

INVERTING THE CLASSROOM IN COLLEGE ALGEBRA: AN EXAMINATION  
OF STUDENT PERCEPTIONS AND ENGAGEMENT  
AND THEIR EFFECTS ON GRADE OUTCOMES

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## **ABSTRACT**

# **INVERTING THE CLASSROOM IN COLLEGE ALGEBRA: AN EXAMINATION OF STUDENT PERCEPTIONS AND ENGAGEMENT AND THEIR EFFECTS ON GRADE OUTCOMES**

by

Robert Walter Jaster, M.S.

Texas State University-San Marcos

May 2013

## **SUPERVISING PROFESSOR: SELINA VASQUEZ MIRELES**

In an inverted college algebra classroom, students viewed videos and took notes outside class and solved problems in class. There were three topics related to the inverted classroom that were of primary concern in this research. One topic was student perceptions, and student perceptions were examined of (a) the inverted classroom as an instructional approach, and (b) the individual elements of an inverted classroom: video viewing, note taking, and problem solving. This research also explored the relationship between perceived learning contributions of elements of an inverted classroom and grade

outcomes, and the relationship between levels of engagement with elements of an inverted classroom and grade outcomes.

Most students indicated a preference for a lecture-based class over the inverted college algebra classroom. Student perceptions of video viewing were both positive and negative, whereas overall students held positive perceptions in regard to problem solving and note taking. Multiple regression analysis indicated that perceived learning contributions of video viewing and note taking were associated with grade outcome. Multiple regression analysis also indicated that level of engagement with video viewing had the greatest influence on grade outcome (in comparison to level of engagement with either note taking or problem solving) for approximately 20% of the students in the sample. For approximately 75% of the students in the sample, level of engagement with note taking had the greatest influence on their grade, followed by level of engagement with problem solving, and then level of engagement with video viewing.

Recommendations were made for future research, teaching practice, and preparation of an inverted classroom for college algebra. Recommendations include investigating the effectiveness of the inverted college algebra classroom, placing a greater emphasis on note taking, and producing videos no longer than 20 to 30 minutes in length.



## **CHAPTER 1**

### **INTRODUCTION**

Mathematics plays a central role in all science and is essential in the interpretation of research findings (Dougherty & McInerney, 2009). The tools and models provided by mathematics are indispensable in scientific inquiry, as they guide and improve the posing of questions, the collection of data, the construction of explanations, and the communication of results (National Research Council, 1996). Nevertheless, as Gray (1988), a former president of the Massachusetts Institute of Technology, noted over twenty years ago, “our educational system has produced generation after generation of young people who are ignorant in science and incompetent in mathematics” (p. B1).

In higher education, problems with college algebra are especially worrisome. College algebra is a required course for various majors, but is viewed by many as a gatekeeper course, controlling student access to degree completion (Reyes, 2010). College algebra provides the foundational skills, conceptual understanding, and mathematical insights needed for success in subsequent courses (Dugopolski, 2010). Application problems and investigations of modeling allow students to see how useful college algebra is in the real world. College algebra is also filled with instruction and practice with problem-solving strategies. Such instruction and practice has been shown

to promote problem-solving transfer, or the ability to use previously acquired knowledge to solve new problems (Phye, 2001).

### **Problem Statement**

Each year in the United States approximately 849,600 students enroll in college algebra<sup>1</sup>, but only about half of these students are successful in completing the course (Allen, Zientek, Griffin, White, & Wilhite, 2006; DeDeo, 2001; Owens, 2003; Small, 2006; Tulsa Community College, Office of Planning and Research, 2007). The nationwide lack of success in college algebra may raise questions concerning quality of instruction.

The American Mathematical Association of Two-Year Colleges (AMATYC, 2006) recommends that faculty design and implement instructional activities that promote the active engagement of students in the learning of mathematics. Yet the Conference Board of Mathematical Sciences (CBMS) 2010 survey (American Mathematical Society [AMS], 2013f) found that at public two-year colleges, 79% of college algebra sections, and 89% of college algebra and trigonometry (combined) sections, were taught mostly by the standard lecture method. The CBMS 2010 survey (AMS, 2013b) asked four-year institutions to report the number of college algebra sections that “primarily used a traditional approach [in instruction] (i.e. sections that were basically the same College Algebra course that was taught in 1990)” (p. 24). Responses showed that about two-thirds of the college algebra sections in four-year institutions were still taught using a traditional approach (AMS, 2013d).

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<sup>1</sup> Details concerning this estimate appear in Appendix A.

Although CBMS 2010 survey results indicate that lecture is the predominant instructional method in college algebra, numerous experimental comparisons of teaching methods have shown that lecture is not the most effective instructional method for promoting thought (Bligh, 2000). Details concerning the choice of lecture in teaching college algebra and the examination of research literature conducted by Bligh appear in Appendix B.

### **Purpose**

The purpose of this research was to (a) ascertain how students perceive an inverted college algebra classroom, (b) identify any relationship between perceived learning contributions of various elements of an inverted college algebra classroom and grade outcome, and (c) identify any relationship between levels of engagement with various elements of an inverted college algebra classroom and grade outcome. Elements included in the studied inverted classroom were video viewing, note taking, and problem solving. To better determine the appropriateness of this inverted classroom for college algebra, each of these elements was examined in terms of student perceptions and engagement. This research also determined, based on student perceptions, engagement, and academic performance, the relative contribution to grade outcome of each of these elements.

### **Significance of the Study**

Online searching that involved several keyword combinations and research databases failed to identify any literature regarding the use of an inverted classroom in college algebra<sup>2</sup>. Similar online searching that left the subject of the course unspecified

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<sup>2</sup> Details concerning the search appear in Appendix C.

yielded several examples of inverted classrooms in other subjects. Aspects of these inverted classrooms are discussed in the next chapter. The paucity (or complete lack) of research literature regarding the application of this teaching strategy in college algebra classrooms implies that much remains to be learned, making the inverted classroom for college algebra a fertile research topic. Moreover, the advent of the inverted classroom introduces a possibility of significantly improving mathematics instruction. This possibility, combined with the apparent absence of research literature concerning the use of the inverted classroom in college algebra, has created a pressing need for available information regarding this topic. This research will make a significant contribution to the field of mathematics education by filling this apparent gap in the research literature.

Also significant, and as investigated throughout this research, the inverted classroom may offer several unique advantages over traditional lecture both inside and outside the classroom. Outside class students may be able to control the delivery of content by pausing or replaying parts of a video, allowing students to learn at their own pace. The additional time available inside the classroom makes individual and collaborative activities possible that may be of greater benefit to students. Refinements in the design of the inverted college algebra classroom may leverage these advantages to increase current dismal student success rates.

### **Research Questions**

This research was exploratory in nature, as it sought to discover student perceptions of an inverted classroom in college algebra. Of particular interest was whether students felt that the inverted classroom was an effective paradigm for learning college algebra.

The following research questions guided this investigation.

1. What are students' perceptions of an inverted college algebra classroom?
2. What is the relationship, if any, between perceived learning contributions of various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?
3. What is the relationship, if any, between levels of engagement with various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?

To better address these questions, Chapter 2 examines research literature relevant to the inverted classroom. A theoretical framework based on the learning theory of constructivism provided principles that contributed to the design and implementation of an inverted classroom for college algebra. Descriptions of inverted classrooms in various disciplines contained in the research literature identified elements that seemed appropriate for college algebra. Details concerning the implemented inverted college algebra classroom begin in Chapter 3.

## **CHAPTER 2**

### **REVIEW OF THE RESEARCH LITERATURE**

This chapter surveys research literature relevant to the inverted classroom. It begins with a description of a theoretical framework that supports and informs this research. An inspection of theory helps to understand how, and why, the inverted classroom may be an effective instructional approach in teaching mathematics, and can help in identifying those elements of the inverted classroom that may be of most benefit to students.

A close look is taken at an inverted classroom as presented by Lage, Platt, and Treglia in their 2000 seminal article. In the article, Lage et al. defined the inverted classroom and described an implementation used to teach an introductory economics course. The article describes the methodology, lesson procedure, and student perceptions and engagement for an early inverted classroom.

Of particular interest for the purposes of this research were the various elements of inverted classrooms, the roles of the elements in student learning, and student perceptions of the elements. This chapter reviews additional studies involving inverted classrooms to find more information regarding inverted classroom elements. The review of studies identify elements that may be included in an inverted classroom to provide greater learning opportunity for the students. Elements of the inverted classroom that

may contribute to learning either inside or outside the classroom are listed and described in the context of the theoretical framework.

Deficiencies in research concerning the inverted classroom are discussed. A chapter summary then presents two tables listing elements of the inverted classroom. Table 1 lists those elements found outside the classroom and Table 2 lists those elements found inside the classroom. The tables provide a description of the means through which each element contributes to learning. The tables also identify principles of constructivism addressed by each element. Considering elements of the inverted classroom in light of learning theory leads to the design of an inverted college algebra classroom in Chapter 3.

### **Theoretical Framework**

As in other qualitative research, this research was designed to inductively build rather than test concepts, hypotheses, and theories (Merriam, 2009). Part of building this knowledge involved the design, implementation, and study of an inverted classroom. As the literature discussed in subsequent sections of this chapter shows, there are many different ways in which to design and implement an inverted classroom. To better ensure the design and implementation of a successful inverted classroom, and in order to contribute knowledge with a solid theoretical foundation, constructivist learning theory provided the basis for this research, guiding its design, student practices both inside and outside the classroom, and the analysis and interpretation of collected data.

The American Mathematical Association of Two-Year Colleges provided goals, principles, and standards for mathematics before calculus in two standards documents (AMATYC, 1995; AMATYC, 2006). In the first standards document, *Crossroads in*

*Mathematics*, AMATYC (1995) established standards for pedagogy that are “compatible with the constructivist point of view” (p. 15). In the second standards document, *Beyond Crossroads*, AMATYC (2006) emphasized the use of a constructivist approach when using a student-centered teaching style, and Lage et al. (2000) encouraged the use of a student-centered teaching style inside the inverted classroom. Hence, the AMATYC standards suggest a constructivist orientation in the design and implementation of an inverted classroom for mathematics. A question now considered is “What is constructivism?”

### **Constructivist Learning Theory**

Pritchard and Woollard (2010) explained that the term *constructivism* can refer to much more than a theory of learning. Constructivist learning theory is situated in a much wider context of constructivism, which extends into areas of social, ethical, and psychological thought. Pritchard and Woollard (2010) described constructivist epistemology as both a “a philosophical approach to investigating the scope, structure and very nature of knowledge which follows a constructivist approach,” (p. 3) and a philosophical perspective taken by some philosophers that consider scientific knowledge as being constructed by scientists and not discovered from the world. As further explained by Pritchard and Woollard, constructivist thought and philosophy guides international relations, mathematics (especially regarding the construction of mathematical proofs), art, and architecture. Constructivism also concerns approaches to both psychological research and therapy and the study of language acquisition. Constructivist learning theory is one of many applications of the thought and philosophy



of constructivism. It is constructivist learning theory that serves as a basis for the theoretical framework that supports and informs this research.

In recent years researchers have described constructivism in a variety of ways, including as a philosophy, a methodology, a pedagogical approach, a model, an epistemology, and a framework of interpretation (Harlow, Cummings, & Aberasturi, 2006). Inconsistent use of the term has led many educators to define constructivism in a general way, such as “the general notion that individuals construct their own knowledge or mental versions of the world” (Harlow et al., 2006). This research adheres to the description of constructivism offered by Pelech and Pieper (2010), who state that constructivism is a philosophy and theory and not pedagogy.

As explained by Pelech and Pieper (2010), constructivism is a philosophy that views knowledge as subjectively constructed from one’s personal experiences and social interactions. Learning from new experiences and situations requires a restructuring of current knowledge to accommodate new knowledge. The role of a constructivist teacher is to manage the classroom environment to provide these learning experiences. Constructivist teachers act as guides, facilitators, and coaches; their role is “*not* one of transmitting knowledge” (Pelech & Pieper, 2010, p. 8).

Von Glasersfeld (2005) explained, according to constructivism, why knowledge and meanings cannot be shared. Meanings and knowledge are conceptual structures that each individual has to build up for him- or herself. These structures cannot be used alternatively by different individuals. Hence conceptual knowledge cannot be transferred from teacher to student by the means of words. Language “does not transport meanings or concepts, [but] . . . enables the teacher to orient the students’ conceptual construction

by precluding certain pathways and making others more likely” (von Glasersfeld, 2005, p. 7). Von Glasersfeld concludes that “the task of the educator is not to dispense knowledge but to provide students with opportunities and incentives to build it up” (p. 7).

Constructivism justifies and informs this research through its claim that people use individual experiences and social interaction to create knowledge. The wide acceptance of constructivism lends support to learning in an inverted classroom. The inverted classroom makes time available in class for active learning experiences and interaction with other students. Constructivism guides the design, practices, and interpretation of this research.

### **Beginnings of Constructivism**

Constructivist learning theory is a result of the work of many individuals. Jean Piaget (1896-1980) is credited with giving rise to the theory, which led to an expansion of understanding of child development and learning (Pritchard & Woollard, 2010). “It would be difficult to overestimate the impact Piaget’s theory has had upon thinking about intellectual development” (Sternberg, 1979, p. 12). Piaget’s theory contributes to this research by providing greater insight into how individuals learn.

However, Piaget was not a social constructivist (Pritchard & Woollard, 2010). Lev Vygotsky (1896-1934) worked in Russia in parallel with Piaget with similar but occasionally diverging ideas (Pritchard & Woollard, 2010). Vygotsky studied the social nature of learning, making an early contribution to constructivist thought (Vygotsky, 1978).

Pass (2004) claimed that “no two people were more responsible for the current way lessons are taught than Jean Piaget and Lev Vygotsky” (p. xiii). The writings of

many other philosophers and psychologists generally agree with the ideas of Piaget and Vygotsky, including those of John Dewey, William James, Richard Rorty, and Eric Jensen (Pelech & Pieper, 2010). However, because Piaget and Vygotsky supply the core hypotheses of constructivism, the remaining discussion of the learning theory has a greater focus on the contributions made by these two men.

### **Cognitive versus Social Constructivism**

The major contribution of Piaget to learning theory most relevant to this research is his constructivism. Piaget's notion of constructivism differs from the more contemporary concept of *social constructivism* (Brainerd, 2003). Piaget's theory has a greater focus on the individual's internal creation of knowledge. Piaget's theory heavily emphasizes the reasoning ability of individuals and how individuals interpret knowledge (Powell & Kalina, 2009), and underpins much of the theory relating to social constructivism (Pritchard & Woollard, 2010). As in the recent article by Powell and Kalina (2009), the term *cognitive constructivism* will be used to refer to the major strand of constructivism that depends on Piaget's theory. On the other hand, the learning theory of social constructivism places emphasis on the role of others and social interaction in the process of constructing knowledge and understanding (Pritchard & Woollard, 2010). "From a social perspective, knowledge resides in the culture, which is a system that is greater than the sum of its parts" (M. A. Simon, 1995, p. 116).

"Whether knowledge development . . . is seen as fundamentally a social process or a cognitive process . . . seems to depend on the focus of the observer" (M. A. Simon, 1995, pp. 115-116). M. A. Simon (1995) illustrates how these two perspectives can

contribute to an understanding of knowledge development in the classroom with an analogy involving physics:

Neither a particle theory nor a wave theory of light is sufficient to characterize the physicist's data. However, it has been useful to physicists to consider light to be a particle and to consider light to be a wave. Coordinating the findings that derive from each perspective has led to advancements in the field. (p. 116)

Hence, instead of contemplating whether the cognitive or social dimension is primary, perhaps a better understanding of knowledge development in the classroom can be obtained by coordinating analyses on the bases of these two perspectives.

### **Principles of Constructivism**

The theoretical framework includes principles of constructivism that describe learning based on constructivist theory. The 12 learning principles were provided by Pelech and Pieper (2010) and are listed below:

1. Students learn by participating in activities that enable them to create their own version of knowledge. This includes creating their own rules, definitions, and experiments. (p. 32)
2. Students learn when they teach others, explain to others, or demonstrate a concept to others. (p. 33)
3. Students learn when they create products from the real world that involves narratives, explanations, justifications, and dialogue. (p. 33)
4. Knowledge comes in multiple forms, and its development is not uniform; hence, students must be given the opportunity to develop each intelligence or domain. (p. 35)

5. Students learn when class activities stimulate multiple senses. (p. 35)
6. A student learns by creating knowledge at different levels of complexity and thinking. (p. 37)
7. A student learns by connecting new experiences with existing knowledge or connecting previously discrete experiences to each other. (p. 38)
8. Students learn when they are continuously presented with problems, questions, or situations that force them to think differently. (p. 39)
9. Students learn by making connections through the “Standard Six”: compare and contrast, hypothesize and predict, express understanding in multiple modes, find patterns, summarize, and find personal relevance. (p. 39)
10. A student regulates his learning by (1) knowing his own ability and learning style preference, (2) analyzing tasks and appropriate strategies, (3) choosing and analyzing appropriate goals, (4) analyzing and appraising his individual level of performance, and (5) managing his time effectively. (p. 40)
11. Students learn by working with other people who are the source of contradiction, different perspectives, and confirmation. (p. 41)
12. Modern society provides the source of authentic products for students to produce. (p. 41)

Each of the elements of the inverted classroom found in the review of the research literature addresses several of the above principles of constructivism. Under the below heading Elements of the Inverted Classroom, the support provided by constructivism for each element is discussed and the principles addressed by the element are identified.

### **Development of the Inverted Classroom**

The inverted classroom was presented by Lage et al. in their 2000 seminal work *Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment*.

Lage et al. defined the inverted classroom as a classroom in which “events that have traditionally taken place *inside* the classroom now take place *outside* the classroom and vice versa” (p. 32).

Lage et al. (2000) described the use of a particular inverted classroom in teaching an introductory economics course. In their article, Lage et al. included details of the selected instructional strategy and reported on student perceptions and engagement for this early inverted classroom. Effective teaching requires the selection of an instructional strategy, and an instructional strategy consists of two components: the methodology and the lesson procedure (Moore, 2008). Discussion of the methodology, lesson procedure, and student perceptions and engagement for the inverted classroom described by Lage et al. follows.

### **Methodology**

Lage et al. (2000) suggested that students would learn more if each student’s learning style matched the instructor’s teaching style. By using a portfolio of teaching styles an instructor could address a variety of student learning types. Nevertheless, a limited amount of student contact time seemingly limited the ability of instructors to vary teaching styles. Lage et al. observed that then recent advances in multimedia development and delivery had made it possible to integrate a variety of methods in teaching economics, including lecture, experiments, group assignments, and self-directed study. Lage et al. introduced the inverted classroom as an approach to instruction that

allows for a mixture of teaching styles without increasing contact time or reducing course content.

Most instructional methods can be categorized as either teacher-centered or student-centered (Moore, 2008). Through use of an inverted classroom, Lage et al. (2000) were able to use both types of instructional methods in teaching students: teacher-centered (e.g., lecture, demonstration, and modeling) and student-centered (e.g., discussion, collaborative learning, and independent study).

Two instructors at Miami University used the inverted classroom described by Lage et al. (2000) to teach principles of microeconomics in Fall 1996. Learning technologies, particularly multimedia, were used to provide new methods for students to learn outside the classroom. Through use of the Internet and multimedia computers (and/or VCRs) students were able to view lectures either in computer labs or at home. The lectures were made available to students in different formats.

Videotaped lectures were available for viewing in labs, and if students brought in blank tapes the university's audio-visual department would make copies for home viewing. Slide-based lectures that covered the same material were available in PowerPoint, with sound. The PowerPoint lectures were accessible in computer labs for copying or listening. Also, the PowerPoint slides could be downloaded over the Internet or purchased as a printed copy.

One of the main components of the inverted classroom described in Lage et al. (2000) was the class website. The website provided information about the videotaped lectures and also supplied students with access to the PowerPoint lectures with sound. In addition, the website provided students with access to assignments and old exams.

Communication tools featured at the website included a chat room and a bulletin board. In the chat room students could communicate with instructors during certain hours of the week. The bulletin board allowed students to communicate with each other. The website also provided a library of additional online and offline resources and optional, interactive quizzes on each topic.

Lage et al. (2000) explained that the independent study that occurred outside the classroom allowed time inside the classroom for students to learn using additional methods. Instructors had time to use hands-on experiments and labs to demonstrate economic principles. Students worked on homework assignments inside the classroom, in groups, leading to student discussion and collaborative learning.

Lage et al. (2000) sought to provide a variety of options for students to use in learning. Presented with an array of learning methods, each student could choose the best method for his or her learning style.

### **Lesson Procedure**

Moore (2008) explains that besides a methodology, an instructional strategy comprises a lesson procedure. Moore defines the lesson procedure as “the sequence of steps that has been designed for leading students to the acquisition of the learning objectives” (p. 128).

The course material in the inverted classroom described by Lage et al. (2000) was divided into topics that corresponded to chapters in the textbook. Students were expected to read about topics in their textbook prior to the first day of discussion. Students were also provided with lectures in a variety of formats and encouraged to view lectures of the



topic being discussed. Students were also expected to complete simple worksheets prior to attending the first class period on a topic.

At the beginning of each class instructors would ask if there were any questions. If students had questions, or wanted an additional example, the instructor usually lectured for approximately 10 minutes. If there were no questions then the instructor would not lecture. “Students were informed that their lack of questions would be interpreted as a sign that they clearly understood the assigned material” (Lage et al., 2000, p. 33).

After answering any questions, the instructor would lead the class in a hands-on experiment or lab that illustrated an economic principle that pertained to the topic. For instance, holding an auction for a can of cola supplied data that was then used to produce a demand curve. In another activity, students made peanut butter and jelly sandwiches to generate data subsequently used to derive production functions and construct cost curves.

During the remainder of class time students focused on the worksheets and review questions. The classroom had movable chairs so they were able to sit in groups. Often students discussed their answers from the worksheet with others in their group and then presented their work to the rest of the class. To encourage students to prepare for class the worksheets would sometimes be collected and scored for completeness but not correctness. The review questions required students to apply the concepts being discussed. Answers to the review questions would also be presented by students, and this work was also sometimes collected and scored. Units concluded with the instructor asking if there were any final questions.

## **Student Perceptions and Engagement**

To capture student perceptions of the class the instructors conducted an end-of-semester survey in each of the five sections taught using the inverted classroom. Lage et al. (2000) reported that most of the students were favorably impressed by the course.

Various aspects of the course were assessed with closed-ended ordinal questions with responses given on a 5-point scale ranging from 1 to 5. Students provided positive feedback regarding the peer group-work component of the course and the individual components of the group work. Students also found the in-class experiments beneficial. The students, however, did not consider the inverted classroom to be an easier type of class.

Open-ended questions allowed students to make comments concerning the course. These comments were mostly positive, agreeing with the numerical scores obtained from the survey instrument. Representative sample comments are given in Lage et al. (2000).

The researchers did not seek to measure student levels of engagement with the various elements of their inverted classroom. However, the instructors reported that students appeared more motivated than in a traditional classroom. The researchers suggested that the increase in motivation in the inverted classroom may be a result of students feeling more responsible for their learning.

The instructors also observed that “students generally enjoyed working together and seemed to learn from having other students explain concepts in different ways” (Lage et al., 2000, p. 37). Students also seemed more comfortable asking questions in class, given the increased opportunity for one-on-one interaction with the instructor and student presentation of material.

## **Conclusion**

Lage et al. (2000) claimed that the inverted classroom is an instructional approach that can engage a wide spectrum of learners. By using learning technologies to greatly reduce or remove events such as lectures from the classroom, events such as homework can occur inside the classroom under the guidance of the instructor. The authors note that such a format allows an instructor to present a variety of learning options while maintaining control over course content.

The evidence presented by Lage et al. (2000) suggests that many students would prefer the inverted classroom to a traditional lecture. As a consequence, the use of an inverted classroom could lead to an increase in student learning.

### **Elements of the Inverted Classroom**

A review of literature led to an identification of elements that may be included in an implementation of an inverted classroom. Some of these elements may be appropriate for an inverted classroom in mathematics, and for college algebra in particular. This section presents an overview of these elements. While the inverted college algebra classroom designed and implemented in this research included three specific elements, other inverted classrooms may benefit from the inclusion of a different subset of the elements discussed below in its design.

The inverted classroom, as defined by Lage et al. (2000), divides events that place as part of an inverted classroom into two categories: those events that take place outside the classroom and those events that take place inside the classroom. The elements described in the literature that are discussed below are categorized in the same manner.

## **Elements Outside the Classroom**

In an inverted classroom, events that traditionally take place inside the classroom instead take place outside the classroom. Hence, outside the classroom one might find elements such as viewing an oral presentation, taking notes, and participating in class discussion.

**Video viewing.** As Bowen (2006) explained, the traditional lecture model was once the most efficient model for teaching. Before textbooks and the Internet, “a lecture was the cheapest and most efficient mode of communicating new knowledge to a large group of students” (Bowen, 2006, p. 4). Advancements in technology now make possible different modes of communication. In particular, lectures can be turned into videos and provided to students over the Internet.

Constructivist learning theory supports the idea of providing content through online video. Students are able to pause or replay parts of the videos, giving students control over timing and the speed at which content is delivered. This allows students to learn at their own pace. According to constructivism, learning involves active restructuring of how one thinks and the relation or connection of new knowledge to previous knowledge (Pelech & Pieper, 2010). When watching a video students can take the time necessary for these learning processes. In fact, only the student can determine if learning has occurred, or if the video needs to be paused at a certain point, or whether a particular part of the video needs to be repeated. Constructivism views knowledge as “an autonomous and subjective construction” (Pelech & Pieper, 2010, p. 8). Constructivism suggests that it is the student, not the instructor, who should control the delivery of content.

Video viewing (including the associated navigation within the videos) addresses at least five of the learning principles listed above under the heading Principles of Constructivism. Video viewing can provide the experiences and opportunities mentioned in Principles 1, 5, 6, 8, and 10.

***Videos in microeconomics.*** As described above under the heading Development of the Inverted Classroom, Lage et al. (2000) made videotaped lectures available to students in computer labs, and students could view videos at home if they had tapes copied by the university's audio-visual department. Information about the videotaped lectures was available to students at the class website.

***Videos in computer science for engineers.*** Foertsch, Moses, Strikwerda, and Litzkow (2002) reversed the homework/lecture paradigm in a large computer science course for engineers. The enrollment in the course was 250-300 students per semester. The authors used a custom streaming video and multimedia application called eTEACH to replace in-class lectures with videotaped lectures and other materials that students viewed on the Internet.

The eTEACH application combined a streaming video presentation, PowerPoint slides, and a table of contents. Students could view “any part of the presentation or return to previously viewed parts with the click of their computer mouse” (Foertsch et al., 2002, p. 269). This created time in class for small team problem-solving sessions facilitated by professors and a teaching assistant. A “course evaluation over two semesters showed that students who took the online lecture version of the course gave significantly higher ratings to all aspects of the course, including lecture usefulness, professor responsiveness, the course overall, and the instructor” (Foertsch et al., 2002, p. 267).

***Online lectures in music.*** Bowen (2006) recommended removing the recitation of content (the lecture) from the classroom. As Bowen stated “if your classes are only lectures and exams, you might as well be teaching online” (p. 4). Delivering lectures online allows time for increased human interaction in the classroom. Bowen identifies this human interaction as a demonstrable learning benefit of residential colleges.

***Establishing the need for navigation.*** Mertens, Ketterl, and Vornberger (2007) stated that lecture recordings can serve as a main content source in a number of didactic scenarios. The authors stress the importance of navigational capability in the presentation. Learning time is used more efficiently when, besides being able to replay the lecture as often as required, users can skip known parts and directly navigate to relevant parts of a recording. The authors presented the virtPresenter lecture recording system to automate production of web lectures. The discussion by Mertens et al. of the importance of navigational capability led to the inclusion of this feature in the videos used for this research.

***Podcasts in computer science special topics.*** In a conference paper Gannod (2007) described the teaching of an inverted special topics course on web services and service-oriented architecture that was cross-listed as both an undergraduate and graduate course. Gannod used podcasting to facilitate this inverted classroom. In a later paper, Gannod, Burge, and Helmick (2008) state:

A “podcast” is a term used to describe the use of a subscription-based broadcasting of video and audio content using *really simple syndication*. The original intent was for the use of podcasting to push content to owners of Apple iPods, although podcasts are not limited to use . . . by just iPod owners. (p. 778)

Gannod provided online podcast videos which included audio, PowerPoint slides, screen recordings showing the use of software, and talking head lectures. Students were expected to view the podcast videos prior to class using either the iTunes music software system as a podcasting client, or a non-podcast client such as a web browser. In the class of 20 students, 85% responded favorably to the inverted classroom structure. “In regards to the use of podcasting as a lecturing medium, students have indicated that the ability to use the play, pause, reverse, and fast-forward capability of the podcast videos beneficial to their ability to learn the material” (Gannod, 2007, p. T1A-2). Students expressed concerns “primarily centered around volume of podcasts, size of video windows in their non-podcast viewer, and the use of the Mac as the demonstration platform (rather than Windows)” (Gannod, 2007, p. T1A-2).

***Podcasts in software engineering.*** Gannod’s 2007 conference paper was followed by a paper by Gannod et al. (2008) presented at another conference. In this second paper Gannod’s computing course is described as the first course to undergo piloting of the inverted classroom for computing at Miami University. Gannod et al. described two more courses in progress that were using similar models. In both courses podcasting was being used as the primary medium for delivering course content, and learning activities were being performed during course contact hours. Gannod et al. reported that based on student perceptions, the inverted classroom appeared to be well-received, although suggestions indicated that the acceptance level was not unanimous. The suggestions also indicated that the viewing of lectures must be incentivized in order to provide motivation for students to prepare for in-class exercises. In conclusion, Gannod et al. state that the inverted classroom “takes advantage of the benefits of both

collaborative learning and distance learning” (p. 785) while at the same time targeting the student of today’s generation.

***Web lectures in user interface design.*** Day (2008) studied the use of web lectures to increase student engagement and active learning as part of his dissertation *Investigating Learning With Web Lectures*. The dissertation work spanned a four-year period during which five naturalistic investigations of student learning with a web lecture intervention were undertaken. These investigations included two formative studies, a large-scale pilot study, and two quasi-experimental studies.

The *web lectures* used by Day (2008) were in some ways different than the presentations of videos that were used in this research. Day defined lecture to be “a slide-based (i.e., PowerPoint), predominantly one-way presentation given by an instructor to multiple students” (p. 2). Day used Microsoft Producer (a plug-in for Microsoft PowerPoint 2003) to integrate video, audio, and PowerPoint slides and then made the presentation (or lecture) available to students over the Internet. Day’s web lectures were slide-based, and the videos showed the instructor explaining the material that appeared on the slides. The video presentations used in this research did not include slides, and instead showed the instructor explaining problems at a whiteboard. The instructor explaining material that simultaneously appears on a PowerPoint slide may be more appropriate for the User Interface Design course in which Day introduced the web lecture intervention than in college algebra which includes a considerable amount of detailed problem solving.

Another difference between the web lecture intervention introduced by Day (2008) and the use of videos in this research is the amount of class time that was



available to the students. In Day's two quasi-experiments, the experimental sections participated in the web lecture intervention, and the control sections were taught using a traditional lecture format. Since the control sections were not required to view the web lectures, there was concern that any difference in performance between sections might be attributable to the additional time on task required of the experimental sections. To balance the required time on task between the two sections, in the experimental section "the total running time of all assigned web lectures was subtracted from in-class time in the form of cancelled class meetings" (Day, 2008, pp. 56-57). This resulted in seven fewer class meetings for the experimental section in each quasi-experiment. The preliminary and primary studies conducted as part of this research, as described in Appendix D, Appendix E, and Chapter 3, did not have experimental designs. There was no need to balance required time on task between an experimental section and a control section, so for the purposes of this research there was no need to cancel any classes.

The web lectures used by Day (2008) were also similar in some ways to the presentations of videos that were used in this research. In Day's synchronized video/slide presentations students could navigate by clicking on links in a table of contents. Similarly, the webpage that delivered videos for this research provided a table of contents as a collapsible menu of links, and students were able to navigate within the video (or start another video) by clicking on a link.

The video player in the web lectures used by Day (2008) had controls for start/stop, forward/backward, forward/backward 10 seconds, forward/backward one slide, and audio volume. The video player for the videos in this research also had appropriate controls for playback, including start/stop control and audio volume controls. The

student was able to jump forward or backward in the video by clicking on the progress bar that appeared along the bottom edge of the video player.

Day (2008) found that although the experimental section in each quasi-experiment attended significantly fewer class meetings, the web lecture intervention produced equivalent or better course performance as well as improved student perception of learning and course enjoyment. In describing the results of his study, Day states that while “our web lecture format could be an effective and efficient alternative to the traditional in-class lecture format for other courses / instructors / institutions” (pp. 130-131), the results found in his study are for a specific course taught by a particular instructor at the a given institution.

***Videos in industrial engineering.*** Toto and Nguyen (2009) describe the design and implementation of an inverted classroom in an industrial engineering course using videotaped lectures. Participants were students in two sections of an industrial engineering course. A total of 74 students consented to participate in the study. The sections were inverted on two instances; survey data was collected during each instance and again at the end of the semester.

Toto and Nguyen (2009) explored students’ perception of the inverted classroom, and wanted to know if students felt that the instructional technique helped their understanding of the course materials and if the strategy should be continued for future semesters. Results from the final strategy survey indicated students generally liked and enjoyed the inverted classroom. The study found that the students felt 30 minutes to be the optimal length for the video lectures. Also students noted that it was somewhat easier to get distracted while watching the video lecture. While students indicated they

preferred attending a live lecture as opposed to a virtual lecture, they also preferred using class time for problem solving and hands-on activities rather than coming to class and attending a lecture.

***Microlectures in engineering.*** Demetry (2010) described the use of pre-recorded multimedia *microlectures* in a large enrollment (N~125) inverted engineering classroom. Microlectures were 10-15 minutes in length and focused on a specific instructional objective. Typically two or three of the microlectures were assigned for each class. Students watched the microlectures covering foundational material and took a five-question test prior to coming to class. The time created allowed for active learning activities in the classroom.

