<th># of Teachers who Responded</th>
<th>% of Teachers who Responded</th>
<th># of Teachers who Participated</th>
<th>% of Teachers who Participated</th>
<th># of Teachers who Did Not Respond</th>
<th>% of Teachers who Did Not Respond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1</td>
<td>26</td>
<td>8</td>
<td>31%</td>
<td>6</td>
<td>23%</td>
<td>18</td>
<td>69%</td>
</tr>
<tr>
<td>Round 2</td>
<td>38</td>
<td>22</td>
<td>58%</td>
<td>17</td>
<td>45%</td>
<td>16</td>
<td>42%</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>30</td>
<td>47%</td>
<td>23</td>
<td>36%</td>
<td>34</td>
<td>53%</td>
</tr>
</tbody>
</table>

Finally, I sent another e-mail to each of the 23 participants in order to accomplish three things—obtain permission from a department head or administrator to perform academic research within their school, acquire informed consent from the participant, and schedule a time to conduct the interview. The follow up e-mail requesting permission to conduct research can be found in Appendix C and the informed consent form can be found in Appendix D.

### Participants

The secondary mathematics teachers participating in this study could do so whether or not they used applets. Of the 23 people who participated in the study, 17 currently use applets in their classrooms. Furthermore, of the six people who do not use applets in their classroom, one used to use applets. This participant stopped using applets because they believe applets are “difficult to learn” and “not user friendly”. In total, 18 of the 23 (78%) participants use or have
used applets in their secondary mathematics classrooms while 5 of the 23 (22%) participants have never used applets.

I also asked each participant to report what courses they currently teach. Specifically, I asked, “What courses do you currently teach?” Fourteen of the 23 participants (61%) reported teaching in multiple mathematical content areas. Altogether, I classified participants’ responses into seven different content areas. These consisted of algebra, general math, geometry, keystone math, calculus, statistics and probability, and computer science. For this study, algebra includes Pre-Algebra, Algebra I, and Algebra II and general math is defined as an amalgamation of content students should understand at their grade level. Keystone math is defined as a course tailored specifically for students who have yet to pass the mathematics Keystone Exams, a standardized test administered in Pennsylvania to assess proficiency in algebra. Finally, the content area calculus includes Pre-Calculus, Trigonometry, and Advanced Placement Calculus AB or BC. Of the 23 participants, 20 teach algebra, four teach general math, five teach geometry, two teach keystone math, five teach calculus, one teaches statistics and probability and one teaches computer science. This breakdown appears below in Table 2.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breakdown of Participants by Mathematical Content Area</strong></td>
</tr>
<tr>
<td><strong>Number of Participants</strong></td>
</tr>
<tr>
<td>Algebra</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Number of Participants</td>
</tr>
<tr>
<td>Percent of Participants</td>
</tr>
</tbody>
</table>

The same question, “What courses do you currently teach?” was also used to determine the academic designation in which each participant teaches. Fourteen of the 23 participants
(61%) reported they teach in multiple designations. Further, their responses fell within four different designations. These consisted of remedial, grade level, honors, and Advanced Placement (AP). The remedial designation is used to indicate a course that is taught at an academic level lower than the grade level in which it is taught, whereas grade level refers to a course where the academic level coincides with the grade level. The honors designation denotes courses that are advanced for their grade level while the AP designation represents a college-level curriculum. Of the 23 participants, a total of 14 teach in a remedial setting, 16 teach at grade level, nine teach in an honors setting and one teaches an AP course. This breakdown appears in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Breakdown of Participants by Academic Designation</th>
<th>Remedial</th>
<th>Grade Level</th>
<th>Honors</th>
<th>Advanced Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Participants</td>
<td>14</td>
<td>16</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Percent of Participants</td>
<td>61%</td>
<td>70%</td>
<td>39%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Analysis

Once I completed the interviews, I compacted and summarized the data from the 23 participants into a single spreadsheet. By this I mean I used the multiple-page transcript from each interview, extracted the most important details, and organized them in a single Microsoft Excel file. To determine the most important details, I cross-referenced my research questions with the transcript of each interview. Specifically, I focused on each research question individually in order to determine which questions from the interview would elicit the most
pertinent responses that I could use to answer each research question. I summarized the responses into a few key words and phrases in order to keep the spreadsheet informative and concise.

First, I focused on the influence the mathematical content area may have on the use of applets. I decided the most applicable interview questions to help answer this research question include “What courses do you currently teach?” “Do you use applets in any of your classes?” “What do you use them for?” and “Why do you use them?” Using the responses to these questions, I believed I would be able to see what each teacher uses applets for and from there I could see if it had any relation to the content area in which they teach. I used the same four questions to address the second research question; whether or not academic designation has any influence on how applets are used. I used the same questions because when the participants responded to the question, “What courses do you currently teach?” they listed both the content area and designation. Akin to the research question concerned with content area, I believed these four questions would allow me to see any relationships between how teachers use applets and the designation in which they teach.

Since the majority of teachers (61%) teach in more than one mathematical content area and academic designation, I asked participants to be as specific as possible during the interviews. For example, if a participant taught in both a remedial and grade level setting and reported using applets for instructional purposes, I asked them to specify in which designation they used the applets for instructional purposes. Sometimes their responses applied to only one content area or designation while other times responses applied to multiple environments. This emphasis on specificity allowed me to better classify and analyze responses according to content area and designation.
Finally, the third research question is concerned with teachers’ perceptions of applets themselves as well their perceived effects on student understanding, motivation, and engagement. I decided the most helpful interview questions to answer this research question include “What do you like about applets themselves?” “Are there things you dislike?” “How would you compare using applets to these types of technology?” and “Have you seen any effects on student understanding, motivation, and/or engagement that you would attribute to your use of applets?” The responses to these questions gave me insight into how teachers feel about applets and their perceived effects on student understanding, motivation and engagement.