***Podcasts in information and computer sciences.*** As part of his doctoral dissertation in computer science, Nickles (2010) investigated the use of slide-based podcasts in an inverted classroom to promote active learning in a large enrollment Information and Computer Sciences (ICS) course. Nickles defined podcast more specifically than Gannod (2007) for the purposes of his study. Nickles defined podcasting as “a collection of MPEG-4 files offered by a subscription feed or website that integrates audio, video, and content specific metadata that is crafted for the capabilities of pocket media players” (p. 13).

The sample for the study conducted by Nickles (2010) were the students enrolled in ICS101 at the University of Hawai‘i at Mañoa in Fall 2009. The usual enrollment in ICS101 consisted of mostly freshmen and sophomores. Nevertheless, it was diverse for higher education, typically including a small number of graduate students, university faculty and staff, a few senior citizens, and a wide range of declared majors.

Nickles (2010) made the podcasts more interactive by subdividing the content into logical sections (or chapters) and providing a menu to navigate among the sections (see Figure 1). Nickles provided navigational capability by taking advantage of the MPEG-4 file format that allows the file to contain indexed metadata. The MP4/iPod + iTunes platform presented this indexed metadata in the form of a menu containing chapter text titles and thumbnail reductions of the chapter slide image. Students could navigate within the synchronized slide/audio podcast by using the mouse to highlight the chapter data displayed in the menu and then clicking to jump to the desired destination.

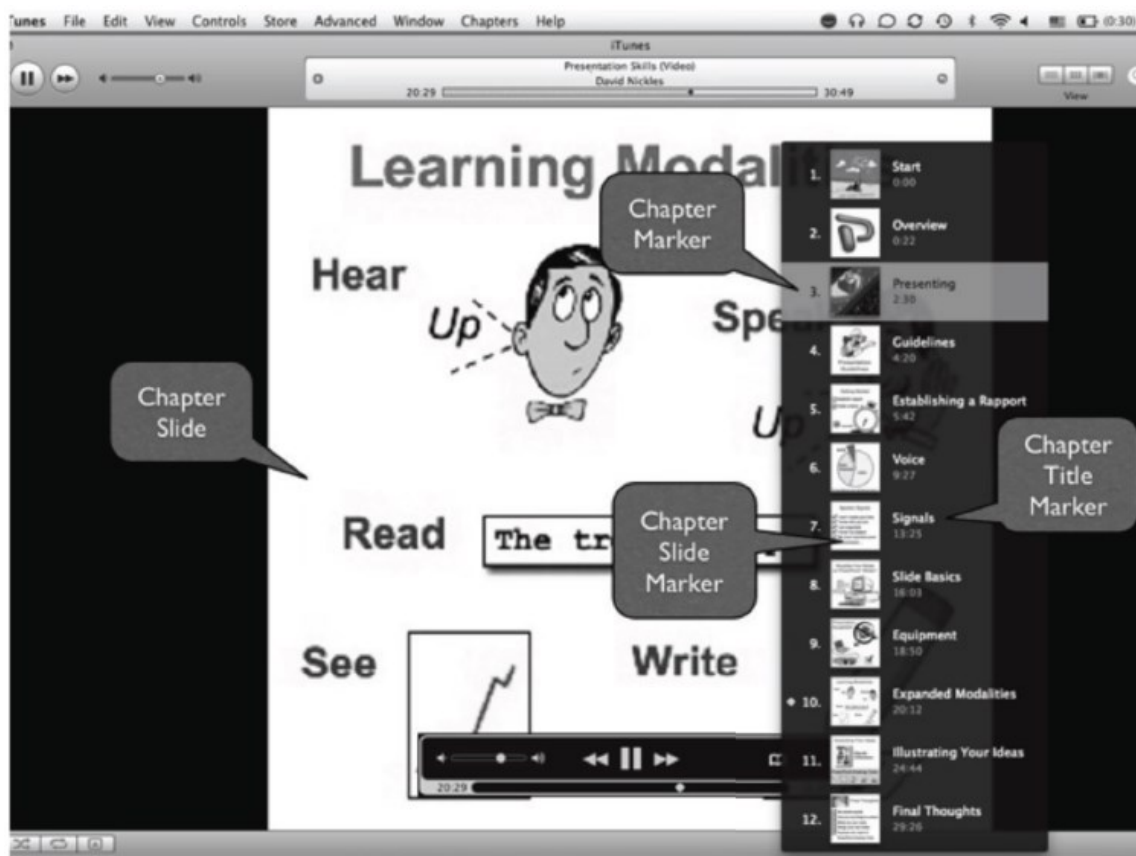


Figure 1. Lecture Podcast Annotated to Highlight the Chapter Metadata Features.  
 SOURCE: From *Informing Complex Interventions in Technology-Rich Teaching Ecologies: A Study of Structured Lecture Podcasting to Facilitate Active Learning* by David James Nickles, copyright © 2010.

Nickles referred to the display of menu data and the navigational capabilities offered by the podcast as *chapter features*. Student acceptance and use of chapter feature technology were of central concern in Nickle's dissertation. The term chapter features appears in each of the four research questions addressed by Nickles.

Nickles (2010) explored (a) students' acceptance of the podcasts with chapter features as a different interface to the lecture material, as well as (b) the students' report of active learning behaviors in use of the chapter features technology. Nickles did not

explore the students' response to having an opportunity for other activities in class due to the time-shift of the lecture.

In discussing student acceptance of the chapter features technology, Nickles (2010) stated that more than half of the students reported engaging chapter features during their lecture studies. The data gathered indicated that 60% of students reported some level of agreement with intending to use the technology, including 19% of the students who strongly agreed.

In the inverted classroom described by Nickles (2010) students were expected to listen to lecture podcasts weekly. Comprehension was measured with weekly online listening quizzes. Each listening quiz was generated randomly from a question bank and contained multiple-choice items. Each quiz measured the student's comprehension of that week's lecture podcast content.

Nickles (2010), however, pointed out that quiz and exam scores alone may not be good indicators of learning outcome. He stated the following in his dissertation:

Quiz and exam scores are a common way of accessing learning outcomes because these measures are easily available and minimize disruption of the teaching ecology. However, these standardized assessments are considered a weak inquiry method and many studies now consider various methods to conceptualize and assess learning through inquiry of content knowledge, comprehension, communication and fluency skills, and socio-emotional learning goals—including decision making, social interaction, participation, alternative perspectives and respect (Cochran-Smith, Barnatt, Friedman, & Pine, 2009). (p. 183).

Nickles notes that integrating self-assessment and social problem solving into the course activities would lead to stronger inquiry and assessment methods.

***Vodcasts in chemistry.*** Instructional videos have been used to invert high school classrooms. High school chemistry teachers Jonathan Bergmann and Aaron Sams recorded, annotated, and posted video lessons online (Tucker, 2012). Bergmann and Sams “still provide direct instruction, but not during class. Students watch online lectures at night and teachers spend class time connecting individually with students—through hands-on activities, projects, and tutoring” (Brunsell, 2011, p. 10). As quoted in Kappan magazine, Sams said

Under a traditional lecture model, kids would write down everything that you wrote on the board, and they would go home and try to interpret that and translate that into the assignment that you gave them to do at home, and there’s a disconnect there. They were having trouble connecting what they had been taught in class with what they were supposed to apply at home. What we realized is that’s when students need us present, when they’re trying to bridge that gap. They need us there to help them understand the content, not to deliver the content. (“Flipping classrooms”, 2011)

According to Sams, videos have changed kids’ attitudes toward doing homework. As quoted by Educational Horizons magazine:

I think their homework has value now. If a kid doesn’t do the homework, which is to watch a video, that’s just like cutting class. They’re going to be behind. In addition, the kids who are struggling to connect their learning with their assignments appreciate being able to just have access to an expert in the room

when they're supposed to be doing their work instead of going home and getting frustrated. ("Flipping the classroom", 2011, p. 7)

At the time of this writing Jerry Overmyer has a website at <http://mast.unco.edu/programs/flipped> devoted to teaching educators how to use online videos to invert their classrooms as done by Jonathan Bergmann and Aaron Sams.

***Videos in intermediate algebra.*** As part of his dissertation, Long (2010) attempted to increase success rates, retention rates, and test scores in two Fall 2009 sections of an intermediate algebra course at a California community college. The study conducted by Long employed a mixed methods action research design. The action plan included two fundamental components: providing students with online instructor-made educational mathematics videos and proactively striving to create a sense of community within the student participant groups. "By delegating some mathematical content to videos viewed outside of class time, in-class time was made available for engagement in community engendering activities" (Long, 2010, p. i).

It probably should be noted that while only 51% of the students at the 110 colleges in the California Community Colleges system are 24 years of age or less, in the study conducted by Long (2010) 90.2% of the participants were 24 years of age or less. Hence, the students studied by Long were closer in age to that of the traditional college student.

For the study conducted by Long (2010), approximately 200 short (generally two to four minute) videos were produced and made available to students using software which recorded voice and screen content. To assess the effect of the educational mathematics videos on participant success Long considered the possibility of a



correlation between the number of mathematics videos a student watched and the student's corresponding course grade. As Long noted, it was not possible to determine the number of mathematics videos each student watched. However, the videos were accessed through Blackboard, and Long explained that Blackboard was configured to record the number of times each student accessed the video entry screen. "A video hit represents access to the video entry screen, not the number of videos watched in that study session" (Long, 2010, p. 123). Nevertheless, the number of such hits may relatively indicate the number of videos watched, and this number was used to simulate the quantity of videos watched.

Long (2010) performed a linear correlation analysis on the number of video hits and total points earned in the course. For a sample size of 58, the analysis produced a Pearson correlation coefficient  $r = .263$  and a  $p$  value  $p = .023$ . Long stated that the statistics indicated the existence of sufficient evidence to support the claim that there is a positive linear correlation between video hits and total points earned. In other words, assuming that the number of video entry screen hits corresponded to number of videos watched, Long found that students that watched more mathematics videos tended to make higher course grades.

Long (2010) reported that the implementation of the first iteration of the action plan was very successful from a qualitative perspective and achieved several statistically significant improvements from a quantitative perspective. Long anticipated enhanced success in a future iteration of an improved action plan.

**Note taking.** An element that may play a significant role in student learning in an inverted classroom is taking notes while viewing videos. As Mundsack, Deese, Deese,

and Morgan (2003) explained, “being a good listener and taking good notes go hand in hand” (p. 44). Taking good notes from lectures requires the student to have an alert mind. “Time spent developing note-taking skills is time well spent” (Mundsack et al., 2003, p. 44). Moreover, when viewing videos of recorded lectures students may be able to pause or replay parts of the video when taking notes. Hence, a supplementary benefit of taking notes while viewing videos may be the slowing down of content delivery, making it easier for the student to understand the lecture. Slowing down content delivery allows time for more reflection during the note-taking process.

Constructivist learning theory supports the idea of taking notes while viewing videos. Note taking addresses Principles 1, 3, 5, 6, 7, 8, 9, and 10 listed above under the heading Principles of Constructivism.

***Notes in materials science.*** Demetry (2010) explained that students were to take notes as part of their individual preparation before coming to their materials science class. Taking notes before class helped students attain the specific instructional objectives of the microlectures.

***Notes in chemistry.*** Tucker (2012) reported a few details of Jon Bergmann’s implementation of an inverted classroom. Bergmann, a high school teacher who teaches in an inverted chemistry classroom, checks that students have taken notes from the video. He also requires students to come to class with a question. As the year progresses, Bergmann sees students “asking better questions and thinking more deeply about the content” (Tucker, 2012, p. 82).

**Reading.** Students may be more encouraged to read if participating in an inverted classroom. In traditional courses, “students generally read the textbook only after the

lecturer has covered the topic (if ever)” (Crouch & Mazur, 2001). However, the active learning activities that may take place in an inverted classroom such as discussion, experiments, and cooperative problem solving require background knowledge and thus emphasize to the student the importance of being prepared for class.

Reading as a learning activity is supported by constructivism. Reading can provide the experiences and opportunities mentioned in Principles 1, 6, 7, 8, 9, and 10 listed above under the heading Principles of Constructivism.

***Reading in microeconomics.*** Reading was expected of students in the inverted classroom described by Lage et al. (2000). Students were also expected to complete simple worksheets before attending the first class period on a topic, which may have provided motivation to complete the reading. The inverted classroom implemented by Lage et al. is described in more detail above under the heading Development of the Inverted Classroom.

***Reading in communication arts.*** Baker (2000), in defining the *classroom flip*, advocated moving lecture material out of the classroom through online delivery. Baker reported that web course management software could be used to deliver content through webpages. “With the essential class content available online, the professor is now free to use class time for other activities” (Baker, 2000, p. 13). Baker suggested using web course management software to also make online quizzes over readings available to the students. The quizzes provide “an incentive for students to read the material and be prepared for class discussion that day” (Baker, 2000, p. 13). Baker suggested beginning the class “by discussing any questions the students have from the assigned readings for the session” (p. 13). Positive student perceptions of the flipped classroom

implementation were reported by Baker in two classes: Graphic Design for Interactive Multimedia and Communication in the Information Age.

***Reading in physics.*** Crouch and Mazur (2001) reported on teaching calculus- and algebra-based introductory physics courses for non-majors over a ten year period. The authors reduced the amount of time devoted to traditional lecture and created time in class for engaging learning activities by assigning reading to be completed by students before coming to class. To provide incentive to complete the reading the authors had students take in-class reading quizzes. Since the quizzes did little to help the students think about the reading, in 1996 and 1997 the reading quizzes were replaced with summary writing assignments. However, most students did not write effective summaries. The reading incentives introduced in 1998 were found most effective, and were three-question web-based assignments. The three open-ended questions probed difficult aspects of the reading and asked students what they found difficult, confusing, or interesting about the reading. Scoring based on effort rather than correctness vastly reduced the effort needed to score the assignments.

***Reading in music.*** Bowen (2006), a music professor, recommended reducing the use of technology inside the classroom and increasing the face-to-face interaction between the instructor and students. He called for instructors to “teach naked” by “moving some of the content, removing some of the personal safety net, and simply trying to connect with our students” (p. 5). Bowen recommended instructors take measures to ensure that students arrive prepared for class. Bowen suggested creating an online mini quiz for each assigned reading, and then making the quiz due an hour before class.

***Reading in materials science.*** Demetry (2010) asked students to augment the reading of instructor-provided lecture notes outside class with textbook reading. Students were expected to then complete an online assignment consisting of two open-ended questions before coming to class.

**Online discussion.** Students may communicate with each other asynchronously through the Internet. Previously called bulletin boards, forums allow students to post messages that can be read by the other students in the class. Conversations that pertain to a particular topic are usually contained in a *thread*.

Students can take time to think about, and perhaps read about, the topic under discussion before posting a message. Having time during a discussion to learn individually may be beneficial according to cognitive constructivism, which has greater focus on the individual's internal creation of knowledge (Brainerd, 2003).

Online discussion is virtual social interaction that involves other students and possibly the instructor. This online interaction could be beneficial according to social constructivism, although this is not as clear since the social interaction occurs over a computer network.

In general, constructivism supports the idea of students learning from each other via online discussion. This can be realized by noting that online discussion can offer the experiences and opportunities mentioned in Principles 1, 2, 3, 6, 8, 10, and 11 listed above under the heading Principles of Constructivism.

***Bulletin board in microeconomics.*** The website provided by Lage et al. (2000) in their implementation of an inverted classroom provided tools for online

communication. Students could post messages at the bulletin board, and instructors were available to answer questions at certain times of the week.

***Threaded discussion in communication arts.*** Baker (2000) recommends the use of threaded discussion to extend classroom conversation. Students “have an opportunity for more interactive discussion than is possible in class” (Baker, 2000, p. 12). Baker points out that many students who are silent during in-class discussion not only are more likely to contribute to discussion given time to prepare, edit, and rewrite their comments, but that their contributions are usually well thought-out and carefully articulated. Thus, the whole class benefits from the added participation of these students.

### **Elements Inside the Classroom**

In an inverted classroom, events that traditionally take place outside the classroom instead take place inside the classroom. Hence, inside the classroom one might find elements such as working with others to solve problems, participating in discussion with classmates, or engaging in hands-on activities.

**Group work.** An inverted classroom provides time for students to apply and practice what they have learned. The most appropriate assignments for group work may depend on the discipline.

According to social constructivism, the role of other individuals and social interaction are essential in the process of constructing knowledge and understanding (Pritchard & Woollard, 2010). In groups students have opportunities to learn from other students and to reinforce their own knowledge when teaching others.

Group work addresses at least eight of the learning principles listed above under the heading Principles of Constructivism. Group work can provide the experiences and

opportunities mentioned in Principles 1, 2, 3, 6, 7, 8, 10, and 11 listed above under the heading Principles of Constructivism.

***Group work in microeconomics.*** Group work inside the classroom led to student discussion and collaborative learning in an early implementation of an inverted classroom as described by Lage et al. (2000). Students often formed groups, discussed their answers to assigned questions, and then presented their work to the rest of the class.

***Group work in communication arts.*** Baker (2000) suggests allowing students to work together in collaborative groups. By selecting activities that involve the students in creative thinking students can “take application beyond the critique stage” (Baker, 2000, p. 14). These activities seem especially appropriate for the graphic design and communication classes studied by Baker.

***Group work in physics.*** In the introductory physics courses discussed by Crouch and Mazur (2001), students attended a weekly two-hour workshop. During the second half of the workshop the students had opportunity to work on selected problems from the homework. Students worked in groups as the instructor circulated around the classroom. The instructor would ask students to explain their work and ask students questions to lead them to the right answer. The students were required to turn in their own written solutions to the homework problems at the end of the week, and the solutions were scored individually on correctness.

***Group work in industrial engineering.*** Toto and Nguyen (2009) reported on the use of problem solving and hands-on activities during inverted classroom sessions in an industrial engineering course. Students worked together in groups participating in these active learning activities during time made available by moving lectures outside of the

classroom. “Students noted that they felt prepared to complete problems in class after watching the video content and felt that . . . having more time to work in groups in class was a beneficial use of class time” (Toto & Nguyen, 2009, p. T4F-3).

***Group work in materials science.*** Demetry (2010) assigned students to work in teams of four during a materials science class. After group members compared and discussed their responses to the five-question test completed prior to coming to class, the instructor reviewed common misconceptions and summarized key concepts. Students on teams then worked together to complete a problem set with higher-level application problems. During class the instructor walked around providing assistance and whole-class clarification when needed. Occasionally the instructor posed a question to the students in the class and asked the students to indicate their responses with clickers. The responses allowed the instructor to see how teams were thinking about questions on the problem set and provide feedback.

***Group work in developmental mathematics.*** Group work was one of the elements of the inverted developmental mathematics classes taught by McDaniel (McDaniel & Caverly, 2010). The group work challenged students at a more conceptual level. “Because in-class direct instructional activities are removed, time is available for student teams to actively analyze and synthesize homework problems, to examine the process of learning math, and to increase the amount of student-to-student and student-to-professor dialogue” (McDaniel & Caverly, 2010, p. 40).

**Board work.** Having students write problem solutions on the board gives students a chance to share solutions with each other. Students can benefit from in-class explanations of the solutions, which can be provided either by other students or the



instructor. Students may be asked to either present solutions individually or in teams. Grading the board work can motivate students to participate and encourage students to find correct answers beforehand. Presentations at the board give students a chance to practice using correct vocabulary in front of their peers to explain mathematics. A presentation may lead to a class discussion.

Social constructivism contends that other individuals and social interaction are fundamental to learning (Pritchard & Woollard, 2010). With board work students have opportunities to interact and learn from everyone in the classroom, including the instructor.

Constructivism in general supports the idea of students learning through board work. Board work addresses Principles 1, 2, 3, 6, 7, 8, and 11 listed above under the heading Principles of Constructivism.

***Board work in developmental mathematics.*** An inverted classroom model used by McDaniel in developmental mathematics included scored board work “for students to explain their developing knowledge” (McDaniel & Caverly, 2010, p. 40). A common mathematical mistake made during an individual or team presentation may be a good opportunity for other students or the instructor to explain the mistake and clear up any misconceptions.

**In-class discussion.** In an inverted classroom more time is available for discussion. Participation in class discussion actively engages students in learning, and through discussion students have the opportunity to share knowledge with each other.

Discussion involves interaction between individuals. According to social constructivism, this social interaction is essential for successful cognitive and intellectual growth (Pritchard & Woollard, 2010).

Constructivism in general supports the idea of students learning through in-class discussion. This can be realized by noting that in-class discussion can offer the experiences and opportunities mentioned in Principles 1, 2, 3, 6, 7, 8, 10, and 11 listed above under the heading Principles of Constructivism.

***Discussing topics in communication arts.*** Baker (2000) suggests “inviting students to add to the assigned material by drawing from their own experience, other reading or what they have learned in other classes” (p. 13). Students are recognized as co-contributors of knowledge, and by drawing upon insights gained from their own life experience the content can be placed in a real-world setting.

***Discussing topics in physics.*** Crouch and Mazur (2001) used peer instruction to engage students in discussion. As the authors explained:

A class taught with PI [peer instruction] is divided into a series of short presentations, each focused on a central point and followed by a related conceptual question, called a ConcepTest . . . , which probes students’ understanding of the ideas just presented. Students are given one or two minutes to formulate individual answers and report their answers to the instructor. Students then discuss their answers with others sitting around them; the instructor urges students to try to convince each other of the correctness of their own answer by explaining the underlying reasoning. (Crouch & Mazur, 2001, p. 970)

Once students had discussed their answers with others for a few minutes, the instructor would poll students for their answers again, reveal the correct answer, and then move on to the next topic. Students were expected to read and complete an assignment prior to coming to class to create time for the ConcepTests.

***Discussing topics in engineering statics.*** Papadopoulos, Santiago-Román, and Portela (2010) used online pre-lecture modules consisting of PowerPoint slides and interactive exercises to deliver all core content in two sections of statics in Fall 2009. This resulted in the lecture itself containing less direct lecturing and more critical discussions and activities. The results of a survey conducted at the end of the semester indicated that 81% of the students preferred the inverted format with a problem-session and no solution manual over a single other alternative of a traditional lecture-only class with a solution manual and no problem-session.

**Hands-on activities.** Students actively involved in the learning task learn more than when they are passive recipients of instruction (Cross, 1987). Hands-on activities in the classroom give students a chance to be actively involved. Moreover, well-chosen activities may clearly demonstrate the principles and concepts being studied.

Social constructivism may support in-class hands-on activities in two ways. Hands-on activities may involve the participation of several students working together. Such activities promote the social interaction between students necessary for learning (Pritchard & Woollard, 2010). Students engaged in hands-on activities in the classroom individually can benefit from direct interaction with the instructor or a teaching assistant.

Hands-on activities address at least six of the learning principles listed above under the heading Principles of Constructivism. Hands-on activities can provide the experiences and opportunities mentioned in Principles 1, 5, 6, 7, 8, and 9.

***Hands-on activities in physics.*** Crouch and Mazur (2001) described the use of cooperative activities in discussion sections of introductory physics. During the first half of a weekly two-hour workshop students practiced conceptual reasoning by engaging in hands-on activities. In their article Crouch and Mazur provided numerous references to publications that provide material for innovative approaches to such teaching. Besides material such as tutorials and problem solving sheets for active learning, references are included to literature in which Socratic dialogue and cooperative grouping is discussed.

***Hands-on activities in software engineering.*** Gannod et al. (2008) described the use of hands-on activities during class time in inverted software engineering classrooms. A laboratory dominated experience is mentioned as particularly appropriate in programming intensive classes. Course contact hours in these courses can be devoted to programming assignments performed in class. In comparing learning activities for traditional and inverted classroom models of instruction, Gannod et al. found that a much higher number of assignments is possible with the inverted classroom. Consequently it is easier to have learning activities which address specific outcomes, instead of traditional homework assignments or projects that might target several learning outcomes at once. Also, students in many instances can be provided with immediate feedback during the in-class activity. Assignments of greater depth may be allowed to span two class periods, or may be started in class and then completed at home.

### **Deficiencies in Current Inverted Classroom Research**

Deficiencies in the research concerning the inverted classroom are identified to show how this research extends, modifies, or contradicts previous work. This identification of deficiencies also provided guidance in the design of the preliminary and primary studies for this research so that they could better augment current inverted classroom knowledge.

Inverted classrooms have appeared in higher education in various disciplines. Studies were previously cited involving inverted classrooms in chemistry, communication arts, computer science, economics, engineering, music, and physics (Baker, 2000; Bowen, 2006; Crouch & Mazur, 2001; Demetry, 2010; Foertsch et al., 2002; Gannod, 2007; Gannod et al., 2008; Lage et al., 2000; Nickles, 2010; Papadopoulos et al., 2010; Toto & Nguyen, 2009; Tucker, 2012). Two other studies previously cited involved the use of an inverted classroom in developmental mathematics (Long, 2010; McDaniel & Caverly, 2010). However, no research literature has been found regarding the use of an inverted classroom in college algebra.<sup>3</sup>

Also, of the studies cited, only in the study described by Long (2010) was the influence of an element of an inverted classroom on student learning measured. Long found a correlation between video viewing and grade outcomes.

This research addresses these deficiencies in current inverted classroom research by investigating an inverted classroom for college algebra. The detailed description of the design, implementation, and evaluation of an inverted college algebra classroom

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<sup>3</sup> Details concerning this search appear in Appendix C.

contained in this document may benefit instructors, departments, institutions, agencies, and governments.

### **Summary**

This chapter surveyed research literature relevant to the inverted classroom. It began with a description of a theoretical framework that supports and informs this research. A close look was then taken at the inverted classroom presented by Lage et al. (2000). The chapter reviewed other studies involving inverted classrooms. Deficiencies in research concerning the inverted classroom were identified.

Theoretical support for the inverted classroom may be better understood by considering principles of constructivism. The principles considered in this research were provided by Pelech and Pieper (2010) and appeared above under the heading Principles of Constructivism. Each of the 12 principles except Principle 4 and Principle 12 is addressed by individual elements of the inverted classroom. The inverted classroom as whole addresses both Principle 4 and Principle 12 by allowing the inclusion of a variety of elements inside and outside the classroom. A variety of elements gives students the opportunity to develop different forms of knowledge in a variety of domains as described by Principle 4. A variety of elements also allows instructors to engage students in real-world activities that use real-world tools, and thus provide students with opportunities to create authentic products that exist in today's society as suggested by Principle 12.

This chapter ends with two tables that list elements of the inverted classroom. The tables include the means through which each element contributes to learning and an identification of those principles that indicate how constructivism supports the element.

Table 1 includes elements of the inverted classroom that take place outside the classroom. Time available to students outside the classroom allows for the internal creation of knowledge as described by cognitive constructivism.

Table 1

*Outside Elements Supported by Cognitive Constructivism*

Element	Means of Learning Contribution	Principles of Constructivism
Video viewing	When viewing videos outside the classroom students can take the time necessary for learning, pausing and replaying parts of the video when desired.	1, 5, 6, 8, 10
Note taking	Additional opportunity is provided for knowledge construction when taking notes outside the classroom. Pausing videos can allow more time for note taking and contemplation during the process.	1, 3, 5, 6, 7, 8, 9, 10
Reading	Students can read at their own pace for comprehension and efficiency. Ample time can be allowed for reflection and engagement in learning processes.	1, 6, 7, 8, 9, 10
Online discussion	Outside the classroom students have more time to engage in learning processes by thinking about a topic under discussion before posting a message. Also, outside class students may have time to investigate topics to make more informative contributions to the discussion.	1, 2, 3, 6, 8, 10, 11

Inside the classroom students may learn either individually or with others. While cognitive constructivism has a greater focus on the individual's construction of knowledge, social constructivism contends that other individuals and social interaction are fundamental to learning (Pritchard & Woollard, 2010). Table 2 presents elements of

the inverted classroom that take place inside the classroom, and explains for each element how interaction with other students can be expected to lead to increased learning.

Table 2

*Inside Elements Supported by Cognitive and Social Constructivism*

Element	Means of Learning Contribution	Principles of Constructivism
Group work	In groups students can learn from their peers and reinforce their own knowledge by explaining material to others.	1, 2, 3, 6, 7, 8, 10, 11
Board work	Presenting problems at the board gives students a chance to share solutions with each other. During presentations students have a chance to interact and learn from everyone in the classroom, including the instructor.	1, 2, 3, 6, 7, 8, 11
In-class discussion	Class discussion can actively engage students in learning. During discussion students have the opportunity to share knowledge with each other.	1, 2, 3, 6, 7, 8, 10, 11
Hands-on activities	Hands-on activities give students a chance to be actively involved in their learning with other students or the instructor. Moreover, well-chosen activities may clearly demonstrate the principles and concepts being studied.	1, 5, 6, 7, 8, 9

This chapter reviewed research literature relevant to the inverted classroom. The knowledge gained informed the design of an inverted classroom for college algebra. The inverted college algebra classroom is described in the next chapter.



## **CHAPTER 3**

### **METHODS**

The purpose of this research was to (a) ascertain how students perceive an inverted college algebra classroom, (b) identify any relationship between perceived learning contributions of various elements of an inverted college algebra classroom and grade outcome, and (c) identify any relationship between levels of engagement with various elements of an inverted college algebra classroom and grade outcome. Chapter 3 describes the basic plan of the research.

The chapter begins by describing the groups of individuals that constituted the population and the sample for the study. The college algebra course as it is taught at the university is then introduced. The intervention that defined the structure of the classroom for the study, an inverted instructional approach to college algebra, is described. The instruments used in the study are presented, and the reliability and validity of each instrument is discussed. An outline of the methods employed in the collection of both qualitative and quantitative data is followed by an overview of the techniques used to extract information from the collected data. Validity, reliability, and ethical considerations of the study are addressed, the rights and welfare of human research subjects are recognized, and then the chapter is briefly summarized.

Two preliminary studies informed the design of the inverted classroom described in this chapter. Preliminary Study One is described in Appendix D, and Preliminary Study Two is described in Appendix E.

### **Population and Sample**

The population for this study consisted of all students at the university enrolled in college algebra on the 12<sup>th</sup> day of class in Fall 2012. The sample for this study consisted of those students in the population enrolled in the two sections of college algebra taught by the researcher in Fall 2012.

Demographic data were obtained from the university registrar's office to describe the students in the population and the sample. The characteristics of students in the population and sample that are reported in Chapter 4 include ethnicity, class (such as freshman), and gender. Characteristics of students in the sample are compared to characteristics of students in the population to see if it might seem reasonable to expect the results of this research to generalize to future populations of college algebra students at the university. The report of student characteristics in Chapter 4 may also allow an investigator to better determine whether the results of the study are likely to transfer to another situation.

### **The College Algebra Course**

The college algebra course is defined by the university's mathematics department, and the course description given in the undergraduate catalog is similar to the following.

College Algebra. (3-0) A course covering linear and quadratic equations, inequalities, word problems, functions, logarithms, systems of equations and other college algebra topics as time permits. Prerequisite: MATH 1311 with a grade of

CR or a grade of C or higher, ACT Mathematics score of 21 or more, SAT Mathematics score of 480 or more, Accuplacer College Mathematics score of 63 or more, Compass Algebra score of 66 or more. (Texas State University, 2012, p. 360)

The prerequisite course identified as MATH 1311 is a developmental course in basic mathematics designed to prepare students for college-level mathematics. MATH 1311 has its own prerequisites, and any student that fails to satisfy the prerequisites for both college algebra and basic mathematics may enroll in MATH 1300, the first course in the developmental sequence. MATH 1300 provides an introduction to algebra at a pre-college level.

The departmental syllabus provides more information regarding the content of the college algebra course. The syllabus lists six topics included in the course, along with subtopics, and a suggested time frame for completing each topic. Topics included in the course are equations and inequalities, functions and graphs, polynomial and rational functions, exponential and logarithmic functions, systems of linear equations in two and three variables, and matrices. The textbook chosen by the department conveniently contained chapters that corresponded with the topics listed in the departmental syllabus. Moreover, the subtopics explained in each chapter of the textbook corresponded with the subtopics that appeared under each topic in the department syllabus. Consequently, the course curriculum was designed to closely follow the textbook. The complete departmental syllabus, including a listing of all subtopics, is contained in Appendix F.

### **An Inverted Classroom for College Algebra**

A theoretical framework based on the learning theory of constructivism guided the design of an inverted classroom for college algebra. Activities in the design can be categorized as either elements or assessments. Elements of the inverted classroom were activities in which students participated primarily for the purpose of learning.

Assessment activities, besides providing a measurement of learning, were designed to encourage students to gain a conceptual understanding of college algebra.

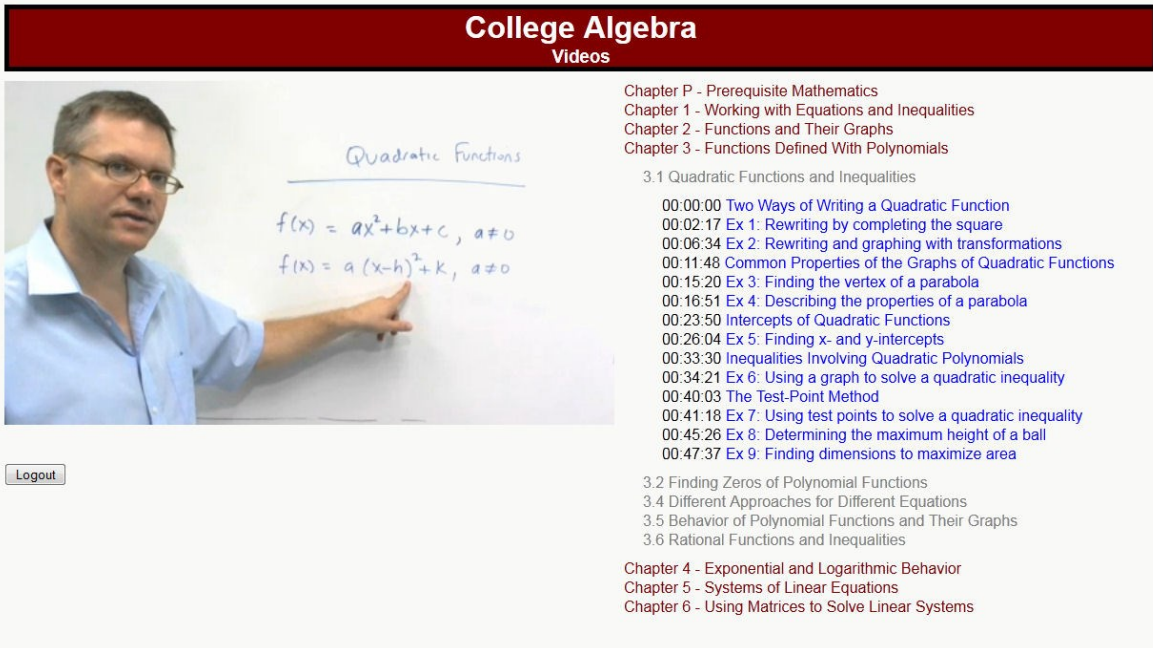
#### **Elements**

Three elements were chosen for inclusion in the inverted classroom: video viewing, note taking, and problem solving. For each textbook section included in the course curriculum, students were expected to take notes while viewing the corresponding video prior to coming to class. In class students sat in groups of four and worked on problems individually and collaboratively.

The time made available by moving the delivery of content outside class allowed students to interact and learn from each other as they solved problems in class. Also, the classroom structure allowed the instructor to circulate among the students offering explanations and assistance with problems. These three elements of an inverted classroom: video viewing, note taking, and problem solving, were the elements investigated in this research.

**Video viewing.** To allow the instructor to act primarily as a “guide, facilitator, and coach” (Pelech & Pieper, 2010, p. 8), the instructor produced a complete set of videos. The instructor explains course content in the videos, and these videos were made

available to students via the Internet. An image of the webpage that provided students with access to the videos appears in Figure 2.



**College Algebra**  
Videos

Quadratic Functions

$$f(x) = ax^2 + bx + c, a \neq 0$$

$$f(x) = a(x-h)^2 + k, a \neq 0$$

Chapter P - Prerequisite Mathematics  
 Chapter 1 - Working with Equations and Inequalities  
 Chapter 2 - Functions and Their Graphs  
 Chapter 3 - Functions Defined With Polynomials

3.1 Quadratic Functions and Inequalities

- 00:00:00 Two Ways of Writing a Quadratic Function
- 00:02:17 Ex 1: Rewriting by completing the square
- 00:06:34 Ex 2: Rewriting and graphing with transformations
- 00:11:48 Common Properties of the Graphs of Quadratic Functions
- 00:15:20 Ex 3: Finding the vertex of a parabola
- 00:16:51 Ex 4: Describing the properties of a parabola
- 00:23:50 Intercepts of Quadratic Functions
- 00:26:04 Ex 5: Finding x- and y-intercepts
- 00:33:30 Inequalities Involving Quadratic Polynomials
- 00:34:21 Ex 6: Using a graph to solve a quadratic inequality
- 00:40:03 The Test-Point Method
- 00:41:18 Ex 7: Using test points to solve a quadratic inequality
- 00:45:26 Ex 8: Determining the maximum height of a ball
- 00:47:37 Ex 9: Finding dimensions to maximize area

3.2 Finding Zeros of Polynomial Functions  
 3.4 Different Approaches for Different Equations  
 3.5 Behavior of Polynomial Functions and Their Graphs  
 3.6 Rational Functions and Inequalities

Chapter 4 - Exponential and Logarithmic Behavior  
 Chapter 5 - Systems of Linear Equations  
 Chapter 6 - Using Matrices to Solve Linear Systems

[Logout](#)

*Figure 2.* Webpage With Corresponding Navigational Links. Students were able to navigate within the video (or start another video) by clicking on links contained in a collapsible table of contents.

Constructivist learning theory claims that learning involves the active restructuring of existing knowledge and relating or connecting new knowledge to previous knowledge (Pelech and Pieper, 2010). While watching a video students could control the delivery of content, allowing students to take as much time as necessary for these learning processes.

The following considerations were made in planning the production and delivery of the videos.

- To allow for communication through the use of hand movements and facial expressions, instructor explanations of the mathematics were video recorded at a whiteboard. It seemed that producing slides for college algebra (which would necessarily include mathematical notation) would be as time consuming, if not more so, than simply recording lectures.
- As mentioned in the previous chapter, Mertens et al. (2007) stressed the importance of navigational capability in web lectures for efficient use of learning time. In this research, each video was presented with an associated table of contents so that students could skip to different parts of the video (or to other videos) simply by clicking on a link.
- Computers have different operating systems (such as Microsoft Windows and Apple's Mac OS X), and students may be more familiar with a particular operating system and have more convenient access to a computer running that operating system. Also, many students today carry hand-held devices such as smartphones and iPods capable to playing videos. The videos were accessible to students on computers running different operating systems and on both desktop and hand-held devices.

Videos were produced with a webcam and video editing software, and a website was created in order to deliver the videos in the most flexible manner possible.

The videos followed the content contained in the textbook closely, covering the same topics and usually presenting examples similar to those found in the textbook. The instructor's explanation of a topic might have differed somewhat from the explanation in the textbook or might have included information not included in the textbook. By

following the textbook closely it was intended that students would be able to refer to the textbook's explanation of the topic if there was any difficulty in understanding the video. Allowing students to use the textbook during in-class problem solving, on the periodic exams, and on the final exam alleviated concerns that students might try to pass the course without obtaining a copy of the textbook.

Some negative consequences of producing videos that closely follow the textbook were realized through the preliminary studies. Every few years, publishers update their textbooks by introducing new content, changing examples, and restructuring existing material. Because of this, the videos produced for this research were short-lived. Also, content is not always equally distributed among sections in the textbook with regard to the amount of time required for teaching. Shorter videos that address specific subtopics could be combined in different ways to allow the instructor to structure the content as he or she sees fit and to allow for a more even distribution of content throughout the semester.

Almost all of the videos produced for this research were around 40 to 50 minutes in length, although one of the videos was as short as 18 minutes, and the longest video was one hour and 20 minutes in length. While the researcher would have preferred videos no longer than about 20 to 30 minutes in length, less total explanation for a given section may have either been inadequate or required the omission of content prescribed for the course.

**Note taking.** Constructivist learning theory supports the idea of taking notes while viewing videos. Each individual has to create their own conceptual structures of

meanings and knowledge (von Glasersfeld, 2005). Taking notes while viewing videos provides students with opportunity to create these structures.

Students were expected to take notes while watching the videos and to submit the notes for credit. Notes were due at the same time that the corresponding problem assignments were due. Late notes were not accepted, however, the lowest three note scores were ignored in calculation of the student's semester average.

Taking notes may have helped students focus on the material being explained in the video. Also, writing what was being said or presented in the video may have reinforced the student's learning. Unlike a live lecture, students could pause, and even repeat, the delivery of content to allow more time for taking notes. The note-taking assignment may also have encouraged students to watch the videos. To encourage students to take good notes the instructor would frequently refer to specific examples or explanations contained in the video while helping students in class. Allowing students to use their notes when taking the periodic exams and the final exam likely further encouraged good note taking.

Some students may have found it useful to take many detailed notes, whereas others may not have found note taking as beneficial. Thus, as long as the set of notes submitted corresponded with the video it received a score of 100. The notes counted only 10% of the student's semester average; however, note taking played important roles in the inverted classroom. Besides the learning gained from the note-taking activity itself, the desire to have useful notes while solving problems and taking exams likely provided incentive for watching the videos.



**Problem solving.** Social constructivism claims that the role of other individuals and social interaction are essential in the process of constructing knowledge and understanding (Pritchard & Woollard, 2010). When working in class to solve problems students can learn from other students and reinforce their own knowledge by explaining solutions to others.

Before each class the tables in the classroom were rearranged so that students could sit together in groups of four. Students quickly became accustomed to moving tables before class to sit in groups, and by the second or third day of class most students had started helping so that all the tables could be moved within a minute or two. At the start of class the instructor assigned problems from the textbook by writing the page number(s) and problem numbers on the board.

Having students sit together in small groups likely gave the students opportunity to get to know each other. Students were permitted to talk with each other and to seek help from each other and the instructor while working on problems. The relaxed atmosphere may have made the class more enjoyable for students and promoted the social interaction necessary for learning (Vygotsky, 1978).

The problem assignments were posted online well in advance of class for any of the students that wanted to get an early start on the assignment. The assignments were posted online using a web tool provided by the university that allows instructors to securely share documents with their students. The problems assigned were similar to the examples shown in the video and discussed in the textbook.

The problems assigned at the beginning of class were not due until the beginning of the next class. With students finishing the assigned problems outside of class, the

instructor could assign several problems without having to worry that students might not have enough time to finish in class. To urge students to learn how to work each problem assigned, students were informed that the problems on the periodic exams and on the final exam would be closely modeled after the problems assigned in class.

The problem assignments counted 18% of the student's semester average. Late problem assignments were not accepted, however, the lowest three problem assignment scores were ignored in calculation of the semester average.

### **Assessments**

Conversations that took place in the classroom helped the instructor understand why students were having difficulty solving particular problems. The informal formative assessments that took place during interactions with the students guided the instructor's choice of questions and explanations during the conversations. The instructor aligned his formative assessment with the instruction provided outside class by expecting and helping students learn to solve problems as demonstrated in the videos.

The formal assessments included in the course were pre-homework, periodic exams, and the final exam. Formal assessments were aligned with instruction by requiring students to solve problems very similar to those assigned in class using methods explained in the videos. This alignment was intended to motivate students to gain a complete and clear understanding of the material.

**Pre-homework.** Pre-homework was completed during the last 10 minutes of class and was due at the end of class (except on exam days). A student's pre-homework average counted only 10% of his or her semester average, but the pre-homework served several purposes. Its primary purpose was to get students to start thinking about one or

more of the topics to be discussed in the next video. To stimulate such thought the pre-homework usually involved concepts covered in the upcoming section of the textbook. Through pre-homework the instructor was able to assess students' prior knowledge of course content.

From a pragmatic standpoint the pre-homework served two other purposes. The pre-homework gave students an incentive to stay in the classroom until the end of class (there was no need for students to stay to turn in the problems since they were not due until the beginning of the next class). It was important for students to stay in the classroom to work on problems to benefit from the presence of their classmates and the instructor. The pre-homework also allowed the instructor to easily check attendance at the end of class. As explained below under the heading Attendance, extra credit was available for students with good attendance. With many students in the classroom, it was important to check attendance both at the beginning and at the end of class.

Pre-homework concerns course content that students have not yet been exposed to, so the scoring of pre-homework was not based on the mathematical correctness of student solutions. Instead, the scoring of each pre-homework was based on apparent effort made by the student and the reasonableness of their solution. Students were instructed that if, after thinking for a few minutes, they are unable to produce a reasonable solution, then they should explain why they are having difficulty. As long as the student provided a reasonable solution or explanation their pre-homework received a score of 100.

**Exams.** To align the exams with instruction, during exams students were required to engage in the same activity (problem solving) as during instruction. Also, as

during in-class problem solving and as permitted outside class, students were allowed to use their textbooks, notes, and in-class work when solving problems on the exams.

*Types of exams.* Two types of exams were given to students: periodic exams and the final exam. Periodic exams were given every few weeks to encourage students to keep up with the material and to assess learning. The final exam was given at the end of the semester.

*Periodic exams.* The periodic exams were not intended to be comprehensive in nature, although solving some of the exam problems required knowledge of material covered on a previous exam. The number of periodic exams given during the semester depended on whether the section met twice or three times a week.

Both sections assigned to the instructor met three times a week, and in sections that meet three times a week there are more class meetings during the semester and the class meetings are shorter than in sections that meet twice a week. In sections that meet three times a week, allocating as many as four class meetings for periodic exams leaves an adequate number of class meetings for problem solving. Also, given the amount of material taught in college algebra, it seemed necessary to give at least four 50 minute exams to make a reasonable assessment of learning. Additional exams would have reduced the number of class meetings available for problem solving. Consequently four periodic exams were given, and each was worth 13% of the semester average.

If the sections assigned to the instructor had met two times a week then only three class meetings would have been allocated for periodic exams to allow sufficient time for in-class problem solving. Each of the three exams would have been designed to require about 80 minutes to complete and would have been worth 17% of the semester grade.

Make-up exams were not given. However, in calculating a student's semester average their final exam score replaced their lowest periodic exam score if doing so improved the student's semester average.

*Final exam.* The final exam was comprehensive, covering material taught since the first day of class. It was given during the university's final exam period, after the last day of class. The final exam was longer than the periodic exams, designed to require about 150 minutes to complete instead of 50 minutes.

The final exam counted at least 10% of each student's semester average. Because the final exam score could replace a student's lowest periodic exam score, the final exam score counted 23% of the semester average for many students.

The exam policies followed for the periodic exams and the final exam were the same. Exam policies concerning content, reviews, calculators, and scoring are discussed below.

**Content.** Each problem on an exam was similar to one of the problems assigned in class. Neither the problems assigned in class nor the exam problems had a multiple-choice format. To receive credit on a problem the students were required to produce the problem solution(s). While each assigned problem selected for an exam was changed slightly to yield an answer different than the original answer, the method of solution for the exam problem remained the same as the method of solution for the original problem.

In fact, the application problems chosen for the exams were copied almost verbatim from the textbook. Students may find understanding and determining the best approach in solving certain application problems challenging and time consuming. If a student had learned how to solve a very similar, previously assigned application problem,

then it seemed likely that the student would have already known how to approach the application problem on the exam.

The instructor developed the exams over a period of three semesters. The exams were originally written by the instructor for the first preliminary study, improved for the second preliminary study, and improved again for the primary study. While each exam problem was similar to a problem assigned in class, during the preliminary studies the difficulty levels of some exam problems were found to be either higher or lower than desired for the exams, and some of the exam problems were found to be too time-consuming for the exams. Such problems were replaced with other problems on subsequent versions of the exams.

**Reviews.** Neither a proper subset of the material covered nor additional problems were specified as review material prior to either a periodic exam or the final exam. Students were expected to learn all material covered, including how to solve all the problems assigned during class. Directing students' attention to such material for review may have been a disservice, because it may have encouraged students to focus on the review material and ignore other material that was equally likely to be on the exam. To prepare for the exam students were told to review all material covered and all assigned problems.

Students were encouraged to make sure they learned how to solve each assigned problem using the techniques taught in the videos and in the textbook as the semester progressed. Computers with access to the Internet and mathematics tutors were available to students in the department's mathematics lab. A student learning center located in the library also offered mathematics tutoring to students.

***Calculators.*** Many of the problems that were assigned in class and which appeared on the exams can be solved using techniques taught in the course without the use of a calculator. Students were expected to solve many of these problems, which involved working with fractions, factoring quadratic polynomials, and sketching graphs of functions, without a calculator.

Allowing calculators on all exam problems may result in some students relying on their calculator in an attempt to avoid learning such foundational knowledge. Fractions can be converted to decimal representations, more advanced calculators can factor, and graphing calculators can show students the shape of a graph. Klein et al. (2005) stated “one of the most debilitating trends in current state math standards is overemphasis of calculators” (p. 14).

To promote the learning of preferred techniques for solving algebra problems, each periodic exam and the final exam consisted of two portions. Students were allowed to use any calculator on one portion of each exam, and were required to complete the other portion of the exam without a calculator.

The calculator portion of each exam contained problems that students could not be reasonably expected to solve in a short amount of time without a calculator even with a complete understanding of the algebraic concepts and techniques taught in the course. The computations required to solve some problems may be tedious and time consuming without a calculator. The calculator portion of the exams included problems involving average rate of change, direct and inverse variation, certain exponential and logarithmic equations, and systems of equations that dealt with dollars and cents. Students were required to demonstrate techniques taught in the course in solving the problems in order

to receive credit. Students were warned that no credit would be awarded for solutions found by trial and error.

The non-calculator portion of each exam included problems that students could be reasonably expected to solve given the techniques taught in the course. Problems required factoring and working with fractions. Examples included solving quadratic equations (including using and simplifying calculations involving the quadratic formula), solving inequalities involving higher-order polynomials, sketching the graphs of piecewise, rational, transformed, quadratic, and higher-order polynomial functions, solving exponential and logarithmic equations, and solving systems of equations using Gaussian elimination and inverse matrices.

**Scoring.** As stated in the departmental syllabus, one of the objectives of college algebra is to provide the foundational skills necessary for later courses. The method of scoring the exams, which was consistent for the periodic exams and the final exam, was conducive to the development of these skills.

Full credit was awarded for a solution on an exam only if all work was shown. Using correct, mathematically valid methods is crucial in solving algebra problems. Only work in which correct methods were used to solve problems received credit. Correct methods for solving the problems were demonstrated in the examples in the videos and were explained by the instructor to students individually during in-class problem solving. The amount of partial credit awarded for a solution was based on the portion of the solution which reflected the use of a correct method.



The instructor scored all exams. Scoring the exams enabled the instructor to identify concepts and techniques with which students were having difficulty. In class the instructor was able to use this knowledge while helping students solve problems.

***Additional Information.*** Students were provided with additional information regarding the exams in a document entitled *Frequently Asked Questions Concerning Exams*. The document was posted online using a web tool provided by the university that allows instructors to securely share documents with their students. The document explained what students should learn to do well on the exams, how the exams would be graded, and what student needed to bring to the exams.

### **Attendance**

Incentive was provided to encourage students to arrive to class on time for problem solving. Good attendance was rewarded with extra-credit percentage points that were added to the student's semester average.

Prior to the start of each class (except on exam days) the instructor placed an attendance sheet on the desk at the front of the classroom. Students were expected to sign the attendance sheet within the first five minutes of class. Once the class had been underway for five minutes the instructor collected the attendance sheet making it inaccessible to any late-arriving students. Any student that failed to sign the attendance sheet received half an absence.

Pre-homework assignments were used to record attendance at the end of class (except on exam days). Any student that failed to turn in a pre-homework assignment received half an absence.

The number of extra credit percentage points awarded depended on the truncated number of absences accrued by the student. A single half-absence did not affect the amount of extra-credit awarded. Table 3 shows the number of percentage points awarded as a function of the truncated number of absences.

Table 3

*Extra-Credit Percentage Points as a Function of Absences*

Truncated Number of Absences	Extra Credit Percentage Points
0-1	6
2	5
3	3
4	0

The course requirements and class policies were identical between the two sections that constituted the sample and are explained in each section's syllabus. The information common between the two syllabi appears in Appendix G.

### **Prerequisite Knowledge**

The instructor was aware through prior experience that typically a large portion of the students enrolled in a college algebra class have difficulty in working with fractions, factoring quadratic polynomials, or both. This mathematical knowledge is contained in the prerequisites for the course and is necessary for solving problems assigned during the semester.

Videos were freely available on the Internet that explained how to add, subtract, multiply, and divide with fractions and how to factor quadratic polynomials. The need for this prerequisite knowledge was emphasized several times during the semester

beginning with the first day of class. Students were encouraged to visit websites listed in a document posted online and watch videos to gain any needed prerequisite knowledge that they were lacking.

The document was entitled *Help With Prerequisite Material* and was posted online using a web tool provided by the university that allows instructors to securely share documents with their students. More details, and the document itself, appear in Appendix H.

### **Instrumentation**

Two instruments were used in gathering data for this study. An essay assignment was used to gather data for describing student perceptions of an inverted college algebra classroom. An online survey was used to gather additional data concerning perceptions, including perceptions regarding learning contributions and levels of engagement.

#### **Essay Assignment**

This research sought to discover student perceptions, so the essay assignment was designed to minimize any constraints imposed on the students and to not in any way inhibit students from characterizing their true impressions, feelings, and insights. The only requirement prescribed by the assignment, other than formatting requirements, was that the student describe what he or she thought about the inverted college algebra classroom.

Questions concerning the inverted classroom were included in the assignment to offer students ideas for topics to write about in their essay. The assignment stated clearly that students were free to answer all, some, or none the questions. Questions asked students what they thought about the structure of the class, what they liked or disliked

about the inverted classroom, which aspects of the inverted classroom they found the most or least beneficial in terms of learning, whether the inverted classroom required more work or less work than a lecture-based class, and how the inverted classroom could be improved. The complete essay assignment appears in Appendix I.

**Reliability.** Kirk and Miller (1986) distinguished three kinds of reliability in qualitative research. One of these, *synchronic reliability*, “refers the similarity of observations within the same time period” (p. 42). An observational protocol would be considered synchronically reliable if, within a given time period, it produces observations that are consistent with respect to given features of interest.

Of particular interest in this study were perceptions of the inverted classroom, and certain perceptions of the inverted classroom were similarly described in the student essays. If the use of synchronic reliability were extended from describing merely observational protocols to describing essay assignments, then the essay assignment in this study could be considered a synchronically reliable instrument. The synchronic reliability of the essay assignment led to the fruitful qualitative analysis detailed in Chapter 4 that produced descriptions of student perceptions of an inverted classroom.

**Validity.** An instrument is valid if it measures what it is supposed to measure (Carmines & Zeller, 1979). Kirk and Miller (1986) explained that a measuring instrument is *apparently valid* if it “is so closely linked to the phenomena under observation that it is ‘obviously’ providing real data” (p. 22). Carroll (2012) identified four types of instrument validity, one of which seems very similar to apparent validity and is referred to as *face validity*. Face validity is further described below under the heading Questionnaire.

The essay assignment was closely linked to student perceptions of the inverted classroom. The assignment asked students to describe their thoughts concerning the inverted classroom. When students described their thoughts concerning the inverted classroom, students described conceptions, feelings, impressions, insights, observations, and opinions contained in their minds. The essay assignment seems to satisfy the requirements of apparent (or face) validity since it requested that students describe precisely what was to be measured: their perceptions. Student perceptions were revealed in their descriptions of their thoughts.

The essay assignment was used once during the semester. Details concerning use of the essay assignment appear below under the heading Data Collection.

### **Questionnaire**

A questionnaire was developed as the survey instrument. The purpose of the survey was threefold. It was designed to gather additional data regarding perceptions of the inverted classroom and some of its aspects, measure the perceived learning contributions of each element of the inverted classroom, and provide data to help measure levels of engagement with each element.

Questionnaire development began during the first preliminary study with an end-of-semester survey designed to collect data regarding student perceptions to complement data collected through an essay assignment. The inverted classroom in the first preliminary study underwent significant changes during Fall 2011, so the initial questionnaire concluded with three open-ended items to capture student feelings toward the inverted classroom at the end of the semester (which differed significantly from the feelings expressed in the essays written earlier in the semester). The data gathered was

positive, supporting the idea of using an inverted classroom in teaching college algebra. Details concerning the first preliminary study are given in Appendix D, and include descriptive statistics of the survey data under the heading Survey.

For the second preliminary study the questionnaire was redesigned. Perceived learning contributions seemed to be relatively concrete constructs that could be accurately measured with only one survey question for each of the three elements of the inverted classroom. On the other hand, level of engagement with each element seemed a bit more abstract and perhaps more difficult to assess. There were four items included in the questionnaire to gather data regarding level of engagement for each of the three elements. There were five additional items included in the questionnaire to obtain feedback regarding learning, workload outside of class, work performed in comparison to other classes, and preference for the inverted classroom format. The questionnaire included a total of 20 items. The survey constructs measured by the questionnaire, and the items that correspond with each construct, appear in Table 4 below. The complete questionnaire, including its introduction and instructions, appears in Appendix J. Details concerning the second preliminary study, including descriptive statistics of gathered survey data, are given in Appendix E.

Table 4

*Survey Constructs and Corresponding Questionnaire Items*

Survey Construct	Questionnaire Items
Perceived learning contribution of video viewing	1
Perceived learning contribution of note taking	2
Perceived learning contribution of problem solving	3
Level of engagement with video viewing	4, 7, 10, 13
Level of engagement with note taking	5, 8, 11, 14
Level of engagement with problem solving	6, 9, 12, 15
Improvement in learning college algebra with inverted classroom instruction when compared with traditional lecture-based instruction	16
Amount of work required outside class	17
Preference for the inverted classroom format	18, 20
Amount of work done in the inverted college algebra class in comparison to the amount of work done in other classes	19

Suggestions provided by Dillman, Smyth, and Christian (2009) in *Internet, Mail, and Mixed-Mode Surveys: A Tailored Design Method* were followed in constructing items for both the initial and redesigned questionnaires. Participant observation and the essay assignment were expected to provide the data needed for a rich qualitative analysis that would serve the purposes of this research. The questionnaire was redesigned to provide data that would be more suitable for quantitative analysis. Beginning with the second preliminary study the questionnaire included only closed-ended ordinal scale questions. Guidelines in Dillman et al. observed in constructing question stems include

asking only one question at a time, using simple and familiar words, using as few words as possible to pose the question, and using complete sentences with simple sentence structures.

There were two types of response options offered on the redesigned questionnaire. On fifteen questions students were asked their level of agreement with a statement and offered a five-point Likert-type scale ranging from “strongly disagree” to “strongly agree.” On five questions students were asked about frequency of behavior, and the five response categories for these questions ranged from 0%-19% to 80%-100%. Guidelines given in Dillman et al. (2009) were observed in ordering the questions. These guidelines include grouping related questions, beginning with questions likely to be salient to nearly all respondents, choosing the first question carefully, and ordering questions so that earlier questions are less likely to affect answers to later questions.

**Reliability.** As explained by Standen (2012), the reliability of a method of measurement refers to consistency. How consistent the method measures within itself is referred to as its internal reliability, and how consistent the method measures when repeated on the same people under similar conditions is referred to as external reliability.

The questionnaire in this study was designed to gather data concerning perceptions, including perceptions concerning learning contributions and levels of engagement. As the semester progressed the values of these constructs could be expected to change. The change between students could also be expected to differ. Consequently, no portion of the questionnaire was expected to be externally reliable.

Portions of the questionnaire were expected to be internally reliable. As shown in Table 4, four constructs were measured by multiple items on the questionnaire. For each



of the four constructs, Cronbach's alpha was used to estimate the consistency of responses to the corresponding items. One of the four constructs, the construct of preference for the inverted classroom format, was measured by only two items on the questionnaire. Some academics believe that Cronbach's alpha is an inappropriate measure of scale reliability when a scale is composed of two items, and that a correlation coefficient should be used instead (Hulin et al., 2001). Chapter 4 reports the calculated values of Cronbach's alpha for the four constructs, and also reports the calculated value of Pearson's  $r$  correlation coefficient for the preference construct.

**Validity.** Carroll (2012) identified four types of instrument validity. The questionnaire appears to possess at least two of the four types: *content validity* and face validity. A third type of validity identified by Carroll is *criterion validity*.

***Criterion validity.*** According to Carroll (2012), criterion validity “focuses on how well the instrument compares with external variables considered to be direct measures of the characteristic or behavior being examined” (para. 1). A measure independent from the survey was taken to estimate level of engagement with video viewing, and is described below under the heading Webpage Access Counts. The level of engagement with video viewing as determined by the tracking of webpage access is an external variable considered to be an approximation of the actual level of engagement. In considering criterion validity of the questionnaire in regard to level of engagement with video viewing, analysis in Chapter 4 compares the level of engagement with video viewing as determined by the survey with the level of engagement with video viewing as determined by the tracking of webpage access.

A measure independent from the survey was also taken to estimate level of engagement with note taking, and is described below under the heading Evaluation of Notes. The level of engagement with note taking as determined by the instructor's evaluation of submitted notes is an external variable considered to be an approximation of the actual level of engagement. In considering criterion validity of the questionnaire in regard to level of engagement with note taking, analysis in Chapter 4 compares the level of engagement with note taking as determined by the survey with the level of engagement with note taking as determined by the instructor's evaluation of submitted notes.

As shown earlier in Table 4, ten constructs were measured by the survey. The previous two paragraphs discuss how two constructs, level of engagement with video viewing and level of engagement with note taking, were also measured independently from the survey. The other eight constructs were not specifically measured independently from the survey. While the discussion in Chapter 5 does consider whether the survey data agrees with any other relevant data collected in regard to each of these eight constructs, without adequate independent measurement the degree of criterion validity regarding each of the eight constructs must be subjectively estimated.

***Content validity.*** Content validity is “concerned with how well the content of the instrument samples the kinds of things about which conclusions are to be drawn” (Carroll, 2012, para. 2). For example, to measure level of engagement with problem solving students were asked to estimate the degree to which they focused on solving the assigned problems (Question 6), the percentage of the assigned problems they attempted (Question 9), how often they asked another student or the instructor for help (Question 12), and the percentage of time during class they were occupied with mathematics

(Question 15). While it seems that each of the above items would provide some measure of level of engagement with problem solving, gauging the ability of these four items to provide an accurate measurement requires personal judgment.

***Face validity.*** Face validity is “often used to indicate whether the instrument, on the face of it, appears to measure what it claims to measure” (Carroll, 2012, para. 4).

Face validity seems very similar to the notion of apparent validity previously described by Kirk and Miller (1986) and discussed above under the heading Essay Assignment. Eight survey questions were written to measure the seven constructs other than the level-of-engagement constructs. Questions 1, 2, 3, 16, 17, and 19 asked the student to provide a single measurement of precisely what was to be measured. For example, Question 1 asked the student to estimate the degree to which viewing videos contributed to their learning, and the construct to be measured was perceived learning contribution of video viewing. Questions 18 and 20 both asked students to indicate their preference for the inverted classroom format, which again was precisely the construct to be measured. The portion of the questionnaire consisting of the eight items not written to measure levels of engagement appears to satisfy the requirements of face (or apparent) validity.

The questionnaire was presented to students as part of an online survey. Details concerning administration of the survey appear in the following section.

### **Data Collection**

A variety of methods were used to gather evidence to address the research questions. The data collected were used in describing perceptions, measuring the perceived learning contributions of the elements of the inverted classroom, and in determining levels of engagement with the elements of the inverted classroom. Each

method of data collection is described below, along with a brief mention of how the data were used.

### **Participant Observation**

In class the instructor was a participant observer, circulating throughout the classroom and working with students while paying attention to any activity or comments that might reflect student perceptions. In addition, classes were video recorded, and a wireless microphone was used to record conversations between the instructor and students as part of the video.

**Field notes.** Observations are a primary source of data in qualitative research (Merriam, 2009). Observations of interactions between students, as well as individual student actions, facial expressions, and comments provided indications of how students perceived their inverted classroom. As a participant observer, the instructor blended informal interviews and conversations with observations of students.

The instructor began describing observations by recording field notes on the first day of class. Notes were not recorded until after class and were recorded outside of the classroom to avoid raising questions or self-consciousness among the students. The field notes are dated and descriptive, and include basic information such as what was observed, when the observation occurred, who was involved, what social interactions occurred, and details concerning the activities that took place. Video recordings of the classroom enhanced the instructor's in-class observations. Reviewing videos of the classroom allowed the instructor to more vividly recall the events that occurred during class and to improve the field notes. The collection of field notes maintained by the instructor served as a data source for the analysis described in Chapter 4.

**Conversation transcripts.** Conversations between the instructor and students that took place in class were audio recorded as part of each video using a wireless microphone. Audio tracks were then extracted from videos and conversations between the instructor and students were transcribed. The resulting transcripts served as an additional source of data for the qualitative analysis described in Chapter 4.

For in-class recording the researcher purchased an Azden WMS-PRO wireless microphone system, a Kodak Playtouch camcorder, and a 7.25 inch high tripod for positioning the camcorder on a table top in the classroom. The system included a lavalier microphone which worked well with the camcorder. By holding the microphone between himself and students the researcher could easily record conversations.

### **Essays**

Once classes had been underway for about a month the instructor assigned a one page typed essay for extra credit. Students were instructed to write what they thought about the inverted classroom. Suggested (but not required) topics included the structure of the classroom, what students liked or disliked about the inverted classroom, and aspects of the inverted classroom that students found the most or least beneficial in terms of learning. A copy of the essay assignment appears in Appendix I.

The essays were collected anonymously by having students place their essay in a large envelope that was passed around by the students during class. Students signed a roll sheet taped to the front of the envelope so that extra credit could be awarded to those students who submitted an essay.

As explained in the introduction of the essay assignment, students were not obligated to participate in the research by writing an essay to earn the extra credit. A

student could have chosen to complete an alternative assignment instead of the essay assignment. The alternative assignment would have been worth the same amount of extra credit and should have taken about the same amount of time to complete as the essay assignment. The alternative assignment would have consisted of working problems assigned from the textbook. No students chose to complete an alternative assignment instead of writing the essay.

The essays collected contained an abundance of qualitative data that provided insight into the perspectives of many students in the inverted classroom. The essays served as a source of data for the qualitative analysis described in Chapter 4.

### **Survey Data**

An online survey that included 20 closed-ended questions was conducted periodically during the semester for extra credit. Approximately one week before each periodic exam, the instructor announced in class that extra credit on the upcoming exam could be earned by completing the survey. Invitations were emailed to students that also explained that extra credit could be earned by completing the survey. The email contained a link to start the online survey. To earn the extra credit, students were required to complete the survey no later than 24 hours before the starting time of the upcoming exam. The complete survey invitation appears in Appendix K, and the complete survey questionnaire appears in Appendix J.

As explained in the invitation to the survey and in the introduction to the questionnaire, students were not obligated to participate in the research by completing the survey in order to earn the extra credit. A student could have chosen to complete an alternative assignment instead of the survey. The alternative assignment would have

been worth the same amount of extra credit and should have taken about the same amount of time to complete as the survey. The alternative assignment would have consisted of working problems assigned from the textbook. No student chose to complete an alternative assignment instead of the survey.

### **Webpage Access Counts**

Viewing the videos required access to the webpage shown in Figure 2. To access the webpage students were required to login by entering a unique identifier and a password.

The website maintained a count of the number of times each student logged in during the semester. The website did not track which videos were watched or the amount of time that the videos were played. However, the videos were the only resource offered at the webpage. Since video viewing was the only apparent reason for logging in, it seems that students that logged in more frequently were most likely more engaged in video viewing.