After choosing the most important questions I began focusing on the responses to these questions. I read through the responses to each of these questions for each participant and summarized them into a few key words and phrases that conveyed the most important information. I put these summarized responses into the Excel file organized according to participants. What resulted was a 24 x 8 spreadsheet containing what I believed to be the most important data for answering my research questions, all organized in a concise and orderly manner. I summarized each participant’s responses using eight areas. These included Participant, Academic Designation, Mathematical Content Area, Use Applets?, Use(s), Advantages, Disadvantages, and Effect(s) on Students.

The Participant category is simply a number to classify each participant. I determined Academic Designation and Mathematical Content Area from the question “What courses do you currently teach?” while Use Applets? was determined based off the question “Do you use applets in any of your classes?” I clarified the category Use(s) via responses to the question “What do you use them for?” Again, I asked participants who teach in multiple content areas or designations to specify the environment in which their reported uses are found. I summarized
responses to this question into a few key words, and then classified each response according to five categories. These categories included Provide Practice, Illustrate Relationships, Assessment, Present/Reinforce/Review Concepts for Instruction, and Visual Representations of Abstract Concepts. I chose these categories because they corresponded to the most common responses and they allowed me to categorize every participant’s response. For example, one participant noted using applets to “graph and compare functions to show relationships...[and] to give additional practice.” Therefore, I listed Illustrate Relationships and Provide Practice for this participant’s uses. Of the 18 teachers who use or have used applets, 15 reported uses that fell into two or more categories. Another participant reported using applets to “introduce a lesson or review a concept.” As a result, I listed Present/Reinforce/Review Concepts for Instruction for this participant.

I placed responses to “Why do you use them?” in the Advantages category because most participants spoke about the advantages of applets when asked this question. I also placed responses to “What do you like about applets themselves?” and “How would you compare using applets to these types of technology?” in the Advantages category. I classified the responses to these questions using seven categories, Differentiation of Instruction, Interactivity, Dynamic Nature, Appeal to Students, Immediate Feedback, Individualized Nature and Easy to Use. Again, these were the most common responses and they allowed me to categorize every participant’s response. I used the question “What do you dislike about applets themselves?” to determine the Disadvantages category. I classified the responses to this question using six categories, None, Technical Issues, Gaming Focus, Can’t Choose Problems, Not User Friendly, and Hard to Come By. Again, these were the most common responses and they allowed me to categorize every participant’s response. Finally, the Effect(s) on Students category utilized responses to “Have
you seen any effects on student understanding, motivation, and/or engagement that you would attribute to your use of applets?” A few examples of spreadsheet entries can be seen in Table 4. These entries were chosen to show variety in as many categories as possible.

Table 4

<table>
<thead>
<tr>
<th>Participant</th>
<th>Academic Designation</th>
<th>Mathematical Content Area</th>
<th>Use Applets?</th>
<th>Use(s)</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Effect(s) on Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Remedial</td>
<td>Algebra</td>
<td>Yes</td>
<td>Provide practice, reinforce concepts</td>
<td>Individualized, engages students, Interactivity, dynamic representations</td>
<td>Technical Issues</td>
<td>Increased engagement and interest</td>
</tr>
<tr>
<td>15</td>
<td>Remedial</td>
<td>Algebra</td>
<td>Yes</td>
<td>Provide practice</td>
<td>Visual representations, reinforce concepts</td>
<td>Gaming focus</td>
<td>Increased engagement</td>
</tr>
<tr>
<td>21</td>
<td>Grade level, Remedial</td>
<td>Algebra</td>
<td>No, but used to</td>
<td>Visual representations, reinforce concepts</td>
<td>Dynamic nature, interactivity</td>
<td>Hard to learn, not user-friendly</td>
<td>Increased interest and understanding</td>
</tr>
</tbody>
</table>

Condensing the data into a single spreadsheet allowed me to analyze it much easier than in the form of lengthy interview transcripts. Because of the rather small group of participants, it proved unreasonable to perform a statistical analysis. Rather, I examined the interview data for common themes and possible relationships. This allowed me to make conjectures and inferences that could help answer each research question.

The first of these research questions was concerned with whether or not the mathematical content area in which the applets are used has an influence on the use of the applets. First, I had to determine which teachers use or have used applets, as these are the only participants who can be considered for this research question. Of the 20 algebra teachers, 14 currently use applets, one used to, and five do not. Further, three of the four general math teachers and four of the five
geometry teachers currently use applets. Finally, all of the keystone, calculus, statistics and probability and computer science teachers use applets.

To answer this research question, I examined the entries in the Use(s) column of the spreadsheet according to mathematical content area. This examination was the same for all content areas. For example, I took note of the reported uses of every algebra teacher, and then every general math teacher, and so on. The majority, about 78% (14 of 18), of teachers who use or have used applets reported multiple uses. I recorded and analyzed these uses in order to determine the most common responses across all content areas. This resulted in five categories of use. These categories include Provide Practice, Illustrate Relationships, Assessment, Present/Reinforce/Review Concepts for Instruction, and Provide Visual Representations of Abstract Concepts. I recorded and observed the frequency of each reported use for each content area. Specifically, I considered it significant if at least 50% of teachers in a specific content area reported the same use. I believed this to be the most promising indicator of an existing relationship. I included data from this analysis in the Results section only if it was reported by three or more participants in a given content area. This allowed me to account for content areas with less than five participants.

The second research question looked to determine whether or not the academic designation in which applets are used influences the use of the applets. Logically, a process similar to that just described was used to investigate this research question. Specifically, I examined the entries in the Use(s) column of the spreadsheet according to designation and this examination was the same for all designations. For example, I took note of the reported uses of every remedial teacher, and then every grade level teacher, and so on. I classified the responses using the same five categories listed above as these were, again, the most commonly reported. I
observed and recorded the frequency of each reported use for each designation. Specifically, I considered it significant if at least 50% of teachers in a specific designation reported the same use. I believed this to be the most promising antecedent of an existing relationship. I included data from this analysis in the Results section only if it was reported by three or more participants in a given designation.