Long (2010) used the same idea as described in his dissertation. In Long's study, access to educational mathematics videos was provided by the Blackboard online learning environment. As Long notes, "knowing the number of math videos each student watched is not possible" (p. 122). Instead, Long obtained a count of the number of times each student accessed the video entry screen from Blackboard. Long then used this access count as a relative measure of the number of videos watched by each student.

In this study both the total number of logins during the semester and survey data were used in determining each student's level of engagement with video viewing. An

explanation of how level of engagement with video viewing was determined is given in Chapter 4.

### **Evaluation of Notes**

Students were expected to take notes while watching the videos and to submit the notes for credit. While the instructor gave students a score of 100 even if only a few notes were taken, the instructor performed a separate evaluation of the submitted notes for the purposes of this study.

Each set of notes also received a score of one, two, or three based on the rubric contained in Appendix L. Both the scores received on the notes and survey data were used in determining each student's level of engagement with note taking. An explanation of how level of engagement with note taking was determined is given in Chapter 4.

### **Data Analysis**

The interpretation of both qualitative and quantitative data yielded information used in addressing the research questions. Techniques were chosen for analysis that would yield the types of information desired. The research questions, which appear at the end of Chapter 1, are repeated below for reference.

1. What are students' perceptions of an inverted college algebra classroom?
2. What is the relationship, if any, between perceived learning contributions of various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?
3. What is the relationship, if any, between levels of engagement with various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?



For each research question, the step-by-step procedures followed in performing the data analysis, and references to literature that describe these procedures in greater detail, are given below.

Data analysis was also performed during both preliminary studies. Data analysis performed for the first preliminary study is described in Appendix D, and data analysis for the second preliminary study is described in Appendix E.

### **Addressing Research Question One**

Qualitative analysis provided descriptions of student perceptions for addressing the first research question. Quantitative analysis provided statistics that augmented those descriptions.

**Qualitative Analysis.** Student essays, field notes, and conversation transcripts were qualitatively analyzed to identify and describe student perceptions. The qualitative analysis procedure described on pages 178 through 193 of Merriam's 2009 book *Qualitative Research: A Guide to Design and Implementation* guided the qualitative analysis for this study. A brief summary of this procedure, as it was applied in this study, is given below.

Qualitative analysis began as soon as possible after the first class meeting and continued throughout the semester. Analysis of each essay, transcript, and set of field notes began with reading the text and then writing notes, comments, observations, and queries in the margins. The notations were written next to parts of the text that seemed interesting, relevant, or important to the researcher for the purposes of this research. This process of assigning codes to any such text is called *open coding* and is the beginning of category construction (Merriam, 2009).

After working through the first document, the comments and notes written in the margin were reviewed in an attempt to group those that seemed to go together into categories. A list of categories and the codes that constituted each category was maintained as a separate document. The process of grouping codes into categories by interpreting and reflecting on meaning is called *analytical coding* (Merriam, 2009).

A similar list was created for the second document, and a merging of these two lists resulted in a master list of concepts. The master list was used as an initial classification system into which subsequent codes were sorted. The challenge was to “construct categories or themes that capture some recurring pattern that cuts across . . . [the] data” (Merriam, 2009, p. 181).

As analysis continued, some categories were renamed to better reflect the data. Other categories were merged into larger categories. “This process of refining and revising actually continues through the writing up of . . . [the] findings” (Merriam, 2009, p. 182).

The process of category construction was highly inductive, as bits of data were clustered together into categories and then the category was named. As more and more text was analyzed, the categorical classification system was modified to better describe the data. Eventually, the categories reflected recurring themes in the data and as more data was analyzed it usually fit into one of the existing categories.

Merriam (2009) explains that data analysis “is a process of making sense out of data” (p. 193). The data analysis may simply provide a way to describe the data, or it may be extended to developing categories that interpret the meaning of the data. In any case, “the categories become the findings of the study” (Merriam, 2009, p. 193).

**Quantitative Analysis.** As shown earlier in Table 4, ten constructs were measured by the twenty items on the survey instrument. The quantitative data presented for each of the constructs complements the descriptions of perceptions that are based on qualitative analysis.

For each construct, the mean and variance of the measures were calculated, and a boxplot was produced which graphically depicts the distribution of the measures. The five number summary for each construct precedes the corresponding boxplot. The descriptive statistics and boxplots appear in Chapter 4.

### **Addressing Research Question Two**

Multiple regression analysis allowed the second research question to be addressed. In the social sciences regression analysis “is by far the most widely employed method for studying quantitative evidence” (Vogt, 2006, p. 145). It is especially useful in explaining relationships between multiple variables. For the second research question, it was useful in explaining the relationship between perceived learning contributions of the different elements of the inverted college algebra classroom and grade outcome.

Calculating measures of regression of the response data values toward the mean made it possible to determine the total contribution of the explanatory variables together. Multiple regression analysis also revealed the comparative influence of the different explanatory variables in determining grade outcome.

The quantitative analysis was performed using R, a software system for data manipulation, statistical computing, and graphical display (R Development Core Team, 2012). According to the R Foundation for Statistical Computing (2012), “R provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-

series analysis, classification, clustering, . . .) and graphical techniques” (Introduction to R section, para. 2). The R environment for statistical computing and graphics includes a programming language which allows users to add statistical capabilities by defining new functions. R is available as free software under the terms of the GNU General Public License.

### **Addressing Research Question Three**

Multiple regression analysis also allowed the third research question to be addressed. The analysis was useful in explaining the relationship between levels of engagement with different elements of the inverted college algebra classroom and grade outcome.

Calculating measures of regression of the dependent data values toward the mean again made it possible to make two determinations. Multiple regression analysis determined both the total contribution of the explanatory variables together, and the comparative influence of the different explanatory variables, in determining grade outcome.

For the third research question, quantitative analysis was again performed using R. The methods of analysis were similar to those used in the analysis for the second research question, using the same response variable but different explanatory variables.

### **Validity and Reliability of the Study**

Research “is concerned with producing valid and reliable knowledge in an ethical manner” (Merriam, 2009, p. 209). This research was rigorously conducted to present results that can be trusted.

Internal validity is concerned with how closely research findings match reality. To better ensure internal validity this study compared data gathered from different sources and at different times for consistency. External validity is concerned with “the extent to which the findings of one study can be applied to other situations” (Merriam, 2009, p. 223). To increase the chances that the results of this study may be applied in other settings, detailed descriptions were provided of the context, the students, the data collected, the website, and other details deemed relevant. Providing such detailed description should help in assessing the similarity between a given setting and the setting of this study.

The reliability of research concerns the replication of findings. However, as Merriam (2009) explains, “reliability is problematic in the social sciences because human behavior is never static” (p. 220). Other studies of inverted classrooms will involve different people in different contexts. Instead of replicability, a goal of this study was merely that the results be consistent with the data collected.

### **Ethical Considerations**

The researcher was obligated to conduct this research in as ethically a manner as possible. Effort was made to objectively approach all activities and to not allow researcher bias to influence any of the procedures or results of this investigation.

The researcher remains obligated to protect the privacy of participants. Also, all data, descriptions, events, and other aspects of this research were reported only as openly and honestly as permitted by law.

### **Rights and Welfare of Humans Research Subjects**

The researcher submitted exemption request EXP2011B9774 to the university's institutional review board (IRB) personnel. Based on information contained in the exemption request that described this research, IRB personnel found the research exempt from full or expedited review by the IRB.

The exemption request included an explanation that the only involvement of human subjects in research activities for this study would be in the exemption category described in title 45, part 46, section 101, paragraph (b)(1)(ii) of the Code of Federal Regulations (CFR). Research activities that satisfy this criterion are explicitly exempted from the policy established in 45 CFR § 46 (Title 45: Public Welfare, 2011).

### **Summary**

For this study, an inverted college algebra classroom was implemented and studied to provide information to stakeholders such as faculty, department heads, administrators, and policy makers. The information provided includes descriptions of student perceptions of an inverted college algebra classroom, an explanation of how grade outcome varied in response to the perceived learning contribution of various elements of the inverted classroom, and an explanation of how grade outcome varied in response to levels of engagement with various elements of the inverted classroom. This information was made available by addressing the research questions.

## **CHAPTER 4**

### **RESULTS**

The results of this research are presented in this chapter. The chapter begins with descriptions of the population and the sample. Statistical analysis of collected data is then used to consider the reliability and validity of the survey instrument. Next, each research question is stated and the procedures followed in addressing the question are described. Procedures followed include collection of data, qualitative and quantitative analysis of the data, and presentation of the results of the analysis.

#### **Descriptions of Population and Sample**

The university registrar's office provided data that describe the students in the population and the sample. The population consisted of the 2,295 students at the university enrolled in college algebra on the 12<sup>th</sup> day of class in Fall 2012. The sample consisted of the 82 students in the population enrolled in the two sections of college algebra taught by the researcher in Fall 2012.

Types of characteristics of the population and sample included in the data provided by the registrar's office were ethnicity (as defined by the Texas Higher Education Coordinating Board), class (such as freshman), and gender. The characteristics included in the data are listed in Table 5 along with the percentages of students in the population and in the sample that possessed each characteristic.

Table 5

*Demographic Characteristics as Percentages of the Population and the Sample*

Characteristic	Population ( <i>n</i> = 2295)	Sample ( <i>n</i> = 82)
<b>Ethnicity</b>		
American Indian or Alaskan Native	0.2	0.0
Asian	1.8	1.2
Black or African American	8.5	6.1
Hawaiian or Other Pacific Islander	0.1	0.0
Hispanic	31.4	25.6
International <sup>a</sup>	0.2	0.0
Multi-Race	2.2	3.7
Multi-Race where one is Black	1.4	0.0
Unknown	0.7	0.0
White	53.3	63.4
<b>Classification</b>		
Freshman	73.8	85.4
Sophomore	15.3	9.8
Junior	7.0	2.4
Senior	3.6	2.4
Post-Baccalaureate	0.3	0.0
<b>Gender</b>		
Female	64.1	67.1
Male	35.9	32.9

<sup>a</sup>International denotes a person who is not a citizen or permanent resident of the United States and who is in the country on a temporary basis and does not have the right to remain indefinitely (Texas Higher Education Coordinating Board, 2010).

### Survey Instrument

Statistical analysis of collected data was used to assess the internal consistency reliability and criterion validity of the survey instrument. Cronbach's alpha was used to check for internal consistency reliability and was computed for all multi-item scales.



Degrees of criterion validity with respect to two survey constructs were estimated by measuring correspondences between sets of survey responses and other sets of measurements that did not involve the survey instrument. Additional discussion regarding the reliability and validity of the survey instrument appear in Chapter 3 under the heading Questionnaire.

### **Internal Consistency Reliability**

As shown earlier in Table 4, four constructs were measured by multiple items on the survey instrument. Three of the constructs concerned level of engagement and the other construct was preference for the inverted classroom format. For each of the four constructs, Cronbach's alpha was calculated to estimate the consistency of the responses between the items corresponding with the construct. Pearson's  $r$  correlation coefficient was also calculated to estimate the consistency of responses between the two items corresponding with the preference construct. For each of the four constructs, values were calculated using all 270 responses to each item that corresponded with the construct.

Values of Cronbach's alpha that represent the consistency of responses for measuring the three constructs regarding level of engagement appear in Table 6.

Table 6

#### *Cronbach's Alpha for Items Corresponding with Level of Engagement Constructs*

Construct	Alpha
Level of engagement with video viewing	0.776
Level of engagement with note taking	0.788
Level of engagement with problem solving	0.807

Although each of the calculated values of alpha shown in Table 6 exceeds the 0.70 standard often considered satisfactory for most purposes in research (Vogt, 2006), further analysis led to an increase in reliability for one of the scales of level of engagement.

Each of the three level-of-engagement constructs was measured with four questionnaire items. For each of the three level-of-engagement constructs, additional calculations were performed to see if removing an item would increase the value of the corresponding alpha. Results of the calculations appear in Table 7 through Table 9.

Table 7

*Reliability Analysis for Four Items in Scale of Video Viewing Engagement*

Questionnaire Item	Alpha if Item Deleted
4	0.745
7	0.668
10	0.780
13	0.693

*Note:* Alpha = .776

As shown in Table 7, if item 10 were deleted from the questionnaire Cronbach's alpha would increase from 0.776 to 0.780. Item 10 asked students to report how frequently they paused or repeated segments of the videos in order to increase their understanding of the material.

Such conduct would seem to indicate greater engagement with video viewing. Although the responses to item 10 are minutely inconsistent with the responses to items 4, 7, and 13 in measuring level of engagement with video viewing, it was decided to retain and use all responses to item 10 for subsequent analysis. The researcher felt that

greater inconsistency should be required before discarding data, and that the student responses may have provided information that resulted in a more accurate assessment of video viewing engagement.

Table 8

*Reliability Analysis for Four Items in Scale of Note Taking Engagement*

Questionnaire Item	Alpha if Item Deleted
5	0.677
8	0.826
11	0.776
14	0.654

*Note:* Alpha = .788

As shown in Table 8, it was determined that deleting item 8 from the questionnaire would result in an increase in Cronbach's alpha from 0.788 to 0.826. Since throwing out item 8 would increase internal consistency reliability, all responses to item 8 were removed resulting in a three item scale for note taking engagement. The responses to item 8 were not used in any of the analysis subsequently described for this research.

Table 9

*Reliability Analysis for Four Items in Scale of Problem Solving Engagement*

Questionnaire Item	Alpha if Item Deleted
6	0.709
9	0.784
12	0.781
15	0.751

*Note:* Alpha = .807

Table 9 shows that deleting any item in the scale of problem solving engagement reduces Cronbach's alpha. All four items in the scale are good, so data from all items were used in subsequent analysis.

As explained in Chapter 3, some academics believe that a correlation coefficient should be used instead of Cronbach's alpha for measuring the reliability of two-item scales (Hulin et al., 2001). The construct regarding preference for the inverted classroom was measured with two items. Consequently both Cronbach's alpha and Pearson's  $r$  correlation coefficient are presented in Table 10.

Table 10

*Cronbach's Alpha and Pearson's  $r$  Correlation Coefficient for Two-Item Scale*

Construct	Alpha	Coefficient
Preference for the inverted classroom	0.897	0.813

### **Criterion Validity**

If the survey instrument possesses criterion validity then measures of a construct obtained from the instrument should agree with direct measures of the construct being examined (Carroll, 2012). While direct measures of level of engagement were not available, measures independent from the survey were available and assumed to approximate the actual levels of engagement.

Of the 78 students that participated in at least one administration of the survey, 13 students had stopped attending class by the end of the semester and did not take the final exam. The levels of engagement as reported by those 13 students before attendance stopped may not reflect their actual levels of engagement for the entire semester.

Consequently, in checking the survey instrument for criterion validity only data for the other 65 students were considered.

**Video Viewing Engagement.** The website maintained a count of the number of times each student logged in to access the webpage of instructional videos, and the videos were the only resource offered on the webpage. There was no other apparent reason for logging into the website other than to view videos, so it is assumed that webpage access is an external variable that provided an approximation of the actual level of engagement with video viewing.

Given webpage access as the criterion variable, a check was made for criterion validity by computing Pearson's  $r$  correlation coefficient as a measure of the association between level of engagement with video viewing as measured by the survey instrument and level of engagement with video viewing as determined by webpage access. The resulting Pearson  $r$  correlation coefficient of 0.443 indicated that only  $0.443^2 \approx 0.196$ , or about 19.6%, of the variance in one of the variables can be explained by the variance in the other (Vogt, 2006). Hence there was some inconsistency between the survey responses and webpage access counts as measures of level of engagement with video viewing.

**Note Taking Engagement.** The instructor assigned a score to each set of submitted notes indicating the apparent amount of effort made by the student in taking the notes. Scores for each student were then averaged at the end of the semester. It is assumed that the instructor's evaluation of submitted notes is an external variable that provided an approximation of the actual level of engagement with note taking.

Given the instructor's evaluation of submitted notes as the criterion variable, a check was made for criterion validity by computing Pearson's  $r$  correlation coefficient as a measure of the association between level of engagement with note taking as measured by the survey instrument and level of engagement with note taking as determined by the instructor's evaluation of submitted notes. The resulting Pearson  $r$  correlation coefficient of 0.508 indicated that only  $0.508^2 \approx 0.258$ , or about 25.8%, of the variance in one of the variables can be explained by the variance in the other (Vogt, 2006). Hence there was some inconsistency between the survey responses and instructor evaluation of notes as measures of level of engagement with note taking.

### **Research Question One**

The first research question was: What are students' perceptions of an inverted college algebra classroom? Both qualitative and quantitative methods were used in capturing and identifying students' perceptions.

#### **Qualitative Methods**

This research is interested in any perceptions that may have contributed to and influenced the construction of meaning that an inverted college algebra classroom had for the students involved. The perceptions may have included anything students achieved understanding of, such as discoveries, observations, feelings, realizations, comprehensions, and appreciations.

**Data Collected.** Qualitative data were collected for addressing the first research question through participant observation and an anonymously submitted essay. As a participant observer, the researcher was also the instructor in the inverted college algebra classroom. Observations of activity and students were translated into two sets of data for

qualitative analysis: field notes recorded by the instructor, and transcripts of recorded conversations between students and the instructor. Essays were collected from 46 students and served as a third set of qualitative data.

**Analyses Performed.** The three sets of qualitative data differed substantially in their content. The essays contained descriptive data that characterized a variety of student perceptions of the inverted classroom. The transcribed conversations identified the specific difficulties perceived by students in understanding and solving assigned problems in their inverted classroom. The field notes contained the instructor's recordings of in-class observations of students and overall impressions of student activity that occurred during different class meetings, providing additional insight into the perceptions held by the students.

Due to the differences in the nature of the content between the three sets of qualitative data, each set of data was analyzed separately. The separate analyses resulted in a set of findings for each set of data. Each set of findings describes students' perceptions of an inverted classroom.

**Results of Analyses.** For each of the three sets of qualitative data: essays, conversation transcripts, and field notes, qualitative analysis yielded categories of perceptions supported by the data from which they were derived. The categories produced by qualitative analysis are findings of the study (Merriam, 2009).

**Essays.** Table 11 summarizes the categorization of perceptions derived from the essays. Perception categories are described immediately following the table. For each category, Table 11 displays the percentage of essays in which perceptions were described that were determined to belong to the category.

Table 11

*Categorization of Perceptions Derived From Essays*

Category of Perceptions	Percentage of Essays
Outside-Class Activity	
Ability to control playing of video helpful	46
Videos allow more time for content delivery	4
Can look at next day's lesson or work ahead	9
Videos are impersonal or do not allow questions	57
Videos or notes are too time consuming	24
More difficult to learn well from a video	17
In-Class Activity	
Additional class activity would be useful in learning	33
Working with classmates or instructor assistance helpful	48
Working on problems in class is beneficial	17
Group Work	
Group work is good for learning	24
Group work is not good for learning	9
Effectiveness	
Inverted format is an effective way to teach college algebra	22
Inverted format is not an effective way to teach college algebra	33
Independence in Learning	
Can learn at own pace	15
Requires self-discipline or teaches responsibility	13
Students required to teach themselves	13
Amount of Work	
Less work required than a lecture-based class	4
Same work required as a lecture-based class	20
More work required than a lecture-based class	33
Efficiency	
More efficient than a lecture-based class	11
Less efficient than a lecture-based class	20
Overall Preference	
Prefer the inverted classroom over the lecture-based class	28
Prefer the lecture-based class over the inverted classroom	54



Descriptions of the perception categories derived from the essays appear below and describe the types of perceptions that students had of the inverted classroom. Excerpts of the analyzed data describe specific examples of perceptions that belonged to each category.

*Ability to control playing of video helpful.* In 46% of the essays students wrote that the ability to control the playing of the video was helpful in learning college algebra. Ability to control video playing included the ability to play the video at a convenient time in addition to the ability to pause, repeat, and skip forward or backward within the video. Statements made by students in the essays follow.

- It is much easier to understand things when watching the videos instead [of] being in a class listening to a teacher talk. With the videos, students are able to stop and rewind them if they didn't understand or got lost during a problem. (Anonymous, essay 002-11, October 1, 2012)
- It is easier to take notes from the video because you are able to rewind and pause as much as needed. (Anonymous, essay 005-22, October 1, 2012)
- The most beneficial part of the inverted classroom is that [on] the problems that I don't understand I can just go to my computer and watch a similar problem. (Anonymous, essay 002-06, October 1, 2012)
- Not only can we watch the lectures at home and take notes when it is most convenient, but we can also rewind or pause the lecture if we need to hear something again or to write something in further detail. (Anonymous, essay 005-04, October 1, 2012)

- I think that this teaching style is easier for me, especially in a mathematics class, simply because you are able to pause, fast-forward, or rewind the video. (Anonymous, essay 002-005, October 1, 2012)

*Videos allow more time for content delivery.* In 4% of the essays students noted that one of the advantages of delivering content by video is that the instructor can take more time to explain concepts and give examples. Statements made by students in the essays include the following.

- When you think about it, this class is almost better with work management because the notes are sometimes over 50 minutes and some are over an hour, giving Mr. Jaster more time to go thru examples, explain equations and give us better notes than would be if we were cramming an hour's worth of notes into a fifty minute class, not even counting questions kids would have. (Anonymous, essay 002-01, October 1, 2012)
- Yeah it's different but I like it more simply because if the professor was to give a lecture and we were to take notes during class we only have a certain amount of time to get the notes done, and if we were to have questions about it we would have to interrupt the professor, and that will take time away from the lecture and we might not get thru all the notes that were supposed to be given that day. (Anonymous, essay 002-16, October 1, 2012)

*Can look at next day's lesson or work ahead.* In 9% of the essays students identified having access to course content before it is covered in class as an advantage of the inverted classroom. The following statements were included in the essays written by students.

- Some of my likes for this style are that you have a chance to get to see what you are going to be working on in class the next day. It gives you a better idea to see what you need to pay extra attention to, and you are able to work ahead and know what you need to ask questions on in class. (Anonymous, essay 002-02, October 1, 2012)
- I will do the majority of the problems at home before class, and later bring in a few that I have questions on to get help from my teacher or fellow classmates. (Anonymous, essay 005-04, October 1, 2012)

*Video is impersonal or does not allow questions.* In 57% of the essays students indicated that learning from video instead of live lecture seemed impersonal or did not allow questions to be asked during explanation of course content. Statements contained in the essays follow.

- The information given is not tailored to the unique classroom environment because it's prerecorded and impersonal. I am a question-based learner and it helps me immensely to be able to ask a question regarding the information being taught immediately after it pops up into my mind, so going without this privilege has made it harder for me to completely understand the topics. (Anonymous, essay 002-04, October 1, 2012)
- My main problem with taking the notes outside of class is the fact that we cannot ask the professor questions when we are confused. (Anonymous, essay 005-20, October 1, 2012)
- I also feel that I do not know you as a professor at all because all I have heard you say in class is a few sentences so I don't feel that I can come up to you

and ask you questions. This whole process seems very cold and impersonal, like we are just cattle being pushed through a class not like you are investing in our learning as students. (Anonymous, essay 005-23, October 1, 2012)

- One thing I hate about watching the videos online is that I am not able to ask my professor questions while he is teaching or explaining how to do a particular problem. (Anonymous, essay 002-17, October 1, 2012)
- Sometimes it is challenging not being able to ask questions while taking the notes. Taking the notes is the primary way a student is learning to do the problems. In my opinion asking questions when taking notes is more crucial than asking how to do a problem in class. (Anonymous, essay 005-22, October 1, 2012)
- The least beneficial learning aspect about the inverted classroom is that I don't feel like I am being taught. During lectures, I generally like to ask questions and be engaged in what is being presented to me. (Anonymous, essay 005-14, October 1, 2012)

*Videos or notes are too time consuming.* In 24% of the essays students implied that viewing videos or taking notes was too time consuming. The essays included the following statements.

- The videos are kind of lengthy. Which means that some students may lose their attention span and not comprehend what they are watching and writing down, defeating the purpose of the video. (Anonymous, essay 002-02, October 1, 2012)

- Having to take extensive notes outside of class is very time consuming and tedious. Sometimes you go too fast through a topic, and as soon as you are done working out a problem and write the answer, you advance scenes/topics, causing me to always have to rewind the video, pause it, and finish writing down the example. (Anonymous, essay 002-04, October 1, 2012)
- I end up having to rewatch most of the parts, on top of doing the problems assigned for that day leads to two hours of math homework three nights a week. (Anonymous, essay 005-002, October 1, 2012)

*More difficult to learn well from a video.* In 17% of the essays students wrote that it is more difficult to learn well from a video than a live lecture. The following statements were contained in the essays.

- At home there are too many distractions that get in the way when I'm trying to focus on completing the videos and notes. (Anonymous, essay 005-14, October 1, 2012)
- I feel like since students would be in class while the professor taught to them and did examples of problems, they would be more alert, aware, and remember more than they are when they are watching videos of the lessons. (Anonymous, essay 002-08, October 1, 2012)
- I feel that I learn better with a teacher teaching in a classroom rather than watching a recorded lecture. (Anonymous, essay 005-10, October 1, 2012)

*Additional class activity would be useful.* In 33% of the essays students suggested that class activity in addition to problem solving, such as the answering of questions at the beginning of class or lecturing in class some of the time would be useful in making

the inverted college algebra classroom more effective. Statements made by students in the essays follow.

- One big [improvement] would be to actually make a point of specifically working problems or [explaining] concepts that a number of students are having trouble on. (Anonymous, essay 002-07, October 1, 2012)
- If you were to improve this I would lecture for half the classes just glossing over the material and provide the videos for an extra supplement for those who needed it and give the other half of the class to students to work on problems and ask you questions. (Anonymous, essay 005-23, October 1, 2012)
- The inverted classroom structure could be improved by . . . reviewing the video quickly with us, to see if anyone had any specific questions. (Anonymous, essay 002-04, October 1, 2012)
- I think the inverted class can be improved by once a week having a lecture class going over what we had watched in the videos. (Anonymous, essay 005-10, October 1, 2012)

*Working with classmates or instructor assistance helpful.* In 48% of the essays students mentioned that working with classmates or assistance from the instructor was helpful in learning college algebra. Statements made by students in the essays include the following.

- Being able to work on your homework in class with the help of other classmates and your teacher allows you to get more done correctly in a less amount of time. (Anonymous, essay 002-02, October 1, 2012)

- Another positive attribute for the inverted classroom is the fact that you are in class with your professor while you are doing your homework. You can utilize the professor for questions that you are having trouble with. This allows each student to receive assistance on the specific material they need help on. (Anonymous, essay 002-20, October 1, 2012)
- I feel like solving the problems in class is a good thing because you can get help from your classmates, and your professor can also help you if you have a question with anything. (Anonymous, essay 002-08, October 1, 2012)
- What I find most beneficial about an inverted classroom is that students are able to work the problems out in class with other students. The students are also able to ask the professor for help on the problems that they need help on. (Anonymous, essay 002-11, October 1, 2012)
- I have help from the other students at my table . . . with problems I would otherwise have to go to a learning center to get help for or struggle to understand on my own. (Anonymous, essay 005-08, October 1, 2012)

*Working on problems in class is beneficial.* In 17% of the essays students wrote that working on problems in class is beneficial, making it easier to learn and usually allowing most or all of the problems to be completed in class. The following statements were included in the essays written by students.

- Since we have an entire class period to do our problems, I like how we are able to get most of our work done and barely have any homework except for watching the next class period's lesson. (Anonymous, essay 002-05, October 1, 2012)

- I like doing the homework in class because students do tend to get lazy and procrastinate, and . . . having an exact time and place that forces us to sit down and do our work is really nice. (Anonymous, essay 005-06, October 1, 2012)

*Group work is good for learning.* In 24% of the essays students indicated that group work is good for learning college algebra. Statements contained in the essays follow.

- Working in a group enables you to learn more and help others to reassure yourself that you know the material as well. (Anonymous, essay 002-02, October 1, 2012)
- I think that if I wasn't able to verbally participate and discuss the different ways of solving a problem with my peers, I wouldn't be able to wrap my mind around some of the concepts – I enjoy their feedback and how-to tips. (Anonymous, essay 005-04, October 1, 2012)
- What I find most beneficial about an inverted classroom is that students are able to work the problems out in class with other students. (Anonymous, essay 002-11, October 1, 2012)

*Group work is not good for learning.* In 9% of the essays students implied that group work is not good for learning college algebra. The essays included the following statements.

- For the most part, I am an independent thinker and I work best alone. It really bothers me that when I am in the middle of doing a problem, someone taps me on the shoulder and solicits my aid on a particular problem. (Anonymous, essay 002-17, October 1, 2012)



- Solving problems in small groups . . . is not beneficial in the slightest if all in the small group have no idea how to solve said problem. (Anonymous, essay 005-13, October 1, 2012)

*Inverted format is an effective way to teach college algebra.* In 22% of the essays students wrote that using an inverted approach in teaching college algebra is effective.

The following statements were contained in the essays.

- I believe I am learning a lot better in an inverted class than in a traditional lecture. (Anonymous, essay 002-11, October 1, 2012)
- Overall, I definitely prefer the inverted classroom experience for an algebra class, and I hope that the math classes that I take after this one work the same way. In my opinion, it is the wisest way to make use of my time because I always have more questions over how to solve a problem myself rather than when somebody else is solving one as an example. (Anonymous, essay 005-04, October 1, 2012)
- I think [the inverted classroom] can help students be pretty successful, as long as they take the time to put in the effort to watch the videos and take notes. (Anonymous, essay 002-13, October 1, 2012)

*Inverted format is not an effective way to teach college algebra.* In 33% of the essays students wrote that using an inverted approach in teaching college algebra is not effective. Statements made by students in the essays follow.

- I believe [the inverted classroom] is a completely unorthodox and ineffective way of teaching. (Anonymous, essay 002-21, October 1, 2012)

- I feel that I'm more involved in the class by watching the videos and taking notes but I'm not mastering the material as well. (Anonymous, essay 005-16, October 1, 2012)
- I feel that I am not learning as well in the inverted classroom simply because it takes the professor entirely too long to answer everyone's questions. Before I know it, the class is over and I am still left with many unanswered questions. (Anonymous, essay 002-18, October 1, 2012)
- The problems would be easier to understand if we were being taught in class. (Anonymous, essay 002-09, October 1, 2012)

*Can learn at own pace.* In 15% of the essays students expressed appreciation for having the ability to learn at their own pace. Statements made by students in the essays include the following.

- It's nice to be able to learn at your own pace without slowing down the whole class. (Anonymous, essay 002-02, October 1, 2012)
- I believe that viewing videos outside of class is beneficial. It is a lot easier to follow along at my own pace than it would be in class. (Anonymous, essay 005-25, October 1, 2012)

*Requires self-discipline or teaches responsibility.* In 13% of the essays students commented that the inverted classroom requires more self-discipline and teaches greater responsibility than a lecture-based class. The following statements were included in the essays written by students.

- Now, having taken the first test, I have come to acquire more self-discipline and actually enjoy the teaching style. (Anonymous, essay 002-01, October 1, 2012)
- An inverted classroom makes one manage their time more wisely. (Anonymous, essay 005-03, October 1, 2012)
- Learning the material outside of class just take responsibility. (Anonymous, essay 002-20, October 1, 2012)

*Students required to teach themselves.* In 13% of the essays students wrote that in an inverted classroom students are expected to teach themselves. Statements contained in the essays follow.

- If the teacher is not to teach then he should not assign homework problems, or even bother to take attendance. If I am to watch videos at a time of my pleasure, then I should have the choice to simply go to the math lab every other day for help on my algebra. The videos make the classroom and the instructor obsolete and a waste of my time and money. (Anonymous, essay 005-11, October 1, 2012)
- I pretty much have to teach myself how to work the problems. (Anonymous, essay 002-06, October 1, 2012)

*Less work required than lecture-based class.* In 4% of the essays students wrote that the inverted classroom requires less work than a lecture-based class. The essays included the following statements.

- I feel like the inverted classroom requires less work than the traditional lecture format. This type of classroom gives me more time to actually learn than the other type of classroom. (Anonymous, essay 005-19, October 1, 2012)
- I think that the inverted classroom requires less work than the traditional lecture format, because I usually take about 45 minutes to an hour to do my homework in a traditional style math class. (Anonymous, essay 005-20, October 1, 2012)

*Same work required as a lecture-based class.* In 20% of the essays students wrote that the inverted classroom requires about the same amount of work as a lecture-based class. The following statements were contained in the essays.

- I think that the amount of work between inverted and lecture-based is pretty even because either way, we would have to be taking notes over the teacher teaching in order to learn and take in what he is saying. Then after that, to fully understand it, we would have practice problems to do in order to make sure we know exactly what we are doing. (Anonymous, essay 002-05, October 1, 2012)
- It is about the same amount of work because regardless of the teaching method you have a learning period of time and a homework period of time. (Anonymous, essay 005-01, October 1, 2012)

*More work required than a lecture-based class.* In 33% of the essays students wrote that the inverted classroom requires more work than a lecture-based class.

Statements made by students in the essays follow.

- I personally think that an inverted class requires more work than traditional style. I feel like it takes twice the energy just to focus. (Anonymous, essay 005-14, October 1, 2012)
- I feel like the inverted classroom is more work because you have to take down every single note. Then work out the problems that are assigned, and having to rewind the video constantly to try and figure out how to work that problem. When in a traditional class when you work problems you can just ask the professor, right there when you don't understand. (Anonymous, essay 002-06, October 1, 2012)
- The videos . . . on top of doing the problems assigned for that day leads to two hours of math homework three nights a week. (Anonymous, essay 005-02, October 1, 2012)

*More efficient than a lecture-based class.* In 11% of the essays students claimed that the inverted classroom is more efficient than a lecture-based class. Statements made by students in the essays include the following.

- Learning in an inverted classroom results in a more efficient use of time so that you can learn more with less effort. (Anonymous, essay 002-11, October 1, 2012)
- Being able to work on your homework in class . . . allows you to get more done correctly in a less amount of time. Allowing you to use your time in an efficient manner. (Anonymous, essay 002-02, October 1, 2012)

*Less efficient than a lecture-based class.* In 20% of the essays students claimed that the inverted classroom is less efficient than a lecture-based class. The following statements were included in the essays written by students.

- I think being in a lecture class would be more time efficient. Spending the required 50 minutes in class learning how to do the problems, and then completing homework outside of class. The homework does not take a long time when you know how to solve all the problems. (Anonymous, essay 005-22, October 1, 2012)
- With all the other students talking, it is really easy for me to get off task so I'm not using my time as efficiently as I could. (Anonymous, essay 002-04, October 1, 2012)

*Prefer the inverted classroom over the lecture-based class.* In 28% of the essays students wrote that they preferred the inverted classroom over the lecture-based class. Statements contained in the essays follow.

- If I were to take this college algebra class again, I would prefer the inverted classroom instead of a lecture-based class. When a professor teaches math on the board, sometimes it's hard to copy the notes and problems while trying to understand at the same time. (Anonymous, essay 002-20, October 1, 2012)
- I would prefer if all my math classes were in this format because it makes math less stressful to learn. (Anonymous, essay 002-02, October 1, 2012)
- I would say I like [the inverted classroom] better, but I just need to make sure I am actually learning the material, since there is no teacher to make sure I'm

paying attention and taking all the notes I need. (Anonymous, essay 005-15, October 1, 2012)

- College algebra is much easier to understand through this method. I hope that all my classes will be taught through this same method of inverted teaching. (Anonymous, essay 002-03, October 1, 2012)

*Prefer the lecture-based class over the inverted classroom.* In 54% of the essays students wrote that they preferred the lecture-based class over the inverted classroom. The essays included the following statements.

- I do not like the way my math class is with the inverted system of teaching. I do not know if it's because of the material or the teaching style but I almost never understand the material fully after the videos. It seems like in the videos the material is easy and straightforward, in class for problems it's a step up from that where I cannot understand, the review is a step up from the homework where I need constant help that I do not get considering the one teacher has 40 students who all need help. (Anonymous, essay 005-24, October 1, 2012)
- I do like being able to work on our homework in class, but I don't find that aspect so beneficial that would make giving up a classroom lecture worth it. (Anonymous, essay 002-04, October 1, 2012)
- Personally, I do not like watching videos outside of class and using class time to work on problems. I think that it avoids many of the vital elements of a classroom, such as interaction [between the instructor and the students] and time to ask questions. I would rather take a class where the teacher lectures

and interacts with the class during class time, then the student does homework at home. (Anonymous, essay 002-15, October 1, 2012)

- A traditional classroom requires the students to be engaged and students are motivated to keep up with the instructor because they don't have the option of pausing or rewinding a video. (Anonymous, essay 005-11, October 1, 2012)
- If I were to take this class again, I would probably choose a traditional lecture format because it's what I'm comfortable with and what I'm used to. Another reason why I probably don't like this non-traditional approach is the fact that it's just different. (Anonymous, essay 002-04, October 1, 2012)
- I feel that if we had the professor teaching us things during our class time, we would be having a much more substantial learning experience and would ultimately be more likely to succeed in the class. (Anonymous, essay 005-09, October 1, 2012)

***Transcribed conversations.*** In conversations with the instructor, students revealed the difficulties perceived in understanding and solving the assigned problems in the inverted classroom. Table 12 summarizes the categorization of perceptions derived from the transcribed conversations. For each category, Table 12 also displays the percentage of conversations in which perceptions were described that were determined to belong to the category.



Table 12

*Categorization of Perceptions Derived From Transcribed Conversations*

Category of Perceptions	Percentage of Conversations
Next step in solving problem cannot be identified or performed	36
Overall strategy for solving problem cannot be determined	26
Operation with fractions cannot be performed	10
Careless mistake cannot be located	6
Definition is unknown or unclear	5
Mathematical notation is not understood or cannot be used properly	2

Perception categories are described below and identify the types of difficulties with problem solving that students perceived in the inverted classroom. Excerpts from the analyzed data describe specific examples of perceptions that belonged to the categories. One excerpt is given for each category in this chapter, and additional excerpts can be found in Appendix M.

*Next step in solving problem cannot be identified or performed.* In 36% of the transcribed conversations students were unable to identify or perform the next step in solving a problem. The following excerpt appeared in the transcribed conversations.

Student: I have a quick question.

Instructor: Yes, ma'am?

Student: I can't figure out how to do that one.

Instructor: Well we could start off by distributing the 0.15. Let's try that.

*Overall strategy for solving problem cannot be determined.* In 26% of the transcribed conversations students needed help in determining an overall strategy for solving the problem. The following excerpt appeared in the transcribed conversations.

Instructor: Yes, ma'am?

Student 1: I need some help finding the domain and range on this one.

Instructor: OK. Well the domain is the set of all possible  $x$  values.

Student 1: I just don't get how, well like I got this one, I just don't know why it wouldn't be the same.

Instructor: This is the domain? Negative infinity to infinity? Are these brackets or parentheses?

Student 1: This is a parenthesis, and this is a bracket.

Instructor: OK. That's not right then, because infinity's not a number, so we can never include it in an interval. So for infinity we always have to use parentheses.

Student 1: OK.

Instructor: So here you're right because the domain is negative infinity to infinity because your  $x$  can be any real number. But down here, for instance, your function is not defined for  $x = -2$ . For which  $x$ 's is it defined?

Student 1: -1 to 1.

Instructor: -1 to 1 including the -1 and 1. So square brackets on the -1 and 1. Then what are the possible  $y$  values?

Student 1: 1, right?

Instructor: 1 (*pause*). I mean (*pause*).

Student 1: 1 to infinity.

Instructor: I don't see any graph up here. I see (*pause*).

Student 1: Infinity to 1?

Instructor: No. What are the possible  $y$  values? I mean there's no graph up here and there's no graph down there. As a matter of fact, the first point I see on the graph has a  $y$ -coordinate equal to 0. And this has a  $y$ -coordinate equal to 1. And I see points for all  $y$ -coordinates in between, right? This point has a  $y$ -coordinate of maybe  $1/2$ . So what are your possible  $y$  values? Don't your values start at 0?

Student 1: Right.

Instructor: So your values start at 0 and they go up to 1?

Student 1: Right.

Student 2: Then why is it infinity? How do you know whether to use infinity or not?

Instructor: Well, here for your range, your graph comes all the way down here and it keeps going. So your  $y$  value can be anything here and on down, forever. This graph stops right here. Or starts, it starts here and goes over to here and then it stops, and it doesn't keep going down. So 0 is your smallest  $y$  value. That's as small as your  $y$  can get. And 1 is as big as your  $y$  can get. It can't get any bigger than 1. Because you don't have any graph down here and you don't have any graph up there. Your  $y$  value has to be between 0 and 1.

Student 1: OK. How do you know it stops though? It looks almost the same to me.

Instructor: This line keeps going. You draw all the way down here to the bottom

of the graph and it keeps going. Where it stops, it ends at a point, so usually we draw a point there to indicate that it ends.

Student: OK.

*Operation with fractions cannot be performed.* In 10% of the transcribed conversations students indicated that they were unable to perform operations (addition, subtraction, multiplication, or division) with fractions. The following excerpt appeared in the transcribed conversations.

Instructor: Yes, sir?

Student: So you distribute that, but what do you do with those two?

Instructor:  $-7/6$  times  $-4$ ?

Student: Yes.

Instructor: OK, so you're multiplying by a fraction, so you're going to multiply by the numerator. So  $-7$  times  $-4$  is positive 28, so that's going to be 28 over 6.

*Careless mistake cannot be located.* In 6% of the transcribed conversations students asked for help in locating a careless mistake. The following excerpt appeared in the transcribed conversations.

Instructor: Yes, ma'am?

Student: I have a question. I don't understand what I'm doing wrong for this one. You plug in 2 for  $h$ , right?

Instructor: First let me see what the problem is. 45? Alright, so we just need to evaluate and write the answer to three decimal places. OK. So  $f$  of  $g$  of  $h$  of 2.

Student: So I would plug in 2 for the  $h$  equation, and I get 1.

Instructor: OK.

Student: Then I would plug 1 in for the  $g$  equation.

Instructor: Right.

Student: And I got 0.

Instructor: OK.

Student: Then I plugged in 0 for the  $f$  equation and I got -1, but I don't think that's the answer. I think it said the answer is 5. And I don't understand why.

Instructor: Section 2.4, 45. OK, let's go back. OK, so 2 into the  $h$  gives you 1, then 1 into the  $g$  gives you 2 (*pause*).

Student: Whoa, it gives me 2?

Instructor:  $g$  is  $x^2 + 1$ .

Student: Oh, that's what I did. OK. Alright, thank you.

*Definition is unknown or unclear.* In 5% of the transcribed conversations students asked questions that reflected either a lack of knowledge or lack of understanding of a particular definition. The following excerpt appeared in the transcribed conversations.

Instructor: Yes, ma'am?

Student: What is the real difference between an identity and a conditional?

Instructor: An identity is true for all values of  $x$  for which both sides of the equation are defined.

Student: So is this one an identity or a conditional?

Instructor: Well, 31?

Student: Yeah.

Instructor: Well it looks like you found that it's true only when  $x = 9$ , so that's a conditional. It's true only for certain values of  $x$ .

Student: So like this one, if  $x$  were any number it'd be true?

Instructor: Right, if  $x$  were any number except for 0 it'd be true, and it's not defined for 0. So that makes it an identity.

Student: OK. Thank you.

*Mathematical notation is not understood or cannot be used properly.* In 2% of the transcribed conversations students did not understand or were unable to properly use mathematical notation. The following excerpt appeared in the transcribed conversations.

Student: Professor, do I have to put a bracket set on the inconsistent ones?

Instructor: Well, inconsistent has no solution, right? So no solution means the solution set is the empty set.

Student: Alright, do you have to draw that,  $\emptyset$ .

Instructor: Either that, or it's the set containing nothing,  $\{\}$ . But almost everybody uses that  $\emptyset$  instead. This  $\{\}$  can be kind of confusing.

**Field notes.** Observations of interactions between students, as well as the behavior of individual students, provided indications of how students perceived their inverted classroom. Descriptions of perception categories derived from the field notes appear in Table 13.

Table 13

*Categorization of Perceptions Derived From Field Notes*

Category of Perceptions	Description
Preparation for class	Perceptions pertaining to the importance of viewing videos and taking notes prior to coming to class to solve problems.
Problem solving in class	Perceptions regarding the benefit of solving problems in class, where help was available from classmates and the instructor.
Group work	Perceptions concerning the value of working in groups where students can interact with each other, asking questions to gain new knowledge and explaining mathematics to others to reinforce existing knowledge.

Recorded observations pertinent to each of the categories shown in Table 13 are discussed below. Also discussed are perceptions that students may have had based on the observations of their actions and behaviors.

*Preparation for class.* Based on the recorded observations, there were large differences between students' levels of preparation for class. Differences in levels of preparation became apparent around the twelfth day of class when several students asked about finding points in order to graph the equation  $y = \sqrt{x^2 - 1}$ , and seemed unaware that the equation could easily be transformed into the standard equation for a circle, as was done in one of the examples in the video and in the textbook. One student asked about graphing an equation involving the greatest integer function, and appeared have no understanding of what the greatest integer function is, although the function was explained in the video and is covered in the textbook. On the other hand, other students were able to solve both problems without assistance.

Differences in levels of preparation for class remained apparent throughout the semester. Two or three students in each of the two sections consistently arrived to class with all or most of the problem assignment already completed. Most students, probably somewhere in the neighborhood of 60 to 70 percent, arrived with notes. Lack of preparation was evident as some students' seemed unaware of the problem solving techniques and strategies that were explained in detail in the video. Some students asked for help in performing even the most basic operations that were explained in the video, such as finding the square root of a negative number, horizontally translating a graph, or a composing two functions.

The differences in levels of preparation may have reflected differences in perceptions pertaining to the importance of viewing videos and taking notes prior to coming to class to solve problems. Students were expected to view videos and take notes prior to coming to class in order better understand the material for in-class problem solving. The problems and associated notes were then not due until the beginning of the next class. Some students may have felt that viewing videos and taking notes prior to in-class problem solving would not increase their understanding enough to make it worth the effort. Students may have been unaware that preparation before class may allow them to more efficiently use their time while solving problems in class, and allow them to take greater advantage of the assistance available from their peers and the instructor.

*Problem solving in class.* During class there were large differences observed between students' levels of engagement with problem solving. At the beginning of the semester it seemed that every student was engaged in problem solving almost the entire class period. By the twelfth day of class the behavior of some of the students had



changed. Some students had started texting (text messaging on their phone) more, using only a portion of their class time for solving problems.

The instructor reflected on the texting that was occurring during class, and the possible distraction from problem solving that it might introduce. The following excerpt is from the entry in the field notes for the fourteenth day of class.

Students of course need to socialize to learn. Today, students can text messages to each other through cell phones. Allowing students to text during an inverted classroom doesn't seem to decrease, but rather seems to increase, learning. A relaxed atmosphere makes the environment more conducive to learning. The students are adults, and they know what they are responsible for learning. If students do not finish the problem assignment in class (where their classmates and the instructor are available for help) they will have to finish the problems outside of class. This fact seems to encourage students to focus on their work. Besides, I cannot force understanding into their minds, but I can allow students to relax and interact with each other to encourage students to gain understanding on their own.

(R. Jaster, field notes, September 28, 2012)

The instructor decided not to prohibit texting in class. A few students (about two or three in each section) did not use their time well, typically chatting with classmates about things not related to mathematics or texting on their phones for extended periods of time. Overall, most students remained reasonably focused on problem solving during class.

The observed differences between levels of engagement with problem solving may have reflected differences between the perceived benefits of solving problems in class. The problems were not due until the beginning of the next class. Some students

may have felt that the help that was available from classmates and the instructor was not worth having to start work on the problems almost 48 to 72 hours before they were due.

*Group work.* The recorded observations seem to indicate that most students held positive perceptions regarding group work. The following observations are based on the instructor's field notes.

As early as the second day of class the instructor noticed that the demand on him to answer questions during class did not seem any more (and may have been less) than the demand on him to answer questions during the second preliminary study, although both sections had more students. During the second preliminary study students did not work in groups. With students working in groups and able to help each other, the instructor had more time to observe class.

Working together in groups seemed to be a positive learning experience for the students. Student behavior indicated group work was accepted and effective. Students explained problem solutions to each other, collaborating while working on the problem assignment. Students better prepared for class frequently explained topics to one or more of the other students in his or her group. Such behavior suggested that not only were the other students in the group learning, but in explaining the topic the better-prepared student was reinforcing his or her own knowledge.

During the course of the semester the students seemed to become quite accustomed to working on problems in their groups. The relaxed atmosphere seemed to allow students to relax. Students communicated well with each and the instructor. The instructor frequently observed students helping each other in solving the problems. Students seemed to enjoy class in addition to learning mathematics.

As the semester progressed students asked less questions. It appeared that students had gotten to know each other a bit, so they relied on each other more than in the beginning of the semester.

In some groups the students became friends with each other. During one recorded observation the instructor overheard one student planning a study session with the other students in her group to take place outside class.

Sometimes at the beginning of class the instructor would see a student sitting alone (either because other students in the group were absent or had recently dropped the course). Whenever this occurred, the instructor would find a group of students for the lone student to sit with and introduce the student to the other students in the group.

### **Quantitative Methods**

Descriptive statistics and boxplots are shown below for each of the ten constructs measured by the survey instrument. Descriptive statistics include the mean, standard deviation, and five number summary (the minimum, lower quartile, median, upper quartile, and maximum) of the measures of each construct. Boxplots graphically depict the distributions of the measures.

**Data Collected.** Quantitative data describing perceptions were collected four times during the semester. Before each periodic exam, students had opportunity to earn extra credit on the upcoming exam by completing an online survey. The survey instrument, described in Chapter 3 under the heading Questionnaire, consisted of twenty items and measured the ten constructs that appear in Table 4. The questionnaire appears in Appendix J.

Four students in the sample chose not to participate in any of the four administrations of the survey. No quantitative data was gathered describing the perceptions of the four nonparticipating students. Construct measures were determined for the 78 other students in the sample, and the descriptive statistics and boxplots below are based on those measures.

**Analysis Performed.** As shown in Table 4, four of the ten constructs were measured by multiple items on the questionnaire. Before calculating descriptive statistics and producing boxplots, for each student, one measure for each construct was determined.

First, for each student one measure for each construct was determined for each administration of the survey. For each of the four constructs measured by multiple items, item responses were averaged to obtain the one measure. For the six constructs measured by single items, item responses served as single measures of each construct. This resulted in one measure of each construct for a given student and administration, with multiple items for any given construct equally weighted.

Next, for each student for each construct, the one to four measures determined for each administration of the survey were averaged. The averaging resulted in one measure for each student for each construct, with data from different survey administrations equally weighted.

**Results of Analysis.** The descriptive statistics and boxplots for the three constructs pertaining to perceived learning contribution are presented together to facilitate comparison and discussion in Chapter 5. The statistics and boxplots for the three constructs pertaining to level of engagement are presented together for the same

reasons. The statistics and boxplots for the remaining four constructs, which pertain to learning, outside work, relative work, and preference, are presented together merely for convenience. No relationship is intentionally implied between the mentioned remaining four constructs.

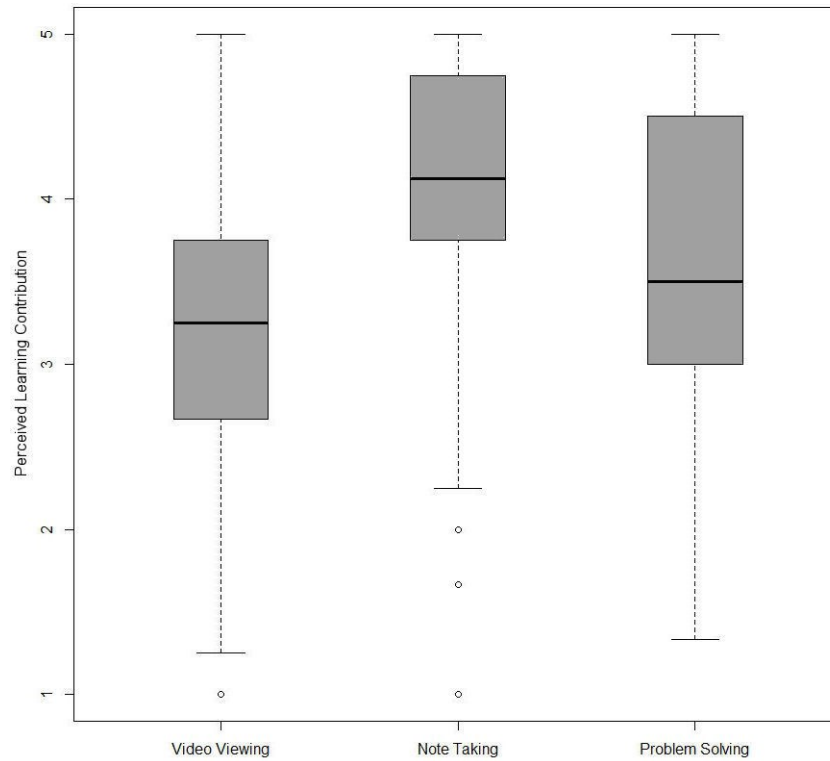
***Perceived learning contributions.*** The mean, standard deviation, and five-number summary of the measures of perceived learning contribution of each of the three elements appear in Table 14. Measures of perceived learning contribution varied from 1.0 (*least contribution*) to 5.0 (*greatest contribution*).

Table 14

*Descriptive Statistics for Perceived Learning Contributions*

Statistic	Video Viewing	Note Taking	Problem Solving
Mean	3.173	4.022	3.556
Standard deviation	1.069	0.870	0.948
Minimum	1.000	1.000	1.333
Lower quartile	2.667	3.750	3.000
Median	3.250	4.125	3.500
Upper quartile	3.750	4.729	4.458
Maximum	5.000	5.000	5.000

Boxplots for the perceived learning contribution of video viewing, note taking, and problem solving appear in Figure 3.



*Figure 3.* Boxplots for Perceived Learning Contribution. Boxplots display the distribution of measures of perceived learning contribution of each of the three elements of an inverted classroom.

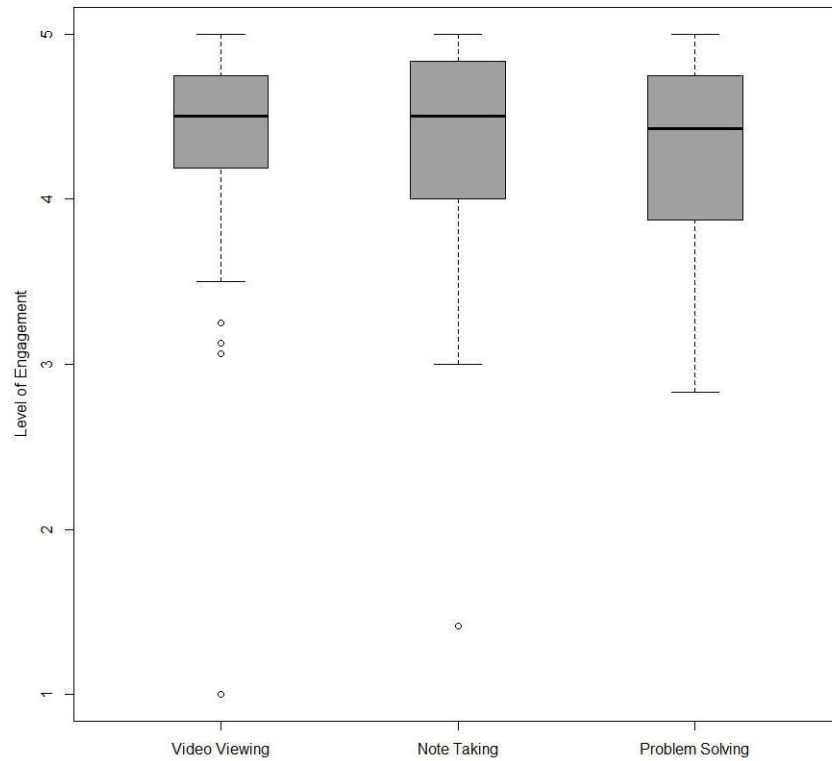
***Levels of engagement.*** The mean, standard deviation, and five-number summary of the measures of level of engagement based on survey data of each of the three elements appear in Table 15. Measures of level of engagement varied from 1.0 (*least engagement*) to 5.0 (*most engagement*).

Table 15

*Descriptive Statistics for Levels of Engagement*

Statistic	Video Viewing	Note Taking	Problem Solving
Mean	4.364	4.364	4.321
Standard deviation	0.595	0.597	0.566
Minimum	1.000	1.417	2.833
Lower quartile	4.188	4.021	3.891
Median	4.500	4.500	4.428
Upper quartile	4.734	4.833	4.750
Maximum	5.000	5.000	5.000

Boxplots for the measures of level of engagement based on survey data with video viewing, note taking, and problem solving appear in Figure 4.



*Figure 4.* Boxplots for Level of Engagement Based on Survey Data. Boxplots display the distribution of measures of level of engagement with each of the three elements of an inverted classroom.

***Learning, outside work, relative work, and preference.*** Four constructs measured by the survey concerned learning, outside work, relative work, and preference. Measures of each construct were determined by student responses that varied from 1.0 to 5.0.

Measures were determined of the perceived improvement in learning when using inverted classroom instruction instead of traditional lecture-based instruction. A measure of 1.0 indicated the least perceived improvement in learning, whereas a measure of 5.0 indicated the most.



Measures were determined for the amount of work required outside of class for the inverted classroom as perceived by the students. A measure of 1.0 indicated the least amount of outside work, whereas a measure of 5.0 indicated the most.

Measures were determined for the amount of work done in the inverted college algebra class relative to the amount of work done in other classes as perceived by the students. A measure of 1.0 indicated the least relative amount of work, whereas a measure of 5.0 indicated the most.

Measures were also determined of student preference for the inverted classroom format. A measure of 1.0 indicated the least preference, whereas a measure of 5.0 indicated the most.

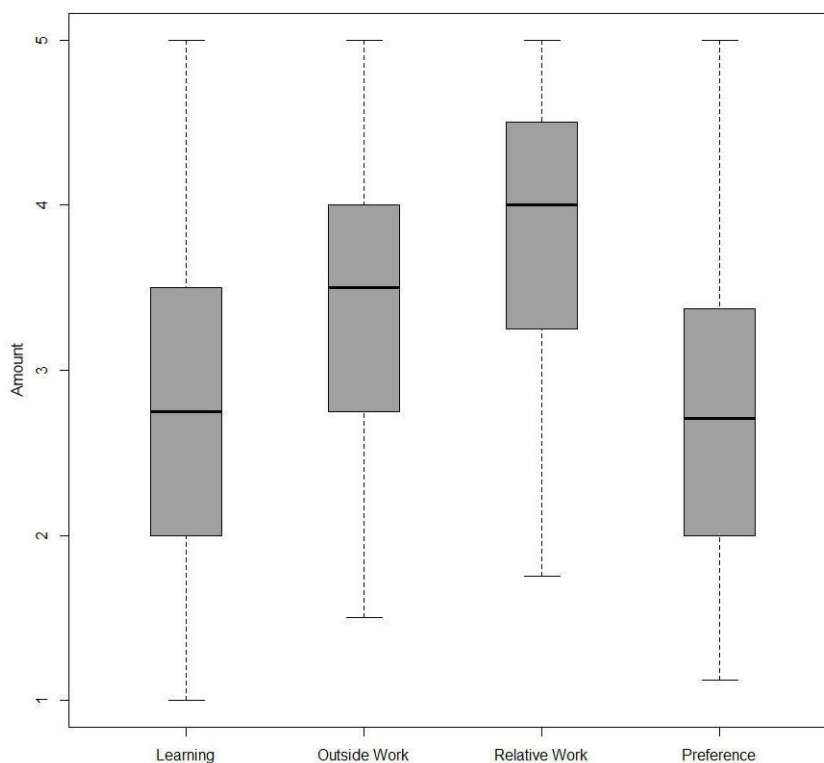
Descriptive statistics for learning improvement, outside work, relative work, and preference appear in Table 16. The statistics include the mean, standard deviation, and five-number summary of each of the four constructs.

Table 16

*Descriptive Statistics for Learning, Outside Work, Relative Work, and Preference*

Statistic	Learning Improvement	Outside Work	Relative Work	Preference
Mean	2.869	3.449	3.890	2.759
Standard deviation	0.982	0.837	0.726	0.927
Minimum	1.000	1.500	1.750	1.125
Lower quartile	2.000	2.750	3.250	2.000
Median	2.750	3.500	4.000	2.708
Upper quartile	3.500	4.000	4.500	3.364
Maximum	5.000	5.000	5.000	5.000

Boxplots for perceived improvement in learning, outside work, relative work, and preference for the inverted classroom format appear in Figure 5.



*Figure 5.* Boxplots for Learning, Outside Work, Relative Work, and Preference. Boxplots display the distribution of measures of perceived improvement in learning, amount of work required outside class, amount of work done relative to other classes, and preference for the inverted classroom format.

### Research Question Two

The second research question was: What is the relationship, if any, between perceived learning contributions of various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?

Quantitative methods were used in measuring variables and analyzing data to search for and describe such a relationship.

### **Data Collected**

The data collected for addressing the second research question consisted of grade outcomes and survey responses to specific items on the questionnaire. The grade outcomes were available to the researcher as a consequence of teaching the course, and students supplied survey responses during each of the four administrations of the survey. The survey is further described in Chapter 3 under the heading Survey Data.

At the end of the semester grade outcome was calculated for each student. The grade outcome was a weighted average, and was based on scores received on pre-homework, problem assignments, notes, and exams. More details regarding the calculation of the weighted average appear in Appendix G, which shows all information common between the syllabi for the two sections that constituted the sample.

For each of the three elements, perceived learning contribution of the element was a construct measured by the survey. For each administration of the survey and for each element, students indicated perceived learning contribution of the element by their response to one item on the questionnaire. Table 4 identifies the item for measuring each of the three constructs. Student responses to a total of three items were collected for addressing the second research question.

A total of 78 students participated in at least one administration of the survey. By the end of the semester 13 of the 78 students had stopped attending class and did not take the final exam. Since it is not known why the 13 students stopped attending, the low grade outcomes of those students may or may not reflect perceived learning

contributions. Two of the 13 students informed the instructor that they had stopped attending due to medical reasons. The other 11 students stopped attending at different times during the semester, resulting in large differences in the amount of work completed (and semester average) among those students. Two of the other 11 students each accrued less than eight absences during the semester, while five of the other 11 students each accrued 18 or more absences. To increase the likelihood of finding a true relationship between grade outcome and perceived learning contributions, data for the 13 students that participated in at least one administration of the survey and did not take the final exam were excluded from analysis. Survey data supplied by the remaining 65 students and the grade outcomes of those students were the data collected for addressing the second research question.

### **Analysis Performed**

Multiple regression analysis was used in addressing the second research question. Grade outcome was the response variable and perceived learning contributions of the elements were the three explanatory variables.

For each of the 65 students, the collected data were used to determine a measure of perceived learning contribution of each of the three elements of the inverted classroom. The measures of perceived learning contribution had been calculated from the collected data in order to provide descriptive statistics for addressing the first research question. The procedure followed in calculating the measures is explained under the above heading Research Question One.

A model was developed that describes grade outcome as a function of perceived learning contributions of elements of the inverted college algebra classroom. The analysis performed in each step of developing the model is described below.

**Data exploration.** Analysis began with an inspection of scatterplots. A scatterplot was generated for each pairwise combination of the variables *grade* (grade outcome), *plcvv* (perceived learning contribution of video viewing), *plcnt* (perceived learning contribution of note taking), and *plcps* (perceived learning contribution of problem solving). The scatterplots were inspected to discover any individual relationships between pairs of variables, identify interesting points, and highlight the need for transformation of one or more of the variables (Ramsey & Schafer, 2002).

The data points shown in each of the three scatterplots involving *grade* were reasonably well distributed, with not many data points clustered on top of each other. No distribution of variable values appeared to be skewed. The plots did not indicate the need of a data transformation for any of the variables to another scale. The plots indicated a positive correlation between grade outcome and each of the three explanatory variables, although since the data points did not clearly form a line the individual correlations did not appear to be strong. The three other plots showed that the explanatory variables *plcvv*, *plcnt*, and *plcps* were related to each other on a pairwise basis. Table 17 shows the Pearson  $r$  correlation coefficients that corresponded to the bivariate relationships that were depicted in the plots. The positive values of  $r$  confirmed the existence of the observed positive correlations.

Table 17

*Pearson r Correlation Coefficients for Grade Outcome and Perceived Learning Contributions*

	plcvv	plcnt	plcps	grade
plcvv	1.000			
plcnt	0.578	1.000		
plcps	0.614	0.470	1.000	
grade	0.247	0.117	0.213	1.000

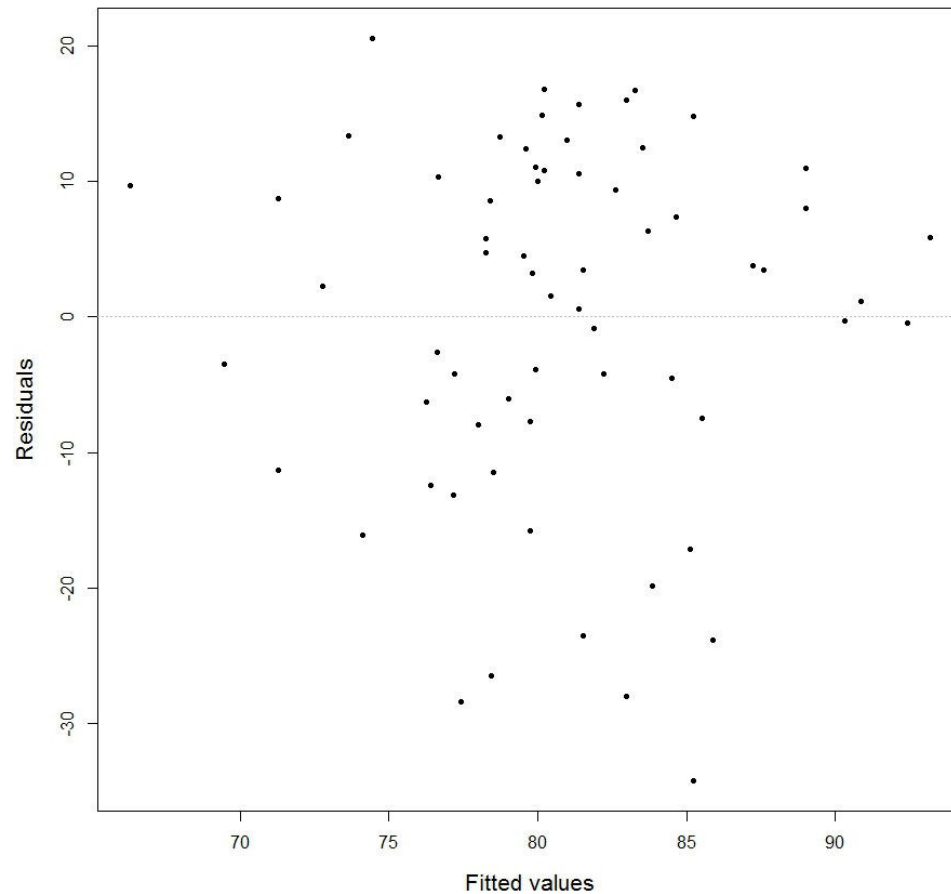
Due to the correlations among the explanatory variables, none of the scatterplots indicated whether any given explanatory variable was associated with *grade* after accounting for the effects of the other two explanatory variables. Additional analysis was needed to identify the relationship between grade outcome and perceived learning contributions.

**Model formulation.** The researcher felt that it was possible for the effect of one explanatory variable on grade outcome to not be constant over all of the values of another explanatory variable. To account for any such interaction, additional variables were constructed as products of the measured explanatory variables and included in the tentative model.

Locally-weighted polynomial regression lines drawn in the scatterplots indicated that any of *plcvv*, *plcnt*, and *plcps* may have had a non-constant effect on *grade*. To account for any curvilinear relationship, variables were included in the tentative model that were squares of individual explanatory variables.