To determine teachers’ perceptions towards applets, I focused on the entries in the Advantages and Disadvantages columns of the spreadsheet. Initially, I examined these responses on a whole group basis, that is, I did not analyze the responses according to mathematical content area or academic designation. I simply examined the responses as a group of 23 participants. I noted whether participants listed more advantages or disadvantages of using applets as well as what the most commonly reported advantages and disadvantages were. Later, I examined whether or not there were any existing trends between these responses and the different content area and designation of each response. For the purposes of this study, more than 50% of participants in a given content area or designation reporting the same advantage or disadvantage constituted a trend. For example, it would be noteworthy if every general math teacher listed more disadvantages than advantages or if 80% of remedial teachers reported differentiation of instruction as an advantage of using applets. I believed this data helped in better understanding teachers’ perceptions towards applets.

Finally, I was concerned with whether or not teachers indicated applets affecting student understanding, motivation, and engagement. To help answer this question, I examined the entries in the Effect(s) on Students column of the spreadsheet, as this was where I recorded whether or not teachers reported any noticeable effects on student understanding, motivation and engagement. I recorded their responses based on whether the participant noted effects on
understanding, motivation, engagement, any combination of categories, or no categories. Specifically, participants had to report noticing an increase and give some sort of evidence in their response. For example if a teacher stated, “Whenever I use applets there is an increase in motivation. Students typically get twice the amount of practice problems done using the applet compared to worksheets” I classified it as a participant noting positive effects on student motivation. Later, I examined whether or not there were any existing trends between this data and the different mathematical content areas and academic designations. For instance, it would be noteworthy none of the grade level teachers noted increases in student motivation or if every algebra teacher reported an increase in student understanding. The results of these analyses are presented in the following section.
Results

Applet Use By Mathematical Content Area

As mentioned in the previous section, I recorded and analyzed participants’ responses to the question “What do you use them [applets] for?” according to mathematical content area. Of the 18 teachers who use or have used applets, 15 reported more than one use. Specifically, ten participants listed two uses while five reported three uses. For the purposes of this study, I decided to include data only if it was reported by at least three participants in a given content area, as anything less is trivial for this analysis. I chose three as the determining value rather arbitrarily. The analysis began with the algebra teachers. Of the 15 algebra teachers who use or have used applets, eight of them reported using applets to Provide Practice, three reported using applets for Assessment, 13 reported using applets to Present/Reinforce/Review Concepts for Instruction, and four reported using applets for Visual Representations of Abstract Concepts. This shows us that participants’ use of applets in algebra courses was fairly varied, but mostly tended towards instructional purposes.

Further analysis showed that all three general math teachers who use applets used them to Present/Reinforce/Review Concepts for Instruction. Of the four geometry teachers, three reported using applets to Present/Reinforce/Review Concepts for Instruction. Lastly, the responses from the calculus teachers were varied as well. All five reported using applets to Present/Reinforce/Review Concepts for Instruction while only three calculus teachers reported
using applets to Provide Practice. The results of this entire analysis can be seen below in Figure 5.

![Figure 5. Number of teachers reporting applet use mathematical by content area](image)

**Applet Use By Academic Designation**

The next analysis examined the use of applets according to the academic designation in which they were used. This examination used the same five categories of use as the analysis amongst mathematical content area. Further, I included reported uses in the analysis only if they were reported by at least three participants in a given designation. Anything less was deemed trivial. Again, this decision was made rather arbitrarily. Overall, this examination produced some interesting results. The analysis showed that 13 of the 14 participants who teach in a remedial
setting use or have used applets. Of these 13 teachers, 11 reported using applets to Present/Reinforce/Review Concepts for Instruction and eight reported using them to Provide Practice. Finally, three remedial teachers noted that they used applets for Visual Representation of Abstract Concepts.

This analysis continued by looking at the grade level teachers, or the participants who teach a course where the academic level coincides with the grade level. Of the 16 participants teaching in this academic designation, 12 use or have used applets. All but one of these teachers used applets to Present/Reinforce/Review Concepts for Instruction while five of them used applets to Provide Practice. Finally, four of the grade level teachers reported using applets for Visual Representation of Abstract Concepts. From here the analysis moved to the honors teachers. There were nine total honors teachers in this study and six of them reported that they used applets. Five of these six participants noted using applets to Present/Reinforce/Review Concepts for Instruction and three honors teachers used applets to Provide Practice. The results of this analysis can be seen below in Figure 6.

![Figure 6. Number of teachers reporting applet use by academic designation](image-url)
Participants’ Perception of Applets

To determine participants’ perception of applets, I decided the most helpful interview questions include “What do you like about applets themselves?” “Are there things you dislike?” and “How would you compare using applets to these types of technology?” I believe that my participants view the advantages of applets as outweighing the disadvantages. This was because of the 23 total participants, 10 reported no disadvantages and 15 reported multiple advantages. I then categorized the reported advantages and disadvantages according to frequency.

After reviewing the advantages, four responses emerged as the most common while three were reported much less often. The most commonly reported advantages of using applets included their dynamic nature, appeal to students, interactivity, and ability to be used to differentiate instruction. The less common advantages included immediate feedback, individualized nature, and their ease in use. Of the 23 total participants, eight listed differentiation of instruction as an advantage, seven listed interactivity, six listed dynamic nature, and three listed appeal to students. Furthermore, two participants listed immediate feedback and individualized nature as advantages while only one reported that applets are easy to use. These results can be seen in Figure 7.
I then analyzed the reported advantages according to mathematical content area and academic designation. I did not notice any major trends when analyzing the advantages by content area. However, looking at these results with designation in mind produced some interesting findings. Of the remedial teachers, 62% listed the ability to differentiate instruction as an advantage of using applets. This was a much greater percentage than any other designation as only 19% of grade level teachers and 11% of honors teachers mentioned the differentiation of instruction as an advantage of applets (the lone Advanced Placement teacher, however, did report this as an advantage). This result corresponds to the fact that the most commonly reported uses of applets amongst remedial teachers were to Present/Reinforce/Review Concepts for Instruction and to Provide Practice. The implications of this finding will be discussed in the Discussion.
I also analyzed the reported disadvantages. Three different disadvantages were commonly reported, and three were not. The most common response was that there were no disadvantages of using applets, which 10 of the 23 participants noted. Beyond this, there were five participants who noted technical issues as a disadvantage and four who noted that there is too much focus on the gaming aspect and not enough focus on rigor. The remaining disadvantages were reported much less often. Only two participants disliked the fact that the teacher cannot choose the problems used within applets. Further, one participant recorded that good applets are hard to come by while another said they are not user friendly. These results can be seen below in Figure 8.

From here, I analyzed the disadvantages according to mathematical content area and academic designation. I did not notice any trends when analyzing the disadvantages by designation. On the other hand, the most noteworthy occurrence was that all 10 participants who reported no disadvantages of using applets were either algebra or calculus teachers. As noted, the most commonly reported uses amongst algebra and calculus teachers were to Provide Practice.
and Present/Reinforce/Review Concepts for Instruction. The implications of this finding will be discussed in the following section.

**Effect on Student Understanding, Motivation, Engagement and Interest**

Finally, the focus shifted to the ways in which teachers perceived using applets to affect students. Originally, this analysis was only supposed to include student understanding, motivation and engagement, but a fourth category, interest, was later added. This was because a large number of participants reported noteworthy effects on student interest, and interest was deemed something different from engagement. Further, while I believe interest plays an important role in motivation, I also believe you can be motivated to do something you are not interested in and that you can be interested in a task but not motivated to complete it. The results were fairly interesting, especially when analyzed according to mathematical content area and academic designation.

Of the 18 teachers who use or have used applets, 11 noted positive effects on student engagement. In other words, 11 participants saw an increase in student engagement levels whenever applets were included in a lesson. Further, eight participants reported an increase in student interest, seven said they noticed an increase in student understanding and four participants reported an increase in student motivation when using applets. When the analysis progressed to mathematical content area and academic designation, it was evident that these effects were most prominent in remedial and algebra classrooms. Specifically, I looked at all of the teachers who reported positive effects on student understanding and took note of their content
area and designation. I then did the same thing for student motivation, engagement, and interest. I then used this information to look for any noticeable trends.

First, consider the participants who reported applets exhibiting benefits for student understanding. Eighty-six percent of these participants were algebra teachers and 71% of which taught in remedial settings. Furthermore, 75% of the participants who noted an increase in student motivation when using applets came from remedial algebra environments. As for participants reporting positive effects on student interest, 88% came from remedial algebra classrooms. Finally, 73% of participants who noted increases in student engagement came from remedial environment while 91% of these participants were algebra teachers. These findings will be further discussed in the following section.
Discussion

The goal of my study is to answer a number of questions regarding the use of applets in secondary mathematics classrooms. Specifically, do different mathematical content areas warrant different uses of the applets? Do different academic designations (e.g. remedial, grade level, honors, AP) have any influence on the use of applets? I also examined teachers’ perceptions of applets and their effects on students. Namely, what are secondary mathematics teachers’ perceptions of applets? What are their advantages and disadvantages? Have they noticed any observable effects the use of applets may have on student understanding, motivation, engagement and interest? The findings related to each of these research questions, and more, will be discussed in this chapter.

The Influence of Environment

In order to determine the influence of mathematical content area and academic designation, I asked participants to report on the ways in which they use applets in their secondary mathematics classrooms. In my study, the influence of most mathematical content areas is negligible except for algebra and calculus. The keystone math teachers did not report any use of applets more than twice, and the only time either the general math or geometry teachers were represented in the analysis of applet use was in the Present/Reinforce/Review Concepts for Instruction category where each content area had only three responses. The remainder of the data comes from the algebra and calculus teachers (see Figure 5).

The results show a striking tendency towards the use of applets to Provide Practice (reported by 53% of algebra teachers) and Present/Reinforce/Review Concepts for Instruction
(reported by 87% of algebra teachers) in algebra classrooms. To borrow terminology from Zbiek (2002), it seems as if applets used in algebra classrooms are most commonly used as information conveyors. For example, I placed any reported uses of applets that involved showing material or visuals to students for instructional purposes in the Present/Reinforce/Review Concepts for Instruction category. As Zbiek (2002) states, showing information or illustrations is an important characteristic of technology used as an information conveyor. Further, many teachers reported using applets to administer practice problems to students. In these instances the students were using the applet as a computational aide. I placed these responses in the Provide Practice category. Finally, in the words of Kamthan (1999), applets of these types would be considered concept illustrating or computational applets.