The tentative model chosen included all products and squares of the measured variables. The next step in analysis was to examine a residual plot to assess the need for

transformation and identify any outliers. Figure 6 shows a plot of the residuals versus fitted values for the tentative model.



*Figure 6.* Residual-Fitted Plot for Tentative Model of Grade Outcome Regressed on Perceived Learning Contributions. The scatterplot shows the relationship between the residual and fitted values that resulted from the fit of the tentative model to the data.

Most of the residuals in Figure 6 appear to be randomly distributed about the 0 line, indicating that the relationship between grade outcome and the perceived learning contributions is indeed linear. The residuals lie approximately in a horizontal band around the 0 line, indicating that the subpopulations of grade outcome have about the

same variance. None of the plotted points in Figure 6 are clearly separated from the others, so no further concern with outliers was required prior to model checking.

Although it is widely believed otherwise, normally distributed outcomes are not required for the  $t$ -test and linear regression (Lumley, Diehr, Emerson, & Chen, 2002). Ramsey and Schafer (2002) state “estimates of coefficients and their standard errors are robust to non-normal distributions” (p. 211) since the tests and confidence intervals are based on the normality of the sampling distributions of the estimates, not the normality of the population distribution. A check for the normality of grade outcomes in the sample (which could have been done with a normal probability plot) was not required.

Although data was collected from two sections, there was no reason to suspect that the grade that a student received was in any way affected by the particular section in which the student was enrolled. The course requirements and class policies were identical between the sections and both sections met in the morning on the same days. Nevertheless, the possibility of cluster effect is reconsidered following Table 18. Other than the possibility of cluster effect, there was no reason to suspect that the grade outcome of any student had an effect on the grade outcome of any other student. It was assumed that the grade outcomes were independent of each other.

Having checked required assumptions and for the presence of outliers, testing to determine which terms should be eliminated from the model began. The sequential variable selection technique followed was *backward elimination* as described in Ramsey and Schafer (2002).

The backward elimination procedure as followed in this research for testing terms in the current model consists of two tasks.



1. For each variable in the current model, the *F*-to-remove (the extra-sum-of-squares *F*-statistic) is calculated as a relative indicator of the amount of unexplained response variation decreased by the inclusion of the variable in the model. The variable with the smallest *F*-to-remove is identified.
2. As long as the smallest *F*-to-remove is less than 4, the explanatory variable is removed from the model to arrive at a new current model and the procedure continues with step 1. Otherwise, the procedure terminates.

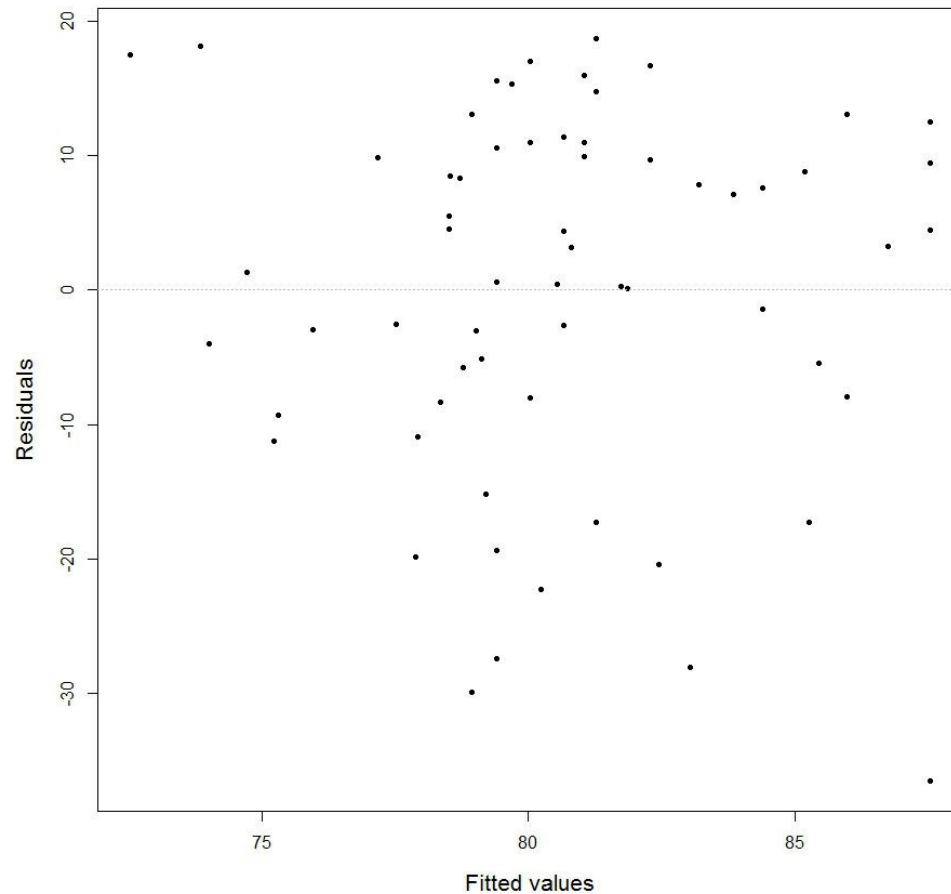
Each iteration of the steps in the described procedure resulted in the elimination of one variable. Table N1 shows the *F*-to-remove calculated the variables for each iteration of the procedure, indicating the order in which variables were eliminated from the model. Backwards elimination continued until only one variable remained, resulting in the following reduced model for mean grade outcome as a function of perceived learning contribution of video viewing and perceived learning contribution of note taking:

$$\mu\{grade | plcvv, plcnt\} = \beta_0 + \beta_1 (plcvv \times plcnt).$$

Note that all terms involving *plcps* were eliminated from the model.

**Model checking.** The reduced model found is quite different than the original model, having only two parameters instead of 11. Further testing was performed to make sure that the reduced model could confidently be used in addressing the second research question.

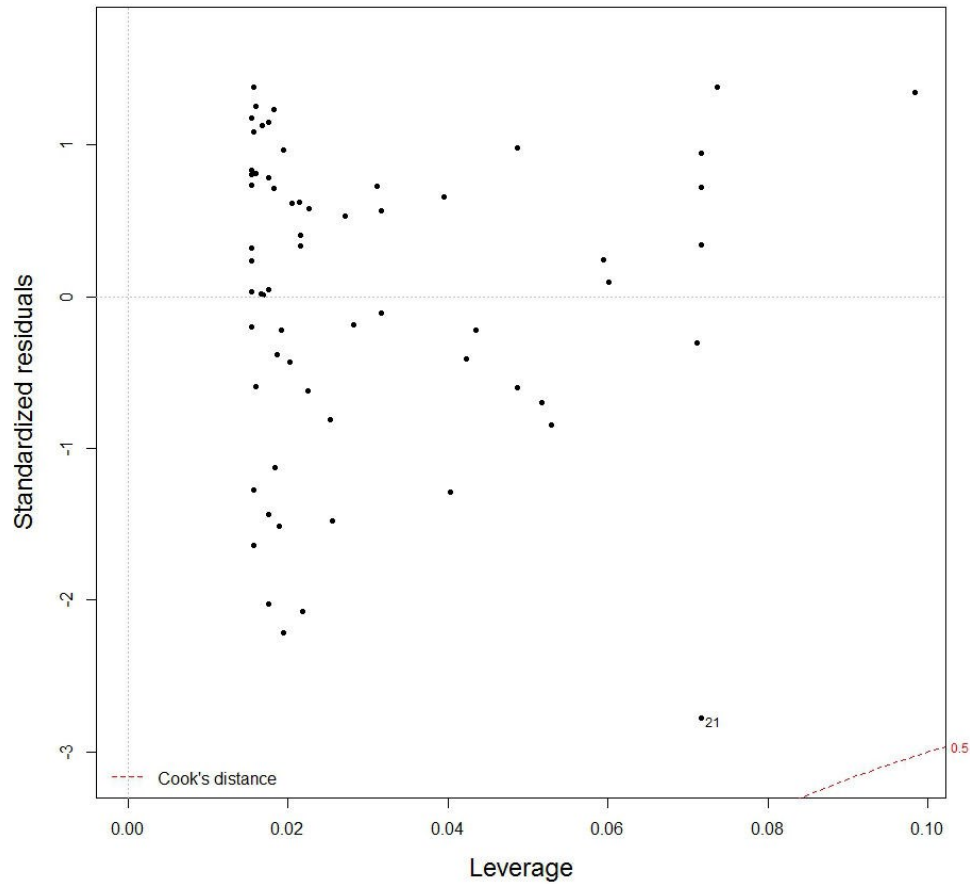
A scatterplot of residuals versus fitted values was examined to check for linearity, equality of variance, and outliers. The plot appears in Figure 7.



*Figure 7.* Residual-Fitted Plot for Reduced Model of Grade Outcome Regressed on Perceived Learning Contributions. The scatterplot shows that relationship between the residual and fitted values that resulted from the fit of the reduced model to the data.

As in Figure 6, most of the residuals in Figure 7 appear to be randomly distributed about the 0 line, indicating that the relationship between grade outcome and the explanatory variable is indeed linear. The residuals lie approximately in a horizontal band around the 0 line, indicating equality of variance between the subpopulations of grade outcome. None of the plotted points appear to be distant enough from all the other points to be considered outliers.

A check was made for individual cases that may have been excessively influential in the regression analysis. The plot of standardized residuals versus leverage in Figure 8 was used to identify any potentially influential cases for the reduced model. The point for the most influential case in the regression analysis is labeled 21, but since it is located outside the contour shown in the plot, Cook's distance for the case was less than 0.5. No case had a Cook's distance close to or larger than one, indicating that no case was excessively influential in the regression analysis that resulted in the reduced model (Ramsey & Schafer, 2002).



*Figure 8.* Residual-Leverage Plot for Reduced Model of Grade Outcome Regressed on Perceived Learning Contributions. Each case had a Cook's distance less than 1.0, indicating that no case had an excessive influence on the estimated coefficients due to its residual or leverage.

## Results of Analysis

The section contains the regression output for the reduced model and calculations of the 95% confidence interval for the coefficient. This section also describes a test conducted to detect any cluster effect that could have been present due to the data being collected from two sections.

**Regression Output.** Regression output for the reduced model is shown in Table 18 and includes estimates of the coefficients along with the standard errors and *p*-values

associated with the estimates. The estimate of the coefficient of  $plcvv \times plcnt$  is 0.625 and its standard error is 0.299. The 97.5th percentile of a  $t$ -distribution with 63 degrees of freedom is 1.998, so the 95% confidence interval for the coefficient is

$$0.625 - 1.998(0.299) \text{ to } 0.625 + 1.998(0.299),$$

or

$$0.028 \text{ to } 1.222$$

Table 18

*Regression Output for Reduced Model of Grade Outcome Regressed on Perceived Learning Contributions*

	Estimate	Standard Error	$p$ -value
(Intercept)	71.902	4.560	<2e-16
plcvv x plcnt	0.625	0.299	0.0406

Residual standard error: 13.663 on 63 degrees of freedom  
Multiple R-squared: 0.065, Adjusted R-squared: 0.050  
F-statistic: 4.371 on 1 and 63 DF, p-value: 0.00406

The regression output in Table 18 includes the  $R^2$  statistic (labeled *Multiple R-squared*), or coefficient of determination. The adjusted  $R^2$  does not have the same interpretation as  $R^2$  (Ramsey & Schafer, 2002).

**Cluster Effect.** To check for cluster effect, a variable was added to the reduced model that indicated the section in which each student was enrolled. Regression coefficients were calculated, and the regression coefficient of the indicator variable was not significant at the 0.05 level. Thus the data failed to provide convincing evidence that the section in which a student was enrolled influenced grade outcome after taking into

account the effects of perceived learning contribution of video viewing and perceived learning contribution of note taking.

### **Research Question Three**

The third research question was: What is the relationship, if any, between levels of engagement with various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome? Quantitative methods were used in measuring variables and analyzing data to search for and describe such a relationship.

### **Data Collected**

The data collected for addressing the third research question included grade outcomes and survey responses to specific items on the questionnaire. Additional data for measuring level of engagement with video viewing was captured by having the website track student access to the webpage that provided access to the videos, as explained in Chapter 3 under the heading Webpage Access Counts. Additional data for measuring level of engagement with note taking was generated by instructor evaluation of the submitted notes, as explained in Chapter 3 under the heading Evaluation of Notes.

Details regarding the determination of grade outcomes appear in Appendix G. Responses were collected during each of the four administrations of the survey during the semester. Throughout the semester the instructor maintained the evaluation of notes in a digital spreadsheet, and the web server maintained a table that included a count of the number of times each student logged into the website to gain access to the webpage that provided access to the videos. Once the semester had concluded the researcher downloaded the table from the website.

For each of the three elements, level of engagement with the element was a construct measured by the survey. For each administration of the survey and for each element, students indicated level of engagement with the element by their responses to four items on the questionnaire. Table 4 identifies the items for measuring each of the three constructs. Student responses to a total of twelve items were collected for addressing the third research question.

A total of 65 students participated in at least one administration of the survey and took the final exam. Grade outcomes, survey responses, instructor evaluations of notes, and webpage access counts for those 65 students were the data collected for addressing the third research question.

### **Analysis Performed**

Multiple regression analysis was used in addressing the third research question. Grade outcome was the response variable and levels of engagement with the elements of the inverted classroom were the three explanatory variables.

For each student, the collected data were used to determine a measure of level of engagement with each of the three elements of the inverted classroom. Measures of level of engagement had been calculated from the survey data in order to provide descriptive statistics in addressing the first research question. The procedure followed in calculating those measures is explained under the above heading Research Question One.

Before embarking on regression analysis to address the third research question, the additional data made available by the tracking of website access were used to refine the original measurements of level of engagement with video viewing that were based solely on survey data. The original measures ranged from 1.0 to 5.0. The student that

accessed the webpage most frequently had an access count of 81, and the student that accessed the webpage least frequently had an access count of zero. To calculate each refined measure, one was added to the product of the student's access count and 4/81. The result was then averaged with the original measure. The calculation of the refined measure of level of engagement with video viewing may be written as:

$$\left( \begin{array}{l} \text{refined measure of video} \\ \text{viewing engagement} \end{array} \right) = \frac{1}{2} \left( \left( \left( \left( \left( \text{access} \right) \times \frac{4}{81} \right) + 1 \right) + \left( \begin{array}{l} \text{original measure} \\ \text{based on survey data} \end{array} \right) \right) \right).$$

The calculation gave equal weight to the data provided by the student and the data provided by the website in determining the refined measure of level of engagement with video viewing for each student.

Similarly, the additional data made available by instructor evaluation of notes were used to refine the original measures of level of engagement with note taking that were based solely on survey data. The original measures ranged from 1.0 to 5.0. The instructor's evaluation of the submitted notes resulted in a score for each student from 0.0 to 3.0 that represented the average apparent amount of effort made by the student in taking notes. To calculate each refined measure, one was added to the product of the score based on apparent effort and 4/3. Then the result was averaged with the original measure. The calculation of the refined measure of level of engagement with note taking may be written as:

$$\left( \begin{array}{l} \text{refined measure of note} \\ \text{taking engagement} \end{array} \right) = \frac{1}{2} \left( \left( \left( \left( \left( \text{score based on} \right) \times \frac{4}{3} \right) + 1 \right) + \left( \begin{array}{l} \text{original measure} \\ \text{based on survey data} \end{array} \right) \right) \right).$$



The above calculation gave equal weight to the data provided by the student and the data contributed by the instructor in determining the refined measure of level of engagement with note taking for each student.

**Data exploration.** Analysis began with an inspection of scatterplots. A scatterplot was generated for each pairwise combination of the variables *grade* (grade outcome), *loevv* (level of engagement with video viewing), *loent* (level of engagement with note taking), and *loeps* (level of engagement with problem solving). The scatterplots were inspected to discover any individual relationships between pairs of variables, identify interesting points, and highlight the need for transformation of one or more of the variables (Ramsey & Schafer, 2002).

The data points shown in each of the three scatterplots involving *grade* were reasonably well separated from each other, with not many data points tightly clumped together. No skewness in the distribution of values for any of the variables was apparent in the plots.. The plots did not indicate the need of a data transformation for any of the variables to another scale. The plots indicated a positive correlation between grade outcome and each of the three explanatory variables. The three other plots also showed that the explanatory variables *loevv*, *loent*, and *loeps* were related to each other on a pairwise basis. The strongest correlation appeared to exist between *loevv* and *loent* since the data points were closer together and more clearly formed a line. Table 19 shows the Pearson  $r$  correlation coefficients that corresponded to the bivariate relationships that were depicted in the plots. The positive values of  $r$  confirmed the existence of the observed positive correlations.

Table 19

*Pearson  $r$  Correlation Coefficients for Grade Outcome and Levels of Engagement*

	loevv	loent	loeps	grade
loevv	1.000			
loent	0.735	1.000		
loeps	0.153	0.250	1.000	
grade	0.247	0.508	0.456	1.000

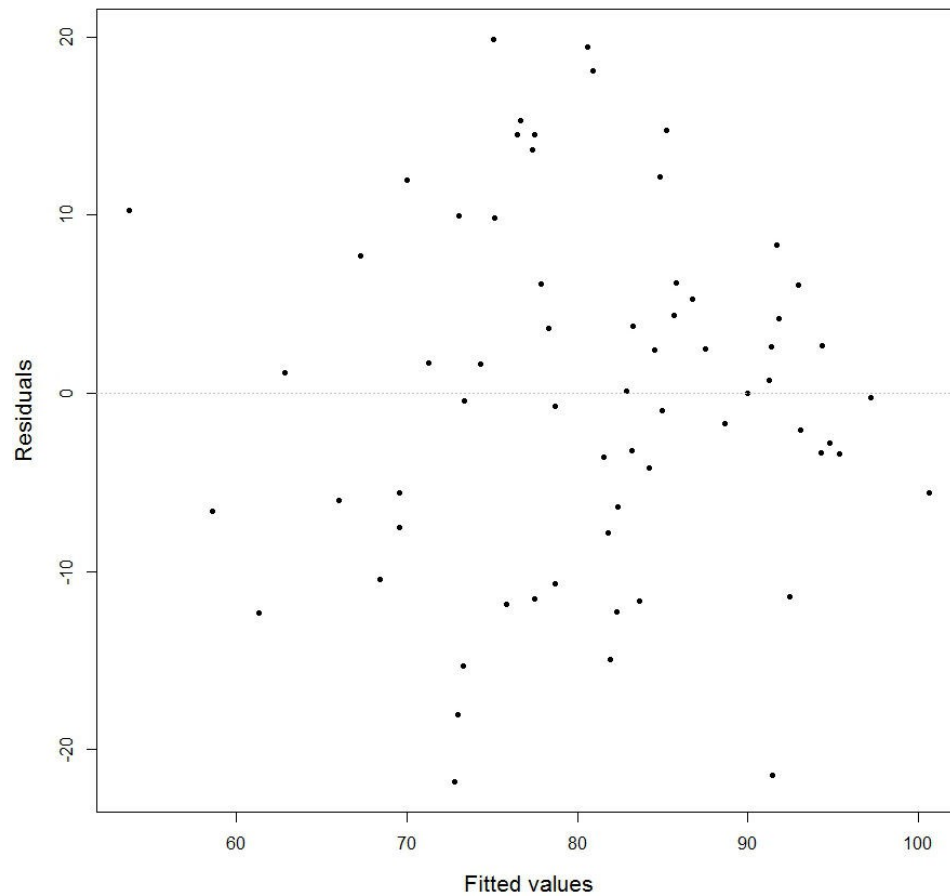
Due to the correlations among the explanatory variables, none of the scatterplots indicated whether any given explanatory variable was associated with *grade* after accounting for the effects of the other two explanatory variables. Additional analysis was needed to identify the relationship between grade outcome and levels of engagement.

**Model formulation.** An initial tentative model was formulated and backward elimination resulted in an initial reduced model. While capable of determining fitted values that resulted in minimal residuals, determining each element's relative contribution to grade outcome based on the values of the coefficient estimates in the initial reduced model was complicated by the presence of interaction terms. Simply comparing coefficient estimates to determine relative contribution was not possible. Calculating the effect on *grade* of level of engagement with a particular element while leaving levels of engagement for the other two elements unchanged doesn't necessarily provide any useful information, since it may not be possible for the value of one variable to change without change in the values of other variables (G. Simon, 2009).

As explained by Ramsey and Schafer (2002), many models may be available, and more than one model may adequately describe the regression and allow for a less complicated interpretation. Searching for a model to more clearly address the third

research question continued with another tentative model that did not include interaction terms.

The next step in analysis was to examine a residual plot to assess the need for transformation and identify any outliers. Figure 9 shows a plot of the residuals versus fitted values for the tentative model.



*Figure 9.* Residual-Fitted Plot for Tentative Model of Grade Outcome Regressed on Levels of Engagement. The scatterplot shows the relationship between the residual and fitted values that resulted from the fit of the tentative model to the data.

The random distribution of residuals that is apparent about the 0-line in Figure 9 indicates that the relationship between grade outcome and level of engagement is linear. The residuals form an approximate horizontal band around the 0 line, indicating that the subpopulations of grade outcome have about the same variance. No points in the scatterplot are distant enough from the other points to be considered outliers.

As previously explained in this chapter in addressing the second research question, it is not necessary that outcomes be normally distributed for linear regression, so a check for the normality of grade outcomes was not required. Also as previously explained in addressing the second research question, grade outcomes were assumed to be independent of each other. The possibility of cluster effect is reconsidered following Table 20.

Required assumptions had been checked and no outliers were found in the data that might have misled the analysis. Testing began to determine which terms should be eliminated from the model. As described above under the heading Research Question Two, backward elimination was used to sequentially select variables for elimination.

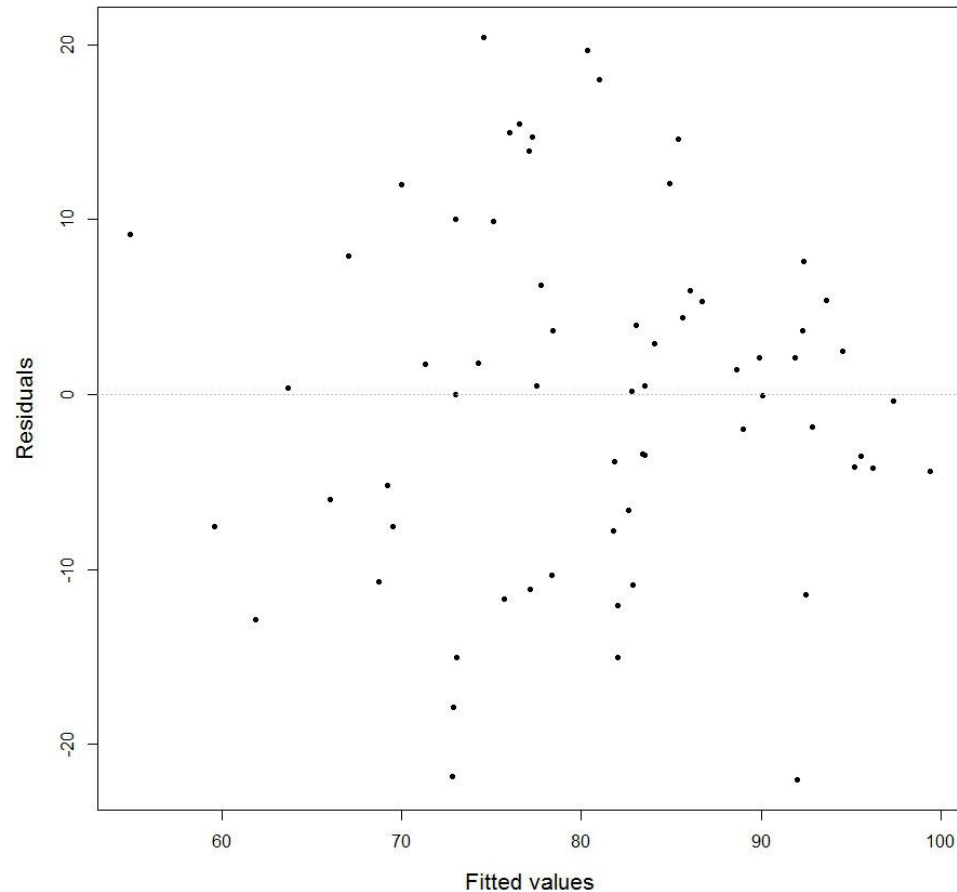
Table N2 shows the *F*-to-remove calculated for each variable for the two iterations of the backward elimination. The procedure terminated after having removed only one variable, resulting in the following reduced model of mean grade outcome as a function of level of engagement with video viewing, level of engagement with note taking, and level of engagement with problem solving:

$$\mu\{grade|loevv,loent,loeps\} = \beta_0 + \beta_1loevv + \beta_2loent + \beta_3loeps + \beta_4(loevv)^2.$$

**Model checking.** Backward elimination reduced the number of parameters in the second model from five to four. Further testing was performed to make sure that

necessary assumptions for least squares estimation were satisfied for the reduced model and given data.

A scatterplot of residuals versus fitted values was examined to check for linearity, equality of variance, and outliers. The plot appears in Figure 10.

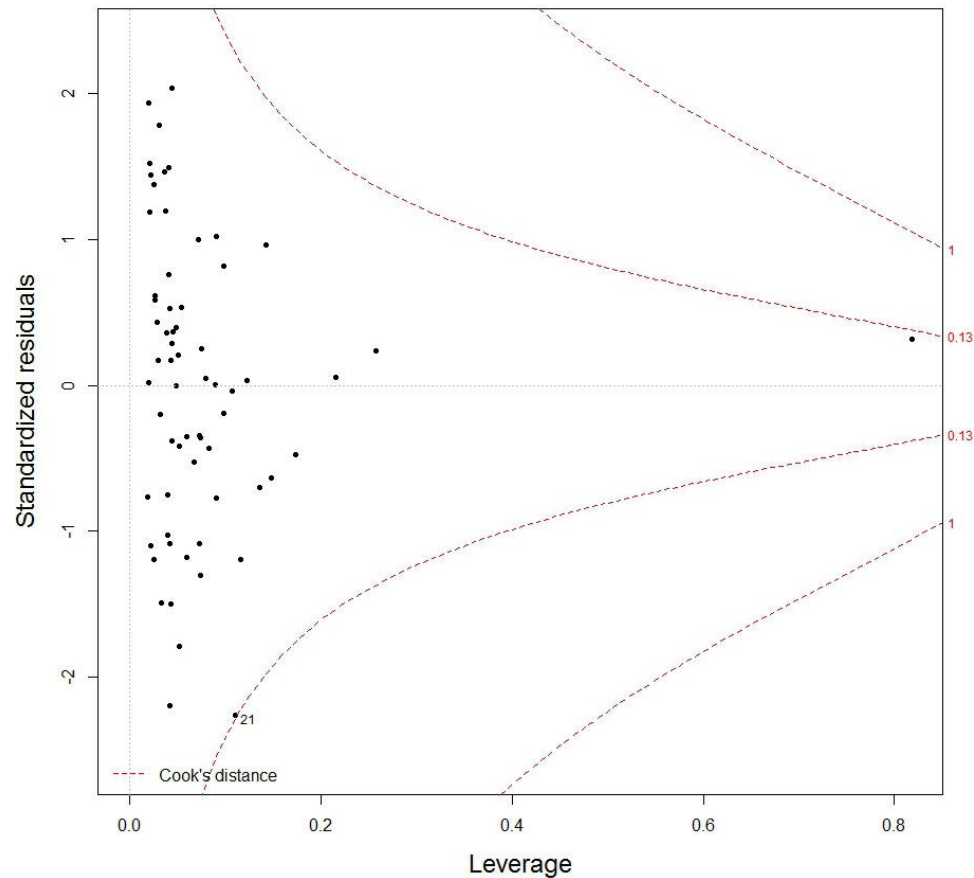


*Figure 10.* Residual-Fitted Plot for Reduced Model of Grade Outcome Regressed on Levels of Engagement. The scatterplot shows that relationship between the residual and fitted values that resulted from the fit of the reduced model to the data.

As in Figure 9, most of the residuals in Figure 10 appear to be randomly distributed about the 0 line, indicating a linear relationship between grade outcome and

the explanatory variables. The plot implies that the subpopulations of grade outcome have about the same variance since the residuals lie approximately in a horizontal band around the 0 line. Also none of the plotted points appear to be far enough from all the other points to be considered outliers.

The residual-leverage plot shown in Figure 11 identified case 21 as the case having the largest Cook's distance. The plotted point for case 21 is touching one of the contours that corresponds with a Cook's distance of 0.13. The point for case 21, and the points for the other cases, are located well outside of the 1.0 contours. Hence no case had a Cook's distance near or larger than one, indicating that no case was excessively influential in the regression analysis that resulted in the reduced model (Ramsey & Schafer, 2002).



*Figure 11.* Residual-Leverage Plot for Reduced Model of Grade Outcome Regressed on Levels of Engagement. Each case had a Cook's distance less than 1.0, indicating that no case had an excessive influence on the estimated coefficients due to its residual or leverage.

## Results of Analysis

The section contains the regression output for the reduced model and calculations of the 95% confidence intervals for the coefficients. This section also describes a test conducted to detect any cluster effect that could have been present due to the data being collected from two sections.

**Regression Output.** One of the objectives in finding the relationship between grade outcome and levels of engagement was to discover each element's relative contribution to grade outcome. Standardized regression coefficients can be compared

directly with each other since they are all in standard deviation units. Consequently, the measures of all variables in the reduced model were standardized prior to executing regression calculations. The letter *s* was prefixed to each variable name to indicate that it had been standardized.

Computer output from the regression calculations are shown in Table 20, and includes estimates of the coefficients along with the standard errors and *p*-values associated with the estimates.

Table 20

*Regression Output for Reduced Model of Grade Outcome Regressed on Levels of Engagement*

	Estimate	Standard Error	<i>p</i> -value
(Intercept)	0.000	0.091	1.000
sloevv	-2.031	0.543	0.000
sloent	0.787	0.147	0.000
sloeps	0.233	0.100	0.023
sloevv <sup>2</sup>	1.698	0.503	0.001

Residual standard error: 0.731 on 60 degrees of freedom

Multiple R-squared: 0.499, Adjusted R-squared: 0.465

F-statistic: 14.917 on 4 and 60 DF, *p*-value: 1.615e-08

*Note.* All measurements were standardized prior to the calculations that resulted in the above output.

The 97.5th percentile of a *t*-distribution with 60 degrees of freedom is 2.000.

Confidence intervals for the estimates are calculated below using the information in Table 20.



- The 95% confidence interval for the coefficient of *sloevv* of is  
 $-2.031 - 2.000(0.543)$  to  $-2.031 + 2.000(2.031)$ , or -3.117 to -0.945.
- The 95% confidence interval for the coefficient of *sloent* is  
 $0.787 - 2.000(0.147)$  to  $0.787 + 2.000(0.147)$ , or 0.493 to 1.081.
- The 95% confidence interval for the coefficient of *sloeps* is  
 $0.233 - 2.000(0.100)$  to  $0.233 + 2.000(0.100)$ , or 0.033 to 0.433.
- The 95% confidence interval for the coefficient of *sloevv*<sup>2</sup> is  
 $1.698 - 2.000(0.503)$  to  $1.698 + 2.000(0.503)$ , or 0.692 to 2.704.

The regression output in Table 20 includes the  $R^2$  statistic, or coefficient of determination. It is labeled Multiple R-squared in the table.

**Cluster Effect.** To check for cluster effect, a variable was added to the reduced model that indicated the section in which each student was enrolled. Regression coefficients were calculated, and the regression coefficient of the indicator variable was not significant at the 0.05 level. Thus the data failed to provide convincing evidence that the section in which a student was enrolled influenced grade outcome after accounting for the effects of level of engagement with video viewing, level of engagement with note taking, and level of engagement with problem solving.

**Relative Effect.** Multiple regression analysis produced the following model of mean standardized grade outcome (*sgrade*) as a function of standardized level of engagement with video viewing (*sloevv*), standardized level of engagement with note taking (*sloent*), and standardized level of engagement with problem solving (*sloeps*):

$$\mu\{sgrade | sloevv, sloent, sloeps\} = -2.031(sloevv) + 0.787(sloent) + 0.233(sloeps) + 1.698(sloevv^2).$$

Since all measures had been standardized prior to regression calculations the intercept is zero and does not appear in the model. The coefficients of *sloent* and *sloeps* are 0.787 and 0.233 respectively, indicating that level of engagement with note taking made a greater contribution to mean grade outcome than level of engagement with problem solving.

The effect of *sloevv* on mean *sgrade* is the change in mean *sgrade* associated with each one unit increase in *sloevv* while holding the values of *sloent* and *sloeps* constant (Ramsey & Shaffer, 2002). The effect of *sloevv* can be calculated by partial differentiation of the model with respect to *sloevv*. The effect of *sloevv* on mean *sgrade* is thus  $3.396(sloevv) - 2.031$ .

Comparison with the coefficients of *sloent* and *sloeps* can now be accomplished by solving the inequality

$$0.233 < 3.396(sloevv) - 2.031 < 0.787$$

which yields

$$0.667 < sloevv < 0.830$$

The above inequality indicates that the contribution of *loevv* to mean *grade* was greater than the contribution made by *loeps*, and less than the contribution made by *loent*, only when *loevv* was between 0.667 and 0.830 standard deviations above its mean. When *loevv* was less than 0.667 standard deviations above its mean, *loevv* made less contribution to mean *grade* than either *loent* or *loeps*. When *loevv* was more than 0.830

standard deviations above its mean, *loevv* made more contribution to mean *grade* than either *loent* or *loeps*.

Z-Scores of 0.667 and 0.830 correspond to percentiles of 74.761 and 79.673 respectively for a normal curve. These z-scores are used to interpret the results regarding relative effect in Chapter 5 under the heading Research Question Three.

### Summary

This chapter presents the results of the primary study of this investigation. After describing the population and sample, and considering the internal consistency reliability and criterion validity of the survey instrument, each research question was stated and addressed.