These findings beg the question, why are applets used for these purposes in algebra classrooms? While there is limited existing research on the use of applets in algebra settings, I can make a few guesses as to why this trend exists. For one, the nature of algebra itself is extremely broad. It is a varied mathematical content area that encompasses topics from linear equations and their graphs to matrices. Further, for the purposes of this study, the moniker algebra includes Pre-Algebra, Algebra I, and Algebra II, with four participants teaching Pre-Algebra, ten teaching Algebra I and eight teaching Algebra II. Needless to say the spectrum of algebraic topics is even larger within the scope of my study. Considering the many algebraic topics and concepts to illustrate, the role technology plays in today’s classrooms, and the fact that there are a litany of applets for any specific topic, it is really no surprise that applets are used so much for instruction and practice in algebra classrooms. In the simplest of terms, there exists an abundance of concept illustrating and computational applets for algebraic topics and I believe these teachers took advantage of this.
I also noticed some trends in the data reported by the calculus teachers. Akin to algebra, the primary uses of applets in calculus settings are to Provide Practice and Present/Reinforce/Review Concepts for Instruction. This was evident because every single calculus teacher reported using applets to Present/Reinforce/Review Concepts for Instruction while 60% reported using them to Provide Practice. Again, applets used in this way can be considered computational applets and concept illustrating being used as information conveyors for the same reasons mentioned in the previous paragraph (Kamthan, 1999; Zbiek, 2002). However, these results are supported by existing literature. As Hohenwarter et al. (2008) point out, calculus applets are typically classified as teacher centered or student centered where teacher centered applets are used more for instruction and student centered applets are used primarily for practice and the self-exploration of concepts. It is not difficult so see that teacher centered applets would be those used to Present/Reinforce/Review Concepts for Instruction while student centered applets would be used to Provide Practice. What teacher centered and student centered applets have in common is that they both focus heavily on the dynamic capabilities of applets—capabilities that allow abstract concepts to be presented in a more concrete manner (Healy et al., 2002).

This proves to be an extremely beneficial capability when working in calculus, a mathematical content area filled with abstract concepts. For example, if a teacher is doing a lesson on derivatives and wants to show how the slope of the tangent line changes as the tangent point moves along a given curve, an applet may be the best option to present this concept. An instructional, dynamic environment would be most beneficial for this, and as previously stated, teacher centered applets include both instructional and dynamic capabilities. Further, imagine giving a group of students practice problems on finding the volume of solids of revolution. While
you could do this using a worksheet or textbook, a student centered applet may prove to be a more efficient means. A student centered applet could provide the student with a dynamic representation of the problem, assist them in solving it, and provide immediate and useful feedback. In this example, a dynamic student centered applet may be the best option to Provide Practice. With that being said, it makes sense that the data show teachers using applets in calculus classrooms to Provide Practice and Present/Reinforce/Review Concepts for Instruction.

I also analyzed the uses of applets according to academic designation. Unfortunately, there was not much to take away from this analysis. I say this because two of the five uses, Illustrate Relationships and Assessment, did not acquire enough responses to register in the analysis. Specifically only two remedial, grade level, and honors teachers reported using applets to Illustrate Relationships while only one teacher in each of these three designations used applets for Assessment. Again, for the purposes of this study, a specific use needed to be reported at least three times to be included in the results. Furthermore, Visual Representations of Abstract Concepts only garnered seven total responses (see Figure 6). In other words, there was limited data to analyze so developing an interesting analysis proved difficult. Nonetheless, one result that stands out is the striking number of remedial (79%) and grade level (69%) teachers who report using applets to Present/Reinforce/Review Concepts for Instruction. At first, I thought that this could imply a trend towards using applets for instructional uses in non-advanced designations. On second thought, I realized that this supposition must be carefully considered. I say this because 17 of the 18 participants who use or have used applets teach in either a remedial or grade level setting. If over 90% of the participants who use or have used applets were honors or Advanced Placement teachers, and reported the same uses, I would be inclined to suppose that
applets are used for instructional purposes in advanced designations. Thus, due to the lack of variation in the participants, it is hard to make a substantiated supposition within this analysis.

One interesting trend occurs in the Provide Practice category. We can see in Figure 6 that as we move up through academic designations in the Provide Practice category, from remedial to honors, the number of teachers who reported this use decreases at a near constant rate. Specifically eight remedial teachers, five grade level teachers, and three honors teachers reported using applets to Provide Practice. This is to suggest that as mathematics courses increase in rigor, the use of applets as a means of providing practice decreases. There is almost nothing in the literature that discusses this notion, but there is one study that suggests using technology to provide practice can have greater effects on student achievement in lower level classes compared to higher level classes (Wenglinsky, 1998). Specifically, the author argues the when teachers use technology to “apply higher-order skills learned elsewhere” in lower level classes, students’ test scores are better than when practice is done via non-technological means (Wenglinsky, 1998, p. 36). Similar results were not evident in higher level classes (Wenglinsky, 1998). Here, we can see that the findings of the current study are somewhat parallel with existing research.

**Teachers and Students**

My study also analyzed teachers’ perceptions of the advantages and disadvantages of using applets in secondary mathematics. As seen in the Results section, the overall view of applets is a positive one. The majority of teachers interviewed currently use applets on a fairly regular basis and many of them reported multiple advantages and no disadvantages regarding their use. The literature shows that while using applets is not necessary, their capabilities make
them a valuable tool in mathematics classrooms (Daher, 2009). It became clear that teachers’ perceptions of applets are consistent with the literature cited as participants viewed applets as a beneficial piece of technology with many advantages. Further, many of the specific advantages that the participants reported reflected what I found in the existing research.

For instance, the most commonly reported advantages of using applets in secondary mathematics classrooms were their dynamic nature, interactivity, and ability to differentiate instruction (see Figure 7). As discussed in the Literature Review, the dynamic and visual nature of applets allow teachers to present information that is difficult to convey in a more traditional manner (Kamthan, 1999). For example, it is arguably more efficient to use an applet within a lesson on limits than only using a chalkboard or whiteboard and paper handouts. The applet allows the teacher to present dynamic illustrations, which the latter cannot provide. Further, with the help of interactivity, capitalizing on these advantages of applets allows students to make discoveries that can help further their mathematical understanding (Lee & Hollebrands, 2006). Clearly my study, and those like it, highlight the many advantages of using applets in secondary mathematics classrooms. Consequently, it should be no surprise that these teachers hold such a positive perception towards using applets.

After the teachers, the focus of the analysis shifted to the students. In particular, the goal was to investigate whether or not teachers perceived their use of applets having any affect on student understanding, motivation, and engagement. The results were interesting. Of these three categories, there exists the most literature concerning the effects on student understanding. Particularly, multiple studies show that using applets in secondary mathematics classrooms can help develop students’ understanding (Forster, 2006; Lee & Hollebrands, 2006; Mawata, 1998; Webb et al., 2006). This notion was marginally supported in my study. Student understanding
was not the most commonly reported area, but some (39%) teachers detailed a noticeable increase. For example one participant reported, “[The applets] help students to understand by visualizing different things, such as volumes of solids with known cross sections” while another said “[applets] provide a different perspective on the concept, and many [students] seem to grasp it better when the paper/whiteboard method isn’t working.” In both of these examples, the teachers were using applets for instructional purposes and reported an increase in student understanding as a result. Further, the analysis of the reported uses of applets showed a tendency to use applets for instructional purposes across all mathematical content areas and academic designations, as shown by the number of responses in the Present/Reinforce/Review Concepts for Instruction category. Thus, participants in my study used applets for instruction and saw an increase in student understanding as a result—a notion consistent with existing literature (Kamthan, 1999; Lee & Hollebrands, 2006).

Next, I analyzed teachers’ perceptions of how using applets affects student engagement. I failed to find any studies supporting the notion of applets increasing student engagement, however it was the most commonly reported area in my study. With the majority (61%) of teachers reporting increases in student engagement, I would think the literature would support this notion. The reverse situation became apparent when looking at student motivation. There is a solid research base supporting the fact that using applets in secondary mathematics can help increase student motivation (Heck et al., 2007; Kamthan, 1999). Conversely, only 22% of teachers in my study reported increases in student motivation.

During the analysis of my study’s data, the category of student interest was added. Student interest was not a category of investigation to begin with because nothing was really said about it in the existing literature. However, it was added because a noteworthy number (44%) of
teachers reported noticeable increases in student interest when using applets. Because of the lack of literature, I am left to conjecture why this is the case. Due to the fact that high school students today have been engrossed in a technology-oriented society for the entirety of their lives, I believe any sort of technology incorporation in the classroom would spark their interest.

Assuming that technology is not used on a daily basis, as was the case for all participants, its incorporation into a lesson could be enough to increase student interest. This is something I have witnessed firsthand, both as a high school student and an instructor. My head has shot up as soon as a teacher allowed us to work with computers or projected a demonstration from the Internet, and I have seen students’ become wide-eyed as I utilized virtual manipulatives and graphing applets. This leads me to believe that regardless of how the applets were used, their use alone would be enough to cause a noticeable increase in student interest, and that is why it was so heavily reported in my study.

Finally, one macro-implication that can be taken from my study involves the use of applets in remedial instruction. As noted in the Results section, an interesting trend occurred when analyzing the reported advantages according to designation. The majority (58%) of remedial teachers, more than any other academic designation, listed their ability to differentiate instruction as an advantage of using applets. Pair this with the fact that applets are mostly used for instructional purposes in remedial settings, as well as the fact that the vast majority of teachers who reported increases in student understanding, motivation, engagement and interest were from remedial settings, and significant insights can be gathered. To me, this shows that remedial teachers are using applets for instruction, but specifically as a means to differentiate instruction. After doing so, these same teachers are reporting increases in student understanding, amongst other things. Therefore, I believe it would be a fair supposition to say that using applets
may be a highly effective means to differentiate instruction in remedial classrooms, which, as the existing research shows, is an incredibly beneficial practice (Garnett, 1998).

Limitations

There were a number of limitations that hindered my study. The primary limitation was the group of participants. For many reasons, I did not obtain as many participants as I would have liked. My goal was to have approximately 50 participants agree to be a part of the study, and I thought contacting 64 potential participants would suffice. I saw 50 as a large enough number, but not unattainably large, to provide me with a varied group of participants. I may have been shortsighted in thinking this, but I surely did not think I would only yield 23 participants from a pool of 64. I could have been more proactive in my search for participants which would have gave me more time to contact more people. I also believe the limited number of participants affected the variation of participants.

By this I mean there was not a whole lot of variation when it came to mathematical content area and academic designation. The vast majority (87%) of teachers taught algebra either in a remedial or grade level setting. The remaining teachers were unequally distributed amongst the remaining content areas and designations. This extremely uneven distribution affected the validity of the results of my study, as mentioned in the previous section. Had I obtained a more targeted and stratified group of participants, this limitation could have been avoided.

Finally, the data collection could have been handled better. I believe the interview protocol I used was efficient but it could have been improved had I referenced preexisting protocols or studies involving interviews. Conducting phone interviews also led to a few
limitations. For one, it was a bit difficult to coordinate viable times for both the participant and myself. With some participants, they were fitting the interview into an already busy schedule, so they may have rushed their responses and not gone into as much detail as possible. For example, when asked, “What do you like about applets themselves? Are their things you disliked?” one participant responded with, “They are good teaching aides. They can look cool too.” Later, when the same participant was asked, “Have you seen any effects on student understanding, motivation, and/or engagement that you would attribute to your use of applets?” they responded with, “Yes, when students get to explore and create.” In both instances, the participant asked to move on to the next question after giving their response.

Secondly, performing phone interviews made it difficult to record each and every interview. I was able to type up the majority of things each participant said, but recording interviews allows the researcher access to things that cannot be obtained by reading words on paper. The ideal means of data collection would have been face-to-face interviews, but my access to transportation and free time did not allow me to pursue this option. Lastly, the use of phone interviews transcends the limitations of other self-report methods of data collection. Nonetheless, it is possible that some questions were leading and participants’ responses were not entirely unbiased. This, of course, could have affected the validity and reliability of my study. However, the level of concern is minimal as the interview protocol was developed and edited with the help of my Academic Advisor in order to help prevent these things.
Further Research

The results of my study open the door for more research to be done. It would be useful to perform a study similar to this one but with all, or most, of its shortcomings addressed, if possible. I believe the research questions at hand are important, but could be better answered with a study carried out by research professionals or educational researchers. This would involve increasing the population of the study, altering the method of data collection, and applying a deeper analysis. My study also provided implications that would benefit from further research.