Qualitative and quantitative analyses produced results for addressing the first research question. The results of the qualitative analyses are the categories of perceptions that appear in Tables 11 through 13. The results of the quantitative analysis are the descriptive statistics that appear in Tables 14 through 16, and the boxplots that appear in Figures 3 through 5.

Multiple regression analysis produced a model of grade outcome as a function of a variable that represented the interaction between perceived learning contribution of video viewing and perceived learning contribution of note taking. Results indicated that the single interaction variable explained 6.5% of the variance in grade outcome ( $R^2 = .065$ ,  $F(1, 63) = 4.371$ ,  $p < .01$ ). The data provided convincing evidence that grade outcome was associated with the interaction variable ( $\beta = .625$ ,  $p < .05$ ).

Multiple regression analysis also produced a model of grade outcome as a function of four variables. Three of the explanatory variables represented level of

engagement with video viewing, note taking, and problem solving. The other explanatory variable was the square of level of engagement with video viewing. Results indicated that the four variables explained 49.9% of the variance in grade outcome ( $R^2 = .499$ ,  $F(4, 60) = 14.917$ ,  $p < .001$ ). The data provided convincing evidence that grade outcome was associated with level of engagement with video viewing ( $\beta = -2.031$ ,  $p = .000$ ), level of engagement with note taking ( $\beta = .787$ ,  $p = .000$ ), level of engagement with problem solving ( $\beta = .233$ ,  $p = .023$ ), and level of engagement with video viewing squared ( $\beta = 1.698$ ,  $p = .001$ ).

Chapter 5 contains interpretations of the results presented in this chapter, and discusses why the results turned out the way they did. The results led to recommendations for future research, teaching practice, and preparation of an inverted college algebra classroom, which can also be found in Chapter 5.

## CHAPTER 5

### DISCUSSION

Each year approximately 849,600 students enroll in college algebra<sup>4</sup>, and about 424,800 of those students ultimately either withdraw from the course or receive a grade of D or F (Allen et al., 2006; DeDeo, 2001; Owens, 2003; Small, 2006; Tulsa Community College, Office of Planning and Research, 2007). This research investigated a relatively new approach to instruction in which content was provided outside class allowing time in class for other activities.

#### Synopsis of the Research

In an inverted classroom, “events that have traditionally taken place *inside* the classroom now take place *outside* the classroom and vice versa” (Lage et al, 2000, p. 32). This research investigated the teaching of college algebra in an inverted classroom. The following three research questions guided the research:

1. What are students’ perceptions of an inverted college algebra classroom?
2. What is the relationship, if any, between perceived learning contributions of various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?

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<sup>4</sup> Details concerning this estimate appear in Appendix A.

3. What is the relationship, if any, between levels of engagement with various elements (video viewing, note taking, and problem solving) of an inverted college algebra classroom and grade outcome?

The results of this research address each of the three research questions.

A theoretical framework based on cognitive and social constructivism guided this research (Piaget, 1963; Vygotsky, 1978). Literature described elements (activities in which students participate primarily for the purpose of learning) that may be included in the design of an inverted classroom. Principles of constructivism addressed by each element were identified to show that theory supports the inclusion of the element in an inverted classroom.

An inverted college algebra classroom was designed and implemented to address the research questions. The researcher was also the instructor in the inverted college algebra classroom. The elements chosen for the inverted college algebra classroom were video viewing, note taking, and problem solving. Videos were recorded and a website was created to make the videos available to students. Students were expected to view videos and take notes outside class, and solve problems in class.

Both qualitative and quantitative methods were employed in conducting the research. The three sets of qualitative data analyzed during the study included student essays, transcripts of student-instructor conversations that were recorded during class, and field notes that described the instructor's in-class observations. Quantitative data analyzed included survey data, webpage access counts, and instructor evaluations of student submitted notes.

To address the first research question, each of the three sets of qualitative data was analyzed. Each analysis resulted in a categorization of perceptions. In the essays students described perceptions regarding outside-class activity, in-class activity, group work, the effectiveness of the inverted format, independence in learning, amount of work, efficiency, and overall preference for the inverted classroom format. In the transcribed conversations students identified the specific difficulties they perceived in solving the assigned problems. The field notes provided indications of how important students perceived the inside- and outside-class activities. Quantitative analysis of survey data provided statistics that contributed to the descriptions of student perceptions. The perceptions described by the qualitative and quantitative data led to findings reported in the next section of this chapter.

Multiple regression analysis provided results for addressing the second research question. Survey data provided strong evidence that perceived learning contributions of video viewing and note taking were associated with grade outcome. Regression analysis indicated that perceived learning contributions explained 6.5% of the variance in grade outcome ( $R^2 = .065$ ,  $F(1, 63) = 4.371$ ,  $p < .01$ ). Students who perceived video viewing and note taking as making large learning contributions tended to have higher grade outcomes.

Multiple regression analysis also provided results for addressing the third research question. Survey data, webpage access counts, and instructor evaluation of notes provided convincing evidence that levels of engagement with video viewing, note taking, and problem solving were associated with grade outcome. Regression analysis indicated that levels of engagement explained 49.9% of the variance in grade outcome ( $R^2 = .499$ ,

$F(4, 60) = 14.917, p < .001$ ). Students who had high levels of engagement with the three elements tended to have higher grade outcomes.

### **Research Findings**

This investigation was guided by three research questions. The findings are as follows.

#### **Research Question One**

Qualitative analysis yielded descriptions and categorizations of perceptions of the inverted college algebra classroom. Findings derived from each data source are highlighted and agreement among findings are noted.

**Elements.** The essays indicated differences in the favorability of perceptions between the elements of the inverted classroom (see Table 11). Students held mixed perceptions in regard to video viewing, whereas most students held positive perceptions in regard to problem solving. Results from other data sources agreed with the favorability of perceptions described in the essays.

**Findings.** The findings below describe student perceptions of an inverted college algebra classroom. Perceptions are described for each of the three elements included in the classroom.

*Video viewing.* In 57% of the essays, a larger percentage than for any other category of perceptions, students commented that the videos were impersonal or did not allow for questions (see Table 11). In 17% of the essays students stated that it was more difficult to learn well from a video for other reasons. Note that the given percentages of essays cannot be summed since some essays may have contained comments that fit both categories and were thus counted in the calculation of both percentages.



The analysis of the conversation transcripts did not identify a category of perceptions in regard to video viewing. The analysis of the field notes revealed that sometimes one or more student had not watched the video prior to class, which may have reflected dissatisfaction with the videos. Based on this consideration, both the field notes and the essays indicated that students held negative perceptions of video viewing.

On the other hand, in 46% of the essays students commented that the ability to control playing of the video was helpful. The analysis of the field notes indicated that at times students were able to solve problems without assistance from their peers or the instructor. The ability to pause or repeat parts of the videos may have helped students in learning course content well enough to solve problems without assistance. Based on this consideration, both the field notes and the essays indicated that students also held positive perceptions of video viewing.

In addition to the essay data, the survey data also indicated that students held mixed perceptions of video viewing (see Table 14 and Figure 3). Descriptive statistics for the survey data indicated that students held only slightly favorable perceptions of video viewing in regard to learning contribution. Also, perceived learning contribution of video viewing had greater standard deviation than perceived learning contribution of either problem solving or note taking, indicating less decisiveness in the survey responses regarding video viewing. Hence, the survey data and the essays indicated that students also held both positive and negative perceptions of video viewing.

Schroeder, Xue, and McGivney (2013) reported that students in their flipped mathematics classrooms liked being able to watch videos as many times as they wished, although students were frustrated that help was not available while watching the videos.

While the videos recorded by Schroeder, Xue, and McGivney were shorter than the videos in this research (only about 10-15 minutes instead of 40-50 minutes in length), student perceptions of video viewing found in their investigation were similar to student perceptions found in this research.

*Problem solving.* While solving problems in class, students worked with classmates and received assistance from the instructor. In 48% of the essays students commented that working with classmates or in-class instructor assistance was helpful. In the essays several students stated that working problems in class was beneficial. Also students worked on problems in groups, so student perceptions of group work may have provided an additional indication of how students felt about problem solving. In almost three times as many essays students reported that group work was good for learning as opposed to reporting that it was not good for learning.

The analysis of the transcribed conversations between students and the instructor resulted in six categories of perceptions (see Table 12). All six categories identify types of difficulties in problem solving experienced by the students, indicating that students were primarily concerned with problem solving when speaking with the instructor. It seems unlikely that students would seek assistance unless they perceived problem solving as helpful. Based on this consideration, both the transcripts and the essays indicated that students held positive perceptions of problem solving.

Based on the analysis of the field notes, while students' levels of engagement with problem solving differed, most students maintained a reasonable focus on problem solving during class. Analysis of the field notes also indicated that students held positive

perceptions regarding group work. Hence, both the survey data and the essays indicated that students held positive perceptions of problem solving.

Descriptive statistics based on the survey data indicated that students' perceptions of problem solving were positive, but not strongly. The mean perceived learning contribution of problem solving was a little greater than for video viewing, but not as great as it was for note taking. Also, the standard deviation for perceived learning contribution of problem solving was almost as large as it was for video viewing (see Table 14 and Figure 3) indicating indecisiveness in the measures. Hence the results obtained from analysis of the survey data only marginally agreed with the results obtained from the essays with regard to perceptions of problem solving.

Although overall perceptions of problem solving were positive, several students felt that an in-class activity in addition to problem solving would have improved the inverted classroom. In the essays several students commented that such an activity would be useful in learning.

*Note taking.* No category of perceptions specifically about note taking was found in the analysis of the essays, conversation transcripts, or field notes. Survey data, however, indicated that students held positive perceptions of note taking. The mean perceived learning contribution of note taking was higher than mean perceived learning contribution of either video viewing or problem solving. Also, perceived learning contribution of note taking had a smaller standard deviation than perceived learning contribution of either video viewing or problem solving, indicating greater decisiveness in the survey responses regarding note taking.

**Discussion.** There were two factors that may have fostered the perception of the videos being impersonal and exacerbated the frustration felt due to the inability of the videos to respond to questions. The first factor is related to the length of the videos, and the second factor is likely due to most students not having taken a lecture-based class in college algebra.

Most of the videos produced for this research were around 40 to 50 minutes in length. Each video contained a complete explanation of all content and included every example shown in the corresponding section of the textbook. Moreover, video editing allowed the video to more efficiently deliver content than lecture. The videos did not contain any instructor mistakes. Video clips were concatenated resulting in very little time between explanations and examples. Also, in the videos the instructor is not distracted by anything in the classroom and does not have to respond to questions. Certainly almost every video contained more content than is typically delivered in 50-minute lecture. The additional content undoubtedly resulted in additional questions in the minds of the students.

As discussed in Chapter 1, the CBMS 2010 survey indicated that most sections of college algebra were taught by the standard lecture method (AMS, 2013d; AMS, 2013f). College algebra is so packed with content that in a lecture-based course many instructors may feel that it is necessary to lecture the entire class meeting in order to deliver the prescribed material. Unfortunately, in such a classroom the instructor is unable to spend much time answering student questions. College freshman, having recently graduated from high school, may be more accustomed to a mathematics classroom in which the instructor has more time to answer student questions. As shown in Table 5, 85.4% of the

students in the sample were freshmen. In the comments extracted from the essays that appear in Chapter 4, students complained about not being able to ask the instructor in the videos questions while he is teaching or explaining how to do a problem. If students had realized the small number of questions that instructors have time to address during a lecture in a lecture-based college algebra course, not being able to ask questions during the video may not have been seen as such a disadvantage.

Shorter videos may mitigate the impact of the previously described factors on student perceptions. More details regarding this recommendation are described below under the heading Preparation.

***Support for constructivism.*** The findings that students held mixed perceptions in regard to video viewing, whereas most students held positive perceptions in regard to problem solving and note taking support the learning theory of constructivism. The elements allowed students to reflect, and thus allowed students to engage in metacognition, to varying degrees. As Pelech and Pieper (2010) explained, metacognition is “the conscious process of regulating, monitoring, and developing and monitoring strategies regarding one’s thinking” (p. 170). Pelech and Pieper discuss research conducted by Hall (2001), Rezvan, Ahmadi, and Abedi (2006), and Trainin and Swanson (2005) that showed metacognition helps college students learn. This supports constructivism’s claim that knowledge is individually constructed (Pelech & Pieper, 2010), and that “knowledge is an autonomous and subjective construction” (p. 8).

Mean perceived learning contribution was highest for note taking (see Table 14 and Figure 3), and note taking (which took place outside class) offered students the greatest opportunity for reflection. Perceived learning contribution of problem solving

(which primarily took place in groups during class) had the second highest mean, and problem solving offered students the second greatest opportunity for reflection. Video viewing offered students the least opportunity for reflection, and video viewing had the lowest mean perceived learning contribution.

The theoretical framework includes 12 principles that describe learning based on constructivist theory. The 12 principles were provided by Pelech and Pieper (2010) and are listed below:

1. Students learn by participating in activities that enable them to create their own version of knowledge. This includes creating their own rules, definitions, and experiments. (p. 32).
2. Students learn when they teach others, explain to others, or demonstrate a concept to others. (p. 33).
3. Students learn when they create products from the real world that involves narratives, explanations, justifications, and dialogue. (p. 33).
4. Knowledge comes in multiple forms, and its development is not uniform; hence, students must be given the opportunity to develop each intelligence or domain. (p. 35).
5. Students learn when class activities stimulate multiple senses. (p. 35).
6. A student learns by creating knowledge at different levels of complexity and thinking. (p. 37).
7. A student learns by connecting new experiences with existing knowledge or connecting previously discrete experiences to each other. (p. 38).

8. Students learn when they are continuously presented with problems, questions, or situations that force them to think differently. (p. 39).
9. Students learn by making connections through the “Standard Six”: compare and contrast, hypothesize and predict, express understanding in multiple modes, find patterns, summarize, and find personal relevance. (p. 39).
10. A student regulates his learning by (1) knowing his own ability and learning style preference, (2) analyzing tasks and appropriate strategies, (3) choosing and analyzing appropriate goals, (4) analyzing and appraising his individual level of performance, and (5) managing his time effectively. (p. 40).
11. Students learn by working with other people who are the source of contradiction, different perspectives, and confirmation. (p. 41).
12. Modern society provides the source of authentic products for students to produce. (p. 41).

Note taking addresses Principles 1, 3, 5, 6, 7, 8, 9, and 10 (see Table 2). Problem solving in groups can provide the experiences and opportunities mentioned in Principles 1, 2, 3, 6, 7, 8, 10, and 11. Video viewing addresses Principles 1, 5, 6, 8, and 10 (see Table 2). Based on the number of principles addressed by each element, the finding that students held mixed perceptions toward video viewing and held positive perceptions of note taking and problem solving supports the theory of constructivism.

**Instructional approach.** Several categories of perceptions derived from the essays disclosed how students felt about the inverted college algebra classroom. Ten of the categories shown in Table 11 converged to better describe the impressions held by the students.

**Findings.** The findings below describe students' perceptions of an inverted college algebra classroom. The perceptions described concern students' preference for the inverted classroom format.

**Preference.** Most students indicated a preference for a lecture-based class over an inverted classroom. In 54% of the essays students wrote that overall they preferred a lecture-based class, versus 28% of the essays in which students wrote that they preferred an inverted classroom. This finding contrasts sharply with findings of the second preliminary study (see Appendix E).

**Other perceptions.** Other perceptions disclosed in the essays also suggested that students would rather be taught in a lecture-based class. In several of the essays students wrote that watching videos or taking notes was too time consuming. In 50% more essays students wrote that the inverted format is not an effective way to teach college algebra, relative to the number of essays in which students wrote that it is. In the essays, more students reported that more work was required in the inverted classroom than would have been required in a lecture-based class in comparison to the number of students who either reported that the amount of work was the same or reported that the amount of work was less. Also almost twice as many students reported that the inverted classroom resulted in a less efficient use of their time for learning than a lecture-based class, relative to those who reported that it resulted in a more efficient use of time.

**Discussion.** In 51% of the essays collected during the second preliminary study, students wrote that they preferred to be taught in an inverted classroom, versus 30% of the essays in which students indicated a preference for lecture (see Table E1). Also during the second preliminary study, students wrote that the inverted classroom resulted



in more learning than a lecture-based class in about four times as many essays as less learning, and students wrote that the inverted classroom resulted in greater efficiency than a lecture-based class in ten times as many essays as lesser efficiency. At the same time, students reported that the amount of work required was more than a lecture-based class in about four times as many essays as a lesser amount. The change in preference led to a consideration of the differences in the designs of the classrooms between the second preliminary study and the primary study.

Most likely the largest single difference between the classrooms in the second preliminary study and the primary study was an increase in the number of problems assigned in class, along with the expectation that students complete each problem assignment outside class before watching the video for the next section. Having students finish the assigned problems outside class allowed the instructor to assign several problems without having to worry that students might not have enough time to finish in class.

For the primary study, for each section covered, the instructor increased the number of problems assigned to the same number of problems he had assigned in prior semesters when teaching college algebra as a lecture-based course. Although students were able to work problems in class, with the dense 40- to 50-minute videos, students were most likely given more work than in the typical lecture-based course.

Amount of work required outside class was one of the constructs measured by the survey instrument (see Table 4). Preference for the inverted classroom format was also measured by the survey instrument. Pearson's  $r$  correlation coefficient was calculated for

the data and confirmed that the additional outside work introduced in the primary study may explain the change in student preference for the inverted classroom.

Had the videos been about 20 to 30 minutes instead of 40 to 50 minutes in length, students would have had more time outside class to complete the problem assignment. This recommendation is described in more detail below under the heading Preparation.

***Support for constructivism.*** The findings that most students preferred a lecture-based class in the primary study and preferred an inverted classroom in the second preliminary study supports constructivist theory. Constructivism's claim that knowledge is individually constructed helps explain how metacognition helps students learn (Pelech & Pieper, 2010). Students have greater opportunity to learn when given adequate time for reflection while learning. If students are assigned so much homework that they do not feel they have adequate time for reflection, students may not engage in metacognition and consequently learn less. Students expected to do too much work outside class may be overworked, frustrated, and dissatisfied.

## **Research Question Two**

Multiple regression analysis produced a model of mean grade outcome (*grade*) as a function of perceived learning contribution of video viewing (*plcvv*) and perceived learning contribution of note taking (*plcnt*). The model included exactly one explanatory variable that indicated *plcvv* and *plcnt* interacted in their effect on mean *grade*.

**Findings.** The presence of the explanatory variable indicated that the effect of *plcvv* on mean *grade* depended on the value of *plcnt*. The greater the value of *plcnt*, the greater impact that *plcvv* had on mean *grade*. Similarly, the effect of *plcnt* on mean *grade* depended on the value of *plcvv*. The greater the value of *plcvv*, the greater impact

that *plcnt* had on mean *grade*. The model shows that students who perceived each of video viewing and note taking as making a large contribution to learning tended to have higher grade outcomes.

The coefficient of determination  $R^2$  indicated that 6.5% of the difference in grade outcomes can be explained by perceived learning contributions of video viewing and note taking. Although 6.5% may not seem to be a large percentage of variance, the regression analysis does indicate that grade outcome was likely affected by perceived learning contributions.

**Discussion.** It seems likely that students who perceived both video viewing and note taking as making large contributions to their learning more earnestly engaged in both activities. The belief that an activity offered ample opportunity to learn may have encouraged students to make greater effort to learn while engaged in the activity.

Taking notes while viewing videos could be expected to be an effective way of learning mathematics. Taking notes may reinforce content explained in the videos. Also, the ability to pause and navigate within the video allows students to control the delivery of content while taking notes, allowing time for reflection.

On the other hand, engaging in one activity without engaging in the other may not be expected to be an effective way to learn mathematics. As with lecture, video viewing may not be as effective as other methods in promoting thought (see Appendix B), making note taking almost essential for learning. Taking notes without watching a video, such as taking notes from the textbook, may leave the student with little understanding.

**Support for constructivism.** The finding that grade outcome is influenced by perceived learning contributions of video viewing and note taking supports

constructivism. It seems likely that students who perceived both activities as beneficial more sincerely engaged in the activities. Taking notes while viewing a video allows the student to pause the video, take notes, and engage in metacognition involving the content being delivered. As explained by Pelech and Pieper (2010), metacognition was shown to help college students learn (Hall, 2001; Rezvan, Ahmadi, & Abedi, 2006; Trainin & Swanson, 2005). The ability to learn through metacognition while viewing videos and taking notes supports constructivism's claim that knowledge is individually constructed, and that it is an "autonomous and subjective construction" (Pelech & Pieper, 2010, p. 8).

Assuming that students who perceived both video viewing and note taking as beneficial more sincerely engaged in those activities, identifying constructivist principles addressed by video viewing and note taking provides additional evidence that this finding supports constructivism. Under the above heading Elements, five of the constructivist principles provided by Pelech and Pieper (2010) are identified as addressed by video viewing, and eight of the principles are identified as addressed by note taking.

### **Research Question Three**

Multiple regression analysis produced a model of mean standardized grade outcome as a function of standardized level of engagement with video viewing, standardized level of engagement with note taking, and standardized level of engagement with problem solving. The model included four explanatory variables, one of which indicated a curvilinear relationship between grade outcome and level of engagement with video viewing.

**Findings.** Assuming that the measures of level of engagement with video viewing were normally distributed, the z-scores presented in Chapter 4 indicate that

engagement with video viewing made the largest contribution to grade outcome (in comparison to engagement with either of the other two elements) for the approximate 20% of the students in the sample most engaged in video viewing. For those 20% of the students, engagement with note taking made the second largest contribution to grade outcome, and engagement with problem solving made the least contribution. For approximately 75% of the students in the sample, engagement with note taking made the greatest contribution to their grade, followed by engagement with problem solving, and then engagement with video viewing. Note that the ordering of elements in the previous statement (which is based on measures of levels of engagement) agrees with the ordering of elements based on mean perceived learning contribution shown in Table 14 and Figure 3.

The coefficient of determination  $R^2$  indicated that 49.9% of the difference in grade outcomes can be explained by levels of engagement with the three elements. The regression analysis indicates that levels of engagement had a substantial influence on grade outcome.

**Discussion.** The finding that engagement with video viewing made the largest contribution to grade outcome for the approximate 20% of the students in the sample most engaged in video viewing could be explained by assuming that videos offered students the greatest opportunity to learn. In other words, it seems reasonable to assume that if a student were sufficiently engaged with video viewing that the video viewing would make the greatest contribution to his or her grade. Under this assumption, approximately 75% of the students were not sufficiently engaged with video viewing in order for video viewing to have the greatest effect on their grade.

**Support for constructivism.** The findings showed that for 75% of the students in the sample, engagement with note taking had the greatest influence on mean grade, followed by engagement with problem solving, and then engagement with video viewing. The findings support constructivism because note taking (which took place outside class) offered students the greatest opportunity for reflection. Problem solving (which primarily took place in groups during class) offered students the second greatest opportunity for reflection. Video viewing offered students the least opportunity for reflection. Reflection allows time for metacognition, which helps students learn (Pelech & Pieper, 2010). Hence the findings support constructivism's claim that knowledge is individually constructed, and that "knowledge is an autonomous and subjective construction" (Pelech & Pieper, 2010, p. 8).

Under the above heading Elements, eight constructivist principles are identified as addressed by note taking, eight principles are identified as addressed by problem solving, and five principles are identified as addressed by video viewing. Based on the number of principles addressed by each element, the finding that for approximately 75% of the students in the sample engagement with video viewing made the least contribution to their grade provides additional evidence that the findings support constructivism.

### **Limitations of the Research**

Descriptive data and details are included in this dissertation so that an investigator may better determine whether the results of this research are likely to transfer to another context. The following limitations may influence the applicability or interpretation of the research results.

**Researcher Bias**

As explained by Patton (2002), “any credible research strategy requires that the investigator adopt a stance of *neutrality* with regard to the phenomenon under study” (p. 51). The researcher did adopt a neutral stance, and did not attempt to confirm any particular perspective or manipulate data to arrive at any desired result.

On the other hand, the researcher was favorably impressed with the inverted classroom prior to beginning this investigation. The possibility of that some aspect of this research was influenced by unconscious bias cannot be ruled out.

**Participant Observation**

As explained by Patton (2002), human perception is highly selective. Since what people see depends on their interests, biases, and previous experience, different people may see different things even when looking at the same thing from the same location. The observations made by the researcher/instructor during class were restricted to observations of those activities that the instructor’s mind chose to perceive. The selective perception of the instructor could have resulted in a greater chance that activities which indicated certain student perceptions were more likely to be recognized and recorded in the field notes. At the same time, the selective perception of the instructor could have resulted in a lesser chance that other activities would be recognized.

The observation itself may have affected the behavior of the students. As explained in Chapter 3 under the heading Participant Observation, classes were video recorded with a camcorder, constantly reminding students that they were being observed for the purposes of research. Patton (2002) noted that being observed can make people self-conscious and generate anxiety.

## **Survey Instrument**

It may have been possible to improve the survey instrument. A few more items could have been added to the questionnaire for measuring the survey constructs, and psychometric techniques could have been used to refine the questionnaire.

## **Recommendations for Research, Practice, and Preparation**

The inverted classroom is a relatively new approach to instruction in college algebra. Consequently much remains to be learned, and there are many paths for research. The recommendations that follow are based on the findings of this study.

## **Future Research**

**Design.** Research may lead to an improved design of the inverted college algebra classroom. A different combination of elements or different lesson procedures may improve instruction based on predetermined criteria. For example, board work might complement in-class problem solving very nicely (McDaniel & Caverly, 2010).

**Elements.** Research might find ways to improve particular elements of the inverted college algebra classroom. For example, refining aspects of the videos in order to increase learning, such as finding an optimal length, improving the explanation of content contained in the videos, or identifying characteristics of effective instructors and then recording instructors that exhibit those characteristics.

**Effectiveness.** Research could compare the effectiveness of an inverted college algebra classroom with another instructional approach. Care should be taken in designing the inverted college algebra classroom to be compared. This research found that student perceptions of two inverted classrooms may differ significantly although the classrooms have the same elements, and perceptions could impact effectiveness.



Research findings concerning effectiveness may lead to improvements in practice. For example, it may be found that due the learning gained inside the classroom, students in an inverted college algebra classroom need not solve as many problems as students in a lecture-based class in order to achieve the same or an even greater level of understanding.

### **Teaching Practice**

Two changes in instruction may have had improved the experience and increased the learning of the students in this research. Each change is described below as a recommendation to future instructors.

**Explanation of learning.** The most frequently reported perception in the essays was that the videos were impersonal or did not allow questions. This is an drawback inherent in the videos, and it should be discussed with students on the first day of class.

It should be explained that the purpose of each video is to give students a basic understanding of the concepts and an overview of the problem solving techniques taught in the section. Students should expect most of their learning to occur during problem solving, which will take place in the classroom where help is available from peers and the instructor. True, the video cannot answer questions, but it should be explained that *many* more questions will arise during problem solving. Students need to understand that help will be available where most learning will occur and where they'll have the most questions.

**Assessment of notes.** Student perceived note taking as making the greatest contribution to their learning, and the relative effect calculations in Chapter 4 showed that note taking had a greater influence on mean grade than problem solving. Based on these

findings, instructors in inverted college algebra classrooms should consider placing greater emphasis on note taking.

The importance of note taking could be emphasized at the beginning of the semester. Notes could be collected and carefully graded. If constrained by time, instructors could grade notes instead of problem solutions. In such a case the exams could hold students accountable for learning how to work the problems assigned.

### **Preparation**

Two recommendations are offered in regard to preparation of an inverted college algebra classroom. One recommendation concerns the design of the classroom, and the other recommendation concerns the videos.

**Design.** Solving problems is essential in learning college algebra. Solving problems in groups allows students to learn individually and socially and is supported by cognitive and social constructivism. Solving problems also allows students to practice metacognition that has been shown to help students learn (Pelech & Pieper, 2010).

To maximize time for problem solving it is recommended to avoid including too many other in-class activities in the design of an inverted college algebra classroom. Too many other activities will reduce the time that students have for solving problems among themselves.

**Videos.** Videos should be kept short, most likely no more than 20 to 30 minutes in length. Otherwise, expecting students to watch a video and take notes, in addition to finishing a typical college algebra problem assignment, is likely to be overdemanding. Also, shorter videos should result in students having less questions outside class where it is more difficult to get the questions answered.

Videos can more efficiently deliver content, so it should not be too difficult to teach one lesson's essential concepts and techniques in a 20 to 30 minute video. Examples can be kept to a minimum since students will have greater opportunity to learn in class by solving problems.

The findings indicated that video viewing may have greater influence on grade outcome than engagement with either note taking or problem solving if the level of engagement with video viewing is sufficient. Given their potential contribution to learning, it may be good idea to provide an incentive for student to watch videos, such as the inclusion of a few practice problems in the video. On random days, the practice problems could be collected for grading once the students arrive to class.

### **Summary**

This research investigated the teaching of college algebra in an inverted classroom. Students were expected to view videos and take notes outside class and solve problems in groups in class. Overall, students' perceptions of problem solving and note taking were positive, while students' perceptions of video viewing were both positive and negative. Most students indicated a preference for a lecture-based class over the inverted classroom, which sharply contrasted with findings of the second preliminary study. A negative correlation between perceived amount of outside work and preference for the inverted classroom suggests that an increase in workload may help account for the change in preference. This research found that for the approximate 20% of the students in the sample most engaged in video viewing, engagement with video viewing made the largest contribution to grade outcome, followed by note taking and then problem solving. For approximately 75% of the students in the sample, engagement with note taking made

the greatest contribution to their grade, followed by engagement with problem solving, and then engagement with video viewing.

## APPENDIX A

### Estimate of the Annual Number of College Algebra Students in the United States

The Conference Board of Mathematical Sciences sponsors a national survey every five years of the nation's four-year and two-year colleges and universities (AMS, 2013a). The CBMS 2010 survey found that in Fall 2010 the number of students enrolled in a college algebra course at a four-year college or university was approximately 242,000 (AMS., 2013e), and at a two-year college was approximately 230,000 (AMS, 2013f), making the total number of these students about 472,000. The CBMS 2010 survey also found that the 2010 national ratio of full-year enrollment to fall-term enrollment in the mathematical sciences programs of four-year colleges and universities was 1.8 (AMS, 2013c). Allowing this ratio to also be used to estimate the full-year enrollment at two-year colleges yields  $(242,000 + 230,000) \times 1.8 \approx 849,600$  students enrolled in college algebra in the 2010 academic year.

In Fall 2010, the number of additional students enrolled in a combined college algebra and trigonometry course at a four-year college or university was approximately 37,000 (AMS, 2013e), and at a two-year college was approximately 11,000 (AMS, 2013f). Again allowing the 2010 national ratio of full-year enrollment to fall-term enrollment in the mathematical sciences programs of four-year colleges and universities

to be used to estimate the full-year enrollment at two-year colleges yields an additional  $(37,000 + 11,000) \times 1.8 \approx 86,400$  students enrolled in a combined college algebra and trigonometry course in the 2010 academic year. Including these students in the above estimate of yields  $849,600 + 86,400 \approx 936,000$  students enrolled in either college algebra or in a combined college algebra and trigonometry course.

The CBMS 2010 survey also found that at four-year institutions in Fall 2010 more students were enrolled in college algebra than in any other college-level precalculus mathematics course (AMS, 2013d). In Fall 2010 the college-level precalculus mathematics course with the second largest enrollment at doctoral-level mathematics departments was precalculus (with approximately 46,000 students versus 88,000 college algebra students), and at masters-level and bachelors-level departments the course was mathematics for the liberal arts (with approximately 98,000 students versus 154,000 college algebra students) (AMS, 2013e).

## APPENDIX B

### The Choice of Lecture in Teaching College Algebra

The common use of lecture in teaching college algebra may seem understandable when one considers that lecture is regarded as one of the best ways to communicate a large amount of material in a short period of time (Moore, 2008). Although a lecture may include clear explanations of mathematical concepts and example problems, students attempting to take notes on complex, difficult material may overload their cognitive capacity and miss much of the lecture (McKeachie, Pintrich, Lin, & Smith, 1987). After an in-class explanation of content, faculty are typically left with little or no time for discussion or other learning activities in which to engage the students (Walvoord & Anderson, 2009).

In his book *What's the Use of Lectures?* Bligh (2000) argued, with reservations, that based on available evidence lecture is as effective as other methods for transmitting information. Bligh examined research literature that described 298 experimental comparisons of lecture with other teaching methods where acquisition of information was the criterion of effectiveness. Bligh counted the comparisons showing lecture less, not differing significantly, or more effective than another method. Bligh found that most of the other teaching methods showed no significant difference when compared with lecture, and those teaching methods that did show a difference when compared with lecture were

fairly balanced either way (except for comparisons of lecture with teaching methods that he classified as either Programmed Learning or Personalized Systems of Instruction). Bligh concluded that lectures are as effective as other methods to teach facts, but not more effective.

In a review of research literature that described 73 experimental comparisons of lecture with other teaching methods where promotion of thought was the criterion of effectiveness, lecture did not fare as well. Again Bligh (2000) counted the comparisons showing lecture less, not differing significantly, or more effective than another method. Bligh found only two studies that suggested that lectures stimulate thought better than discussion methods. A total of 29 of the 32 comparisons that contrasted lecture with discussion found lectures to be less effective than discussion in getting students to think. Bligh cited and briefly described studies conducted by Asch (1951); Barnard (1942); Bloom (1953); Dawson (1956); Hovland and Mandell (1952); and James, Johnson, and Venning (1956) as indicating that most lectures are not as effective as discussion methods in promoting thought. Bligh acknowledged that thought may take place during lectures. His claim, however, was that “the traditional style of exposition does not promote it in such a way as to justify lecturing to achieve this objective” (Bligh, 2000, p. 11).

Bligh (2000) explains that the main objective of lectures should be the acquisition of information by the students, and not the promotion of their thought. The evidence presented by Bligh calls into question the choice of lecture as the primary instructional method in college algebra.