One of these implications is the use of applets for instruction in remedial mathematics settings. Research shows that using applets with mathematics students with special needs can be beneficial for their thinking and reasoning by allowing students to “focus more on mathematical processes and relationships” (Suh & Moyer-Packenham, 2008, p. 7). As discussed earlier in this section, the results of my study suggest that using applets is an effective way to differentiate instruction in remedial math classes. I encourage researchers to take this idea and run with it. Studies could be conducted that focus on this idea alone, and the results could be beneficial in the field of mathematics education as well as special education. Secondly, my study showed promising inferences on the positive affect applets can have on student understanding, motivation, engagement and interest. Any four of these areas could be the focal point of a single study in which researchers try to discover how applets enhance these areas. This would help expand the research base on these topics and, again, be beneficial in the field of mathematics education. As I stated before, there is limited existing research on the use of applets in secondary mathematics classrooms. If more research is done, it could be used to educate teachers and provide them with information regarding a fantastic teaching and learning tool. Finally, studies could be performed to analyze the use of applets in primary mathematics education as well as
any level of science education. To me, science is the only other subject where the use of applets would make sense due to the nature of scientific topics and the subject’s heavy inclusion of mathematics.

Conclusion

In order to investigate the use and perception of applets in secondary mathematics classrooms, I conducted interviews with secondary mathematics teachers. Unfortunately, the number of teachers was much less than I had hoped and the participant group was not as varied as I would have liked it to be. Despite this fact, the results provided useful insights for answering my research questions. When looking at the uses of applets, it became apparent that applets are used mostly for instruction and practice in algebra and calculus classrooms. This may be due to the fact that algebra includes a large variety of topics and there exists multiple applets for almost every one of these topics. Further, their use in calculus classrooms could be due to applets’ ability to convey abstract topics in a concrete way in conjunction with the prominence of abstract concepts in calculus. Not much can be deduced about the uses of applets according to academic designation, which opens the door for further research.

This study also provided a lot of promising results for the future use of applets in secondary mathematics. Due to the many advantages of using applets, such as their interactive, dynamic, and illustrative abilities, teachers hold an extremely positive perception towards their use in mathematics classrooms. Further, it has been shown that applets can help increase student understanding, engagement, motivation and interest. However, there is room for much more research to be done on this notion.
These findings are also useful on an individual and professional level. I have personally used applets in my teaching, but this study opened my eyes to various uses of applets as well as numerous capabilities, of which I was unaware. I have always believed technology plays a critical role in mathematics education, and this research has only strengthened this belief. I believe I can use some of the things I found in this study in my own classroom. For instance, if I find myself teaching an algebra course, it may prove beneficial to incorporate applets for instructional purposes. Further, this study has shown that using applets to differentiate instruction in remedial classroom settings could have positive results. Overall, this research has been thoroughly interesting and enjoyable and I am excited to see more studies done on these topics as well as to personally implement what I have learned.
Appendix A

Interview Protocol

BASIC BACKGROUND

Date: 
Name of interviewee:

INTRODUCTION

Hello, my name is Kyle O’Donnell. I am a senior Schreyer Honor Scholar majoring in Secondary Mathematics Education with a minor in Special Education. For my honors thesis, I am investigating the use of applets in secondary mathematics classrooms. Specifically, I am focusing on the environments in which applets are used as well as both teachers’ and students’ perceptions of applets. Furthermore, I will be looking into how these factors are related to the uses of applets as well as their effects on student understanding, motivation, and engagement, if possible. Before we begin I would like to thank you in advance for taking the time to answer these questions. I know it will prove to be a big help in writing my thesis as well as in my career as an educator.

THE INTERVIEW

Before we begin with the formal questions, I would like to provide you with what I mean whenever I use the word “applet.” I would define the word applet as an interactive, computer-based application that performs a specific task.

Background Information

What courses do you currently teach?
Are there any other teachers who teach these courses as well?
   If yes, To what extent do you utilize group planning for these courses?
How long have you been teaching these courses?
How long have you been teaching, in general?
What year did your professional development process (e.g. undergraduate, graduate, student teaching) begin?
At any point in your professional development process did you learn about using applets in the classroom?
Does your school’s curriculum require the use of technology in the classroom?

The Questions

Do you use applets in any of your classes?
   If yes, What do you use them for?
      How frequently do you use them?
Why do you use them?
From what sources do you draw your applets?
What do you like about applets themselves? Are there things that you dislike?
How do your students react (if at all) when you incorporate applets into a lesson?

Have you seen any effects on student understanding, motivation, and/or engagement that you would attribute to your use of applets?

There are other types of technology that could be used in a mathematics classroom. Included in this list are worksheets, overheads, PowerPoints, white boards, SMART Boards, Skype lessons/lectures, and graphing calculators. How would you compare using applets to these types of technology?

To what extent would you recommend using applets to other teachers?

If yes, Why?

Who else might you recommend the use of applets to?

If no, Why not?

If no, Have you ever used them?

If yes, Why did you start using them?

Why did you stop using them?

What did you dislike about the applets?

Despite your stopping the use of them, were there things about the applets you liked? Would you ever consider using them again? Why or why not?

How did your students react when you incorporated applets into a lesson?

Did you see any noticeable effects on student understanding, motivation, and/or engagement while you used the applets?

If no, Why have you not used them?

Are there things about applets that you like?

Are there things about applets that you dislike?

Do you think you will ever use applets in the classroom?

In what ways do you think applets could affect student understanding, motivation, and/or engagement?

There are other types of technology that could be used in a mathematics classroom. Included in this list are worksheets, overheads, PowerPoints, white boards, SMART Boards, Skype lessons/lectures, and graphing calculators. How would you compare using applets to these types of technology?

That concludes the set of questions. Again, I would like to thank you for your time and contributions. Have a great day!
Subject: Seeking participants for a research study

Hello,

My name is Kyle O’Donnell and I am an undergraduate student at The Pennsylvania State University, Schreyer Honors College working on a research study regarding the use of applets in secondary mathematics classrooms. I am seeking participants for the study, and you are receiving this e-mail because you are a secondary mathematics teacher in Pennsylvania. Your e-mail address was given to me by _______________________.

For this study, I am investigating the use of applets in secondary mathematics classrooms. Specifically, I am focusing on how applets are used and perceptions of their usefulness in terms of student understanding, engagement, and motivation.

If you choose to take part in the study, it will require an interview that will take approximately 20 to 30 minutes to complete.

If you are interested in participating or have any questions about the study, please feel free to e-mail me at kmo5180@psu.edu or call me at 267-574-1175. Thank you for your time.
Appendix C

Follow Up E-mail Requesting Research Permission

Kyle O’Donnell
255 East Beaver Ave, Apt 502
State College, PA 16801

Date

Address

Dear ,

My name is Kyle O’Donnell and I am an undergraduate student at The Pennsylvania State University, Schreyer Honors College. I am working on a research study regarding the use of applets in secondary mathematics classrooms. Specifically, I am focusing on how applets are used and perceptions of their usefulness in terms of student understanding, engagement, and motivation.

I am writing to you today because I am requesting your cooperation in carrying out my study. I wish to conduct interviews with several secondary mathematics teachers in your school/school district. Your help would be greatly appreciated; please let me know if there is anything else needed.

I hope to do most of my research during the current academic year, roughly December 2013 to May 2014. During this time, it would be ideal if I could obtain access to teachers’ contact information (only name and email address) in order to obtain consent and establish interview times. If you would be willing to assist me with these endeavors, that would be greatly appreciated.

Thank you for your time and I look forward to hearing back from you.

Sincerely,

Kyle M. O’Donnell
The Pennsylvania State University
Schreyer Honors College
College of Education
Appendix D

Informed Consent Form

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: Applets in Secondary Mathematics Education

Principal Investigator: Kyle O’Donnell
113 Creekwood Drive
Feasterville, PA 19053
kmo5180@psu.edu
267-574-1175

Advisor: Dr. Rose Mary Zbiek
Department of Curriculum and Instruction
272 Chambers Building
Penn State University
University Park, PA 16802
814–863-1210
rmz101@psu.edu

1. Purpose of the Study: The purpose of this research is to investigate the use of applets in secondary mathematics classrooms. Specifically, I am focusing on how applets are used and perceptions of their usefulness in terms of student understanding, engagement, and motivation.

2. Procedures to be followed: You will be asked about 30 questions in an interview. I prefer that this interview take place in person, but I am willing to do it via phone if necessary. The audio of the interview will be recorded for the purpose of the research.

3. Duration/Time: The interview will take one session of approximately 30 minutes.

4. Statement of Confidentiality: Your participation in this research is confidential. The data will be stored and secured at on my computer and cellular phone in a password-protected file. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

5. Right to Ask Questions: Please contact Kyle O’Donnell at (267) 574-1175 with questions
or concerns about this study.

6. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this form for your records.

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<thead>
<tr>
<th>Participant Signature</th>
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<table>
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<tr>
<th>Person Obtaining Consent</th>
<th>Date</th>
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References


Academic Vita

Kyle O’Donnell
113 Creekwood Drive
Feasterville, PA 19053
kmo5180psu@gmail.com

Education
Bachelor of Science in Secondary Mathematics Education
Minor in Special Education
Honors in Secondary Education
Penn State University, Schreyer Honors College, Fall 2014

Honors and Awards
Dean’s List (Fall 2010-13, Spring 2011-14)
Dr. Joseph E. Ferderbar Memorial Scholarship (Fall 2010)
Robert E. and Virginia L. Mountz Scholarship in Mathematics Education (Fall 2012, 2013, 2014)
Schreyer Honors College Academic Excellence Scholarship (Fall 2013)
Schreyer Honors College Endowment for Academic Excellence Scholarship (Fall 2013)
College of Education Commencement Student Marshal (Fall 2014)

Association Memberships/Activities
Honor Societies: Phi Kappa Phi, Pi Lambda Theta
Education Groups: Student Pennsylvania State Education Association, Education Student Council, National Council of Teachers of Mathematics
Philanthropic: Atlas THON
Collegiate Organization: National Society of Leadership and Success
Recreational: Intramural Softball, Football, and Soccer

Professional Experience
Student Teacher, Bäckadalsgymnasiet
Supervisor: Eve Shellenberger, Co-Coordinator of CI Field Experiences and Assistant Professor of Education
Jönköping, Sweden Fall 2014

Staff Advisor, Penn State Summer Study Programs
Supervisor: Mike Sirowitz, Director of Programs and Operations
State College, PA Summer 2014

Pre-Service Student Teacher, Phillipsburg-Osceola Senior High School
Supervisor: Anna Persson, Curriculum and Instruction Field Experience Supervisor
Phillipsburg, PA Fall 2013
Mathematics Tutor, State College Volunteers in Public Schools (VIPS)
Supervisor: Catherine Lehman, Volunteer VIPS Coordinator
State College, PA  Spring 2013

Volunteer Mentor, LifeLink PSU
Supervisor: Michelle Kump, Learning Support Teacher
State College, PA  Fall 2011 – Spring 2012