## APPENDIX C

### Details of Online Search of Research Literature

On January 11, 2012 an online search was performed for any research literature that pertained to both the inverted classroom and college algebra. Several databases were searched for various keyword combinations in order to identify any existing research literature on this topic.

Two databases, ERIC and Education Full Text, were identified by the university library's website as core resources for educators and researchers. Eleven additional online resources were identified. The names of all resources searched for research literature relevant to the inverted college algebra classroom appear below.

Feasibly searching for any research literature relevant to an inverted college algebra classroom required a consideration of search criteria. To search efficiently Boolean operators and the truncation symbol were used in the search string.

The terms *flipped classroom* and *reverse classroom* are synonymous with *inverted classroom*. Consequently, the search string was constructed to initially match any form the word *flip*, *reverse*, or *invert*. The asterisk truncation symbol will match zero or more characters, so appending an asterisk to a word will match different forms of the word. For example, *flip\** matches flip, flips, flipped, and flipping. The Boolean OR operator was used to return results containing any form of any of the three words.

The Boolean AND operator was used to restrict results to those that also contained the term *college algebra*. This term was enclosed in quotation marks since it consists of two words. The following search string encompasses all the criteria discussed above, and was used in all searches for any research literature specific to an inverted college algebra classroom: (flip\* OR reverse\* OR invert\*) AND “college algebra”.

First, the following seven databases were searched simultaneously through the EBSCOhost online reference system:

- ERIC,
- Education Full Text,
- eBook Collection (EBSCOhost),
- Education Research Complete,
- PsycINFO,
- Social Sciences Full Text, and
- SocINDEX with Full Text.

The search of these seven databases for any research literature that matched the search string yielded two results. Inspecting each result yielded no literature that was pertinent to the inverted classroom.

Next, the following three databases were searched simultaneously for research literature that matched the search string:

- ProQuest Dissertations and Theses,
- ProQuest Education Journals, and
- ProQuest Research Library.

The search of these three databases yielded the same research literature previously found to be irrelevant to the inverted classroom.

Next, the Social Sciences Citation Index database was searched for any research literature that matched the search string. Searches for any research literature that contained matching words either *in Topic* or *in Title* were performed. Neither search yielded any results.

Next, the Google Scholar database was searched for any research literature that matched the search string. Google Scholar returned 262 results. None of these results led to literature that was found to be relevant to the inverted college algebra classroom.

Finally, the Google Books database was searched for any research literature that matched the search string. Google Books returned two results, neither of which led to a literature related to the inverted college algebra classroom.

In total, thirteen resources were searched for any research literature pertinent to an inverted college algebra classroom. No such literature was found.

## **APPENDIX D**

### **Preliminary Study One**

The first preliminary study of an inverted college algebra classroom took place during the Fall 2011 semester. Much was learned during this first attempt at an untried instructional strategy. The experience gained guided changes in the design of the classroom for the second preliminary study.

#### **Initial Design of the Inverted College Algebra Classroom**

The initial design of the inverted classroom for college algebra had a few flaws which led to difficulties that surfaced around the time of the first exam. Fortunately, the problems with the design were later resolved resulting in the inverted classroom being well received by students during the last one-third of the semester. Although some difficulties were encountered, most students nevertheless gained a reasonable understanding of college algebra and managed to pass the class.

Each of the three design flaws is discussed below. These design flaws were easy to correct once they were identified by students in an anonymously submitted essay.

#### **Lack of Outside Learning Incentives**

In the inverted classroom as originally designed, students had little incentive to learn the content outside of class. The homework assignments (to be completed prior to coming to class) each consisted of watching a video, optionally taking notes, and working

a few problems (usually about 8 or 10) that corresponded to the examples in the video and the textbook. Students were expected to submit the problems at the beginning of class.

The solutions to the assigned problems (including all details) were shown in the back of the book. Students could check their work to see if they solved the problems correctly. However, students could also simply copy the solutions in the back of the book, and not watch the videos or learn how to solve the problems. Once the homework problems were submitted for credit at the beginning of class, the student had no further apparent use of the problem solutions.

To make matters worse, these beginning college students had no way of knowing that they were headed for trouble. The homework problems were scored, and unsurprisingly, most students received high scores on the homework. The students received no other feedback until the first exam.

### **Lack of In-Class Learning Incentives**

In the original inverted classroom, students were assigned additional problems to work on during class. However, other than the upcoming periodic exam and the final exam, students had little incentive to make a serious effort in learning how to solve the assigned problems.

The lack of learning incentives to learn how to solve the assigned problems in class led some students to question the purpose of attending class in the first place. For the anonymously essay assignment (described below) one student wrote that in the inverted classroom students shouldn't be expected to attend class.

### Overdemanding Assignments

Results on the first exam were poor. Aware that detailed solutions of the assigned homework problems had been available to students prior to the exam, the instructor sought to increase learning by assigning problems whose solutions were not in the book. Two unanticipated difficulties were discovered with these assignments.

First, the college algebra curriculum required that a considerable amount of material be covered in each class. Consequently, most of the videos were about 40 to 50 minutes in length. Since students could pause and repeat parts of the videos, it could reasonably be estimated that watching each video required, on average, about an hour. The difficulty arose with the assigned problems. Solving the problems could reasonably be estimated to have required an additional hour to complete, *if the students were able to solve the problems*. Although the solution methods were explained in the videos, many students may have lacked prerequisite knowledge, making the techniques explained in the videos difficult to understand. Many students were unable to complete the problems prior to coming to class.

Secondly, students felt that they should not be required to submit the homework problems for credit without having had an opportunity to ask questions concerning the material. The students (especially those underprepared for the course) may have had many questions concerning the content. Several students felt that they should be not held responsible for making frequent trips the mathematics lab for help needed to solve the homework problems because they could not ask questions during a lecture.

### **Student Resistance**

Students had done poorly on the first exam and were likely frustrated with the overdemanding assignments. Students blamed the inverted classroom, and several students went to the mathematics department to complain. After consulting with other faculty regarding this research, the chair of the mathematics department contacted the instructor for a meeting.

Guided by the department chair, the instructor immediately brought an end the student complaints by asking students if they would prefer to continue with the inverted classroom or switch to a traditional, lecture-based class. A vote was held, and an overwhelming majority of the students voted to change to traditional lecture. During the second one-third of the semester content was delivered in class via live lecture, and problems were assigned for homework and due at the beginning of the next class.

Having read studies of successful implementations of the inverted classroom in other disciplines, the instructor felt that the difficulties experienced were more than likely not due to the inverted classroom itself, but to the way in which it had been designed and implemented for college algebra. The instructor did not understand why the students did not like the inverted classroom and sought answers from the students.

### **Essay**

To understand why so many of the students disliked the inverted classroom, the instructor assigned an essay for extra credit. The assignment was for the student to write one page explaining what he or she liked or disliked about the inverted classroom. The essays were completed and submitted anonymously to allow students to feel free to be completely honest in expressing their opinions.

A qualitative analysis of the essays led to the identification of the three major design flaws detailed above. After a considerable amount of thought, the instructor redesigned the inverted classroom for college algebra.

### **Resolution**

With the second exam approaching the instructor presented the new design to the class. Students were asked to vote whether to remain with lecture after the second exam or to switch to the following new design.

- Prior to coming to each class, students will be expected to watch a video and take notes. The problem assignment to be made during class will be posted online in case anyone wishes to better prepare for class. However, students will not be expected to solve problems outside of class, and there should be sufficient time in class to complete all the problems.
- Students will be assigned problems to work on in class. A quiz will be held at the end of class. The quiz will consist of one of the assigned problems. The quiz will be open-note and open-book. Students will be allowed to use any written material on the quiz, including notes taken from the video and solutions to the problems worked during class.
- At the end of class both the notes and the quiz are to be turned in for credit.
- The periodic exams and the final exam will be open-note and open-book.

Students voted overwhelmingly to switch from lecture to the new design.

The class immediately improved. Students seemed to like the new design more than either the initial inverted class or traditional lecture. Students went back to talking in class and helping each other solve problems.



The redesigned classroom addressed each of the flaws previously discussed. The homework assignments were no longer overdemanding, requiring students to only watch the video and take notes. The submission of notes, the quizzes, and the open-note and open-book exams gave students incentive to learn the material, take good notes, and focus on solving the assigned problems in class.

### **Survey**

An online survey was given at the end of the semester to collect additional feedback regarding student perceptions, including perceptions regarding learning contribution and level of engagement. The feedback provided at the end of the semester was much more positive than feedback collected after the first exam through the anonymously submitted essays.

On average, students reported that both the problem solving and the note taking contributed more to their learning than the video viewing (with mean responses of 4.0, 3.9, and 3.2 on a five-point Likert-type scale, respectively). Students reported roughly equal levels of engagement with the three elements. Average responses were 4.3, 4.3, and 4.2 for the level of engagement with problem solving, note taking, and video viewing, respectively.

### **Conclusions**

The redesigned inverted classroom appeared to be successful. Students certainly seemed to enjoy being able to work together on problems instead of having to listen to a lecture. Student attitudes toward the class noticeably improved after the second exam.

Moreover, the results on the third exam indicated that students were learning more. Notes submitted for grading many times consisted of several pages containing

multicolor graphs and highlighter. Also, students remained engaged solving problems during the entire class.

## **APPENDIX E**

### **Preliminary Study Two**

The second preliminary study of an inverted college algebra classroom took place during the Spring 2012 semester. As in the first preliminary study, two sections of college algebra were taught using an inverted approach. The semester progressed smoothly, and the students seemed to enjoy being able to work with each other on problems in class instead of having to listen to a lecture.

#### **An Improved Design of the Inverted College Algebra Classroom**

An inverted college algebra classroom was successfully implemented during the last one-third of the semester during the first preliminary study. The same design was followed in the second preliminary study in hopes of having a successful semester.

The classroom in the second preliminary study was essentially designed as follows.

- Students were expected to prepare for in-class problem solving by watching an online video and taking notes before coming to class. The problem assignments were posted online in case any students wanted to get started on the problems early, but students were not expected to solve any problems outside of class.

- At the beginning of class the instructor would write the problem assignment on the board. The instructor attempted to make the assignments long enough to keep students engaged during all available class time, while not assigning more problems than a prepared student could complete before having to take the quiz.
- At the end of each class (except on exam days) a quiz was given. The quiz consisted of one of the problems assigned at the beginning of class.
- Upon completing the quiz students were required to submit their video notes and the quiz for credit.

Students were allowed to use their books, notes, problem solutions, and any other printed material on all quizzes and exams. This leniency allowed students to focus on learning how to solve the assigned problems when preparing for quizzes and exams instead of having to take time to memorize formulas or steps of long procedures. Students were warned that there would not be enough time during an exam to learn how to solve the problems by reading the textbook or looking at notes copied from the videos. It was emphasized that in order to do well on the exams students should already be familiar with the examples in the sections covered and *completely understand* their solutions so that that knowledge could be applied to a different, but similar problem.

### **Essay**

An essay assignment sought to discover student perceptions of the inverted college algebra classroom in the second preliminary study. Students were offered extra credit to write a one to two page essay to be submitted anonymously before the third exam. The only requirement of the assignment, besides formatting requirements, was

that the essay describe what the students thought about the inverted classroom. The essay assignment was almost identical to the assignment used in the primary study of this research. The essay assignment used the primary study appears in Appendix I.

Forty-three essays were collected from the students. A qualitative analysis of the essays found that the students held many common perceptions of the inverted classroom. As in the primary study, the qualitative analysis procedure described on pages 178 through 193 of Merriam's 2009 book *Qualitative Research: A Guide to Design and Implementation* guided the qualitative analysis for the second preliminary study. This procedure is described in more detail in Chapter 3 under the heading Qualitative Analysis.

The qualitative analysis of the essays found that perceptions described fit into several categories. For each category, the essays in which one or more perceptions were mentioned that fit into the category were counted. The categories, the total count of essays for each category, and the percentage of total essays that each count represents appears in Table E1.

Table E1

*Categorization of Perceptions of an Inverted College Algebra Classroom*

Category	Total out of 43 essays	Percentage of 43 Essays
Video viewing		
Ability to pause repeat, or defer viewing	20	47
Convenience of availability outside of class	19	44
Can't ask questions during video	18	42
Requires a lot of time	7	16
Note taking		
Helpful	5	12
Problem Solving		
Working with classmates helpful	15	35
Instructor assistance helpful	22	51
Insufficient time in class or teaching assistant would help	21	49
In-class activity		
Some lecture or questions from class would be good	15	35
Learning		
More than in a lecture-based class	14	33
Less than in a lecture-based class	3	7
Amount of work		
More required than a lecture class	12	28
Less required than a lecture class	3	7
Efficiency		
Greater than lecture-based class	10	23
Less than lecture-based class	1	2
Overall Preference		
Inverted classroom	22	51
Lecture	13	30

For example, the qualitative analysis revealed two categories of perceptions in regard to learning. In 14, or 33% of the 43 essays, students wrote that they perceived that more learning was occurring in the inverted classroom than if the class had been lecture-

based. On the other hand, in 3, or 7% of the 43 essays, students wrote that they perceived that less learning was taking place.

### **Survey**

During the second preliminary study the survey's questionnaire was redesigned and offered to students at the end of the semester for extra credit. The questionnaire was used again in the primary study of this research, so a more detailed description of the instrument and its development appears in Chapter 3 under the heading Questionnaire. The complete questionnaire, including its introduction and instructions, appears in Appendix J.

On average, students reported that both problem solving and note taking contributed more to their learning than video viewing. Mean responses on a five-point Likert-type scale (with standard deviations in parentheses) for perceived learning contributions of problem solving, note taking, and video viewing were 4.25 (0.84), 4.33 (0.77), and 3.73 (1.08) respectively.

On average, students reported a higher level of engagement with problem solving than either note taking or video viewing. Mean responses on a total scale of 4 to 20 (with standard deviations in parentheses) for levels of engagement with problem solving, note taking, and video viewing were 17.96 (2.24), 16.96 (2.84), and 16.69 (3.04) respectively.

Descriptive statistics were also calculated for each of the last five questions on the survey. These questions were designed not to measure perceived learning contributions or levels of engagement, but to instead obtain feedback regarding learning, workload, and preference for the inverted classroom. Each of the five questions and its mean response and standard deviation appear in Table E2.

Table E2

*Mean Responses and Standard Deviations of Last Five Survey Questions*

Number	Question	M (SD)
16	I believe that I was able to learn college algebra better with inverted classroom instruction than I would have with traditional lecture-based instruction.	3.45 (1.48)
17	There is too much work to do outside of class for this course.	2.78 (1.15)
18	I prefer the inverted classroom format to a traditional lecture format.	3.27 (1.51)
19	I worked more in this class than in my other classes this semester.	3.29 (1.13)
20	I would like my future mathematics instructors to teach using an inverted classroom approach.	3.25 (1.54)

**Conclusions**

Qualitative analysis of the essay data and descriptive statistics of the survey data indicated that overall students preferred the inverted classroom. Problem solving and note taking were identified as greater contributors to learning than video viewing, and level of engagement was highest for problem solving.

The second preliminary study set the stage for the more in-depth primary study of this research which took place in Fall 2012. The positive results encouraged the researcher make a few changes in the design of the classroom for the primary study so that students would have opportunity to gain more practice in solving problems. The design of the classroom for the primary study is described in Chapter 3 under the heading An Inverted Classroom for College Algebra.



## **APPENDIX F**

### **Course Content and Suggested Time Frames**

The content of the college algebra course is determined by the university's mathematics department and specified in the departmental syllabus. This syllabus lists six topics included in the course, along with subtopics, and a suggested time frame for completing each topic. Details appear in Table F1.

Table F1

*Topics, Subtopics, and Suggested Time Frames for College Algebra*

Topic and Subtopics	Weeks
Equations and Inequalities	3.0
linear equations and inequalities in one variable including absolute value equations and inequalities; equations and graphs in two variables including equations of lines and circles; slope of lines; parallel and perpendicular lines; distance and midpoint formulas; and complex numbers	
Functions and Graphs	3.0
definition of a function, domain, and range; graphs of functions and relations; transformations of functions; even and odds functions; increasing, decreasing, and constant intervals for a function, operations with functions, inverse functions; and constructing functions with inverse and direct variation	
Polynomial and Rational Functions	2.0
graphs of a polynomial and rational functions with an emphasis on quadratics; solving quadratic, higher order, rational, and radical equations; solving polynomial and rational inequalities; and applications	
Exponential and Logarithmic Functions	2.0
exponential functions and equations; logarithmic functions and equations; rules of logarithms; applications	
System of Linear Equations in Two and Three Variables	1.0
solving systems of linear equations using graphing, substitution, and methods of elimination	
Matrices	1.5
solving linear systems using matrices, operations with matrices, inverses of matrices	

*Note:* The description of course content and suggested time frames appear in the departmental syllabus as specified by the university's mathematics department.

## **APPENDIX G**

### Syllabus

The syllabi for the two sections in the sample were identical except for the section number, the index number, the meeting time, the room number, and the date and time of the final exam. All course requirements and class policies were the same between the two sections.

All information common between the two syllabi appears in the remainder of this appendix. The value of each of the five items mentioned in the previous paragraph has been removed.

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Syllabus

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<b>Course</b>	MATH 1315
<b>Section Number</b>	
<b>Semester</b>	Fall 2012
<b>Index Number</b>	
<b>Time</b>	
<b>Room</b>	

<b>Instructor</b>	Mr. R. Jaster
<b>Email</b>	rj1095@txstate.edu
<b>Office</b>	DERR 209
<b>Office Phone</b>	(512) 245-4751
<b>Office Hours</b>	MW 12:00noon-1:30pm F 12:00noon-2:00pm Other hours by appointment

**COURSE TITLE**

College Algebra

**COURSE DESCRIPTION**

A course covering linear and quadratic equations, inequalities, word problems, functions, logarithms, systems of equations and other college algebra topics as time permits.

Prerequisite: MATH 1311 with a grade of CR or a grade of C or higher, ACT

Mathematics score of 21 or more, SAT Mathematics score of 480 or more, Accuplacer College Mathematics score of 63 or more, or Compass Algebra score of 66 or more.

**OBJECTIVES**

The goal of College Algebra is to provide students an opportunity to learn algebra concepts and to develop algebraic problem solving skills. The goal will be achieved by meeting the following objectives. The student will be able to:

- solve equations and inequalities (linear, quadratic, other polynomial equations, exponential, logarithmic),
- develop the concept of function (inverse, rational, polynomial functions),
- understand related functions through symmetry, transformation, and operations with functions,
- solve systems of linear and nonlinear equations,
- operate with matrices and complex numbers,
- translate real world situations into mathematical models,
- use a graphing calculator as a tool for thinking about algebraic concepts.

**TEACHING PHILOSOPHY**

The course will be taught using a student-centered approach. Learning theory and mathematics education research support the need for students to experience mathematics and to build conceptual understanding especially via social interactions. To allow more time for this experience and social interaction, explanations of course content have been video recorded and made available on the internet. During class students will have opportunity to deepen their understanding and improve their problem-solving ability working individually and collaboratively.

**REQUIRED MATERIALS**

<u>Textbook</u>	Mark Dugopolski, <i>College Algebra</i> , 5th Ed., Pearson/Addison Wesley, 2010. ISBN-13: 978-0-321-64474-9; ISBN-10: 0-321-64474-3.
<u>Graphing Calculator</u>	TI-84 recommended.
<u>Internet Access</u>	On campus wireless internet access is available to anyone with their own computer, and computers with internet access are available to students in labs throughout campus. Videos may be viewed off-campus with sufficiently fast internet service.
<u>Ear Buds?</u>	If you watch the videos in the on-campus computer labs you will need a pair of ear buds or headphones.

**ATTENDANCE POLICY**

Students are expected to attend each scheduled class meeting. It is unusual for students to perform adequately who are frequently absent from class.

**IMPORTANT DATES**

Exams	
Exam 1	Sep 19, 2012
Exam 2	Oct 12, 2012
Exam 3	Nov 07, 2012
Exam 4	Dec 05, 2012
Final Exam	

Deadlines	
Drop with no record	Sep 12, 2012 midnight
Drop with automatic W	Oct 25, 2012 5:00 pm
Withdraw from university (drop all classes)	Nov 27, 2012 5:00 pm

**GRADING**

At the end of the semester each student's weighted average is computed using the following percentages.

Letter grades are assigned according to the student's weighted average.

Pre-Homework	10%
Problem Assignments	18%
Notes	10%
Exam 1	13%
Exam 2	13%
Exam 3	13%
Exam 4	13%
Final Exam	10%
<b>Total</b>	<b>100%</b>

Semester Grade	Weighted Average
A	90-100
B	80- 89
C	70- 79
D	60- 69
F	0- 59

**Pre-Homework (10%)**

Pre-homework is completed during the last 10 minutes of class and due at the end of class. The lowest three pre-homework scores will be dropped. Pre-homework is not accepted late.

**Problem Assignments (18%)**

Problems will be assigned at the beginning of class. The problems are due at the beginning of the next class. The lowest three problem assignment scores will be dropped. Problems are not accepted late.

**Notes (10%)**

Course content is explained in videos available on the internet. Students are expected to take notes while viewing each video. Notes are due at the same time that the corresponding problem set is due. The lowest three scores on notes will be dropped. Notes are not accepted late.

**Exams (62%)**

To receive credit for a problem on an exam the student must show all work. Partial credit is available on certain types of problems. If partial credit is available then the amount of partial credit awarded is based on the portion of the student's solution which is correct.

Additional review problems are not given before an exam. Students should instead review their notes and the assigned problems.

Make up exams are not given for any reason. One exam score may be replaced by the final exam score.

**Pencil & Paper**

Pre-homework, problem sets, and exams must be completely neatly in pencil. There is a 25% penalty for not using pencil. Pre-homework, problem sets, and notes must be completed on standard-size loose-leaf notebook paper. There is a 25% penalty for not using standard-size loose-leaf notebook paper.

**Notebook**

It is suggested that students maintain a notebook that contains all of pre-homework, notes, and problem sets. It will be useful in studying for each exam during the semester and for the final exam at the end of the semester.

**Extra Credit**

Students may receive up to 6 percentage points added to their semester average for good attendance. The number of extra credit points awarded depends on the number absences. The only absences excused are for religious holy days (see UPPS No. 02.06.01) or university-sponsored functions (see UPPS No. 02.06.03).

<b>Number of Absences</b>	<b>Extra Credit Percentage Points</b>
0-1	6
2	5
3	3
4	0

### **SPECIAL NEEDS**

Students with special needs, as documented by the Office of Disability Services, should identify themselves at the beginning of the semester.

### **ACADEMIC HONESTY STATEMENT**

Learning and teaching take place best in an atmosphere of intellectual fair-minded openness. All members of the academic community are responsible for supporting freedom and openness through rigorous personal standards of honesty and fairness. Plagiarism and other forms of academic dishonesty undermine the very purpose of Texas State and diminish the value of an education. Specific sanctions for academic dishonesty are outlined in the student handbook. The Honor Code may be found at <http://www.txstate.edu/effective/upps/upps-07-10-01.html>

### **ELECTRONIC DEVICES**

Any electronic devices that may distract from the class, including cell phones, iPods, and pagers, should be turned off before class begins and may not be on the desk during exams.

### **RESOURCES**

The **Math Tutoring Lab** in Derrick Hall 233 provides free tutoring and computer use. Details are available at <http://www.math.txstate.edu/resources/lab.html>

The **Student Learning Assistance Center (SLAC)** on the 4th floor of Alkek Library provides a variety of services (including tutoring) to help students succeed in college. Details are available at <http://www.txstate.edu/slac>

The **Collaborative Learning Center** is a free computer lab and tutoring center open to all students in the College of Science. It is located on the 4th floor of the RF Mitte Technology & Physics Building. Details are available at <http://hlsamp.cose.txstate.edu/clc.html>

For **open computer labs** see

<http://www.its.txstate.edu/departments/academiccomputing/computinglabs.html>

## **APPENDIX H**

### **Help With Prerequisite Material**

Students lacking prerequisite knowledge were provided with help on the first day of class in a document entitled *Help With Prerequisite Material*. This document was made available to students on the web at the class's TRACS site.

TRACS is a web tool provided by the university that allows instructors to securely share information with their students, such as documents and grades. The complete document appears in the remainder of this appendix.



## Help with Prerequisite Material

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### *Fractions*

For help adding, subtracting, multiplying, and dividing with fractions, search for what you would like help on at one of the following websites.

<http://www.khanacademy.org> (dot org, not dot com)

<http://www.google.com>

For example, searching on “multiplying fractions” at **KAHNACADEMY** yields several short videos that explain the process.

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### *Factoring*

For help with factoring search for a video that explains the ac-method.

Try searching for **ac-method** (with and without the dash) at one of the following websites.

<http://www.youtube.com>

<http://www.google.com>

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## APPENDIX I

### Essay Assignment

The instructional approach in our class is different than in other college algebra classes since students are expected to watch videos and take notes *outside* of the classroom, and then solve problems *inside* the classroom. This approach to instruction is an example of an *inverted classroom*.

A study is being conducted of our class for mathematics education research. By completing this extra-credit assignment you will be participating in the study and providing data that may be used to improve mathematics education. Participation is voluntary and participants may withdraw from the study at any time without penalty. Your grade in the class will in no way be negatively affected by any aspect of this study.

Students who choose to participate in the study by submitting an anonymous essay will receive 10 points extra credit on the final exam. Students are not obligated to participate in the study to earn the extra credit. A student who chooses not to participate in the study will not be able to receive extra credit for submitting an essay. However, he or she may complete an alternative assignment worth the same amount of extra credit that should take about the same amount of time to complete. The alternative assignment consists of working problems from the textbook. If you wish to complete the alternative

assignment instead of submitting an essay you must notify the instructor in person or by email before 11:59 pm on Tuesday, September 25, 2012.

To receive extra credit the essay submitted must be at least one full page and no more than two pages in length, typed double spaced in a 12-point font on 8½ x 11 paper, and have one-inch margins on all four sides. The first line may be used for a title for the essay. There should not be any extra spacing between paragraphs. This statement of the extra-credit assignment that you are reading conforms to these requirements.

Each student will be able to submit their essay anonymously by inserting it into a large envelope to be passed around during class. Students will sign a roll sheet taped to the front of the envelope so that extra credit can be awarded to those students who submitted an essay. If any essay fails to meet any of the formatting requirements it will be rejected, and the essays will be returned and recollected.

The study is primarily concerned with student perceptions of an inverted college algebra classroom. Besides the formatting requirements previously described, the only other requirement is that the essay describe what you think about the inverted college algebra classroom. In doing so you may answer all, some, or none the following questions:

- What do you think about learning college algebra by viewing videos and taking notes outside of class, and solving problems in class?
- What do you like or dislike about the inverted classroom?
- Which aspects of the inverted classroom do you find the most or least beneficial in terms of learning?
- If you were to take the class again, would you prefer an inverted format or the

traditional lecture format?

- Do you believe that you are learning better in the inverted classroom than if the class were being taught using traditional lecture?
- Does the inverted classroom require more or less work than a lecture-based class?
- Does learning in an inverted classroom result in a more efficient use of time, so that you can learn as much (or more) with less effort? Or is the opposite true?
- How can the inverted college algebra classroom be improved?

Only hard copies of the essay will be accepted, and essays will not be accepted late.

**The essay is due at the beginning of class on Monday, October 1, 2012**

## **APPENDIX J**

### **College Algebra Questionnaire**

Welcome to our class survey!

This survey is part of a study being conducted for mathematics education research. By completing the survey you will be participating in the study and providing data that may be used to improve mathematics education.

Any information that is obtained in connection with this study and that can be associated with you will remain confidential and will be disclosed only with your permission or as required by law.

Participation is voluntary and participants may withdraw from the study at any time without penalty. Your grade in the class will in no way be negatively affected by any aspect of this study.

Students who choose to participate in the study by completing this survey will receive 10 points extra credit on the next exam. Students are not obligated to participate in the study to earn the extra credit.

A student who chooses not to participate in the study will not be able to receive extra credit for the online survey. However, he or she may complete an alternative assignment worth the same amount of extra credit that should take about the same amount of time to complete. The alternative assignment consists of working problems from the textbook. If you wish to complete the alternative assignment instead of the online survey you must notify the instructor by email before 11:59 PM on [date].

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This study has received Institutional Review Board (IRB) exemption from the Office of Research Compliance at Texas State University-San Marcos. Federal regulations describe six categories of research that may qualify for exempt status. This study is categorized as

(1) research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

For more information on the exemption you may contact the Office of Research Compliance at 512-245-2314. Make sure to reference exemption approval #EXP2011B9774.

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Instructions:

There are no correct or incorrect responses to the statements in this survey, and your responses will not affect your grade in any way. Select exactly one response for each of the twenty statements. A response to each statement is required to complete the survey.

Please respond to each statement thoughtfully and as honestly as possible.

1. I feel that viewing videos contributed to my learning.  
(strong disagree) 1 2 3 4 5 (strongly agree)
2. I feel that taking notes contributed to my learning.  
(strong disagree) 1 2 3 4 5 (strongly agree)
3. I feel that solving problems in class contributed to my learning.  
(strong disagree) 1 2 3 4 5 (strongly agree)
4. I tried to learn as much as possible while viewing the videos.  
(strong disagree) 1 2 3 4 5 (strongly agree)
5. I took all notes that I thought would be helpful for learning.  
(strong disagree) 1 2 3 4 5 (strongly agree)
6. In class I focused on solving the assigned problems.  
(strong disagree) 1 2 3 4 5 (strongly agree)
7. On average, I watched about \_\_\_\_\_ of each video at least once.  
1: 0%-19% 2: 20%-39% 3: 40%-59% 4: 60%-79% 5: 80%-100%
8. On average, I took notes on about \_\_\_\_\_ of the material that was covered for each section in the textbook.  
1: 0%-19% 2: 20%-39% 3: 40%-59% 4: 60%-79% 5: 80%-100%

9. On average, I attempted about \_\_\_\_\_ of the problems assigned in class.  
1: 0%-19% 2: 20%-39% 3: 40%-59% 4: 60%-79% 5: 80%-100%
10. I frequently paused or repeated segments of the videos in order to increase my understanding of the material.  
(strong disagree) 1 2 3 4 5 (strongly agree)
11. When taking notes I tried to understand what I was writing.  
(strong disagree) 1 2 3 4 5 (strongly agree)
12. If did not understand how to do a problem in class I would ask another student or the instructor for help.  
(strong disagree) 1 2 3 4 5 (strongly agree)
13. I watched approximately \_\_\_\_\_ of the videos this semester.  
1: 0%-19% 2: 20%-39% 3: 40%-59% 4: 60%-79% 5: 80%-100%
14. I made considerable effort to take useful notes.  
(strong disagree) 1 2 3 4 5 (strongly agree)
15. I was occupied with mathematics approximately \_\_\_\_\_ of the time during class.  
1: 0%-19% 2: 20%-39% 3: 40%-59% 4: 60%-79% 5: 80%-100%
16. I believe that I was able to learn college algebra better with inverted classroom instruction than I would have with traditional lecture-based instruction.  
(strong disagree) 1 2 3 4 5 (strongly agree)
17. There is too much work to do outside of class for this course.  
(strong disagree) 1 2 3 4 5 (strongly agree)
18. I prefer the inverted classroom format to a traditional lecture format.  
(strong disagree) 1 2 3 4 5 (strongly agree)
19. I worked more in this class than in my other classes this semester.  
(strong disagree) 1 2 3 4 5 (strongly agree)
20. I would like my future mathematics instructors to teach using an inverted classroom approach.  
(strong disagree) 1 2 3 4 5 (strongly agree)

## **APPENDIX K**

### Survey Invitation

Subject: Extra credit in College Algebra

Dear [First Name] [Last Name],

This is an invitation to complete an online survey for extra credit in College Algebra. Successful completion of the survey will earn 10 extra points on the next exam. The maximum score on the next exam is 110.

This email contains a link to start the survey. To receive extra credit for taking the survey the survey must be started by clicking on the link in this email.

The survey consists of 20 questions and should not require more than 10 minutes to complete. All questions on each page of the survey are required, and each question must be answered before the browser will let you continue to the next page.

Your responses to the survey will not in any way affect your grade in the class (no matter how positive or negative they may be). Your semester average will be calculated exactly as described in the syllabus.

Please make an effort to respond thoughtfully and honestly to each of the 20 questions. The information you provide will be used for mathematics education research and may help improve mathematics education around the world.

Students are not required to participate in the research to earn the extra credit. Students may complete an alternative assignment instead of the survey for the same amount of extra credit. More details are provided in the questionnaire's introduction, which may be viewed after clicking on the link below to start the survey.

If you choose to take the survey it must be successfully completed by [Time] on [Date].

Here is the link to the survey:  
[Survey Link]



R. Jaster  
Department of Mathematics - MCS 470  
Texas State University  
601 University Drive  
San Marcos, TX 78666  
(512) 245-4751 (office)  
(512) 245-3425 (fax)

Please note: If you prefer not to receive any future offers of extra credit, click on the link below and you will be removed from the mailing list.

[Remove Link]

## APPENDIX L

### Rubric for Assessment of Notes

Each set of notes submitted for credit received two scores. One score was used in determining the student's note taking average. The student's note taking average contributed to his or her semester average.

Another score of one, two, or three was assigned to be used at the end of the semester in determining the student's level of engagement with note taking. The score was intended to serve as a rough indicator of the amount of effort made by the student in taking the notes. The rubric in Table L1 shows the criteria used in estimating amount of effort.

Table L1

#### *Rubric for Assessment of Notes*

Score	Criteria
1	For most students, the volume of notes taken would fit on one page or less. Much of the content taught in the video and most examples are missing.
2	For most students, the volume of notes taken would require exactly two pages. Details of content and/or examples are missing.
3	For most students, the volume of notes taken would require three or more pages. Many if not all important details of content and most if not all examples are included.

## APPENDIX M

### Additional Excerpts From Transcribed Conversations

Conversations between the students and the instructor were recorded in collecting data for addressing the first research question. The categorization of perceptions derived from the transcripts of conversations appear in Table 12.

Following Table 12, a description of each perception category is accompanied by an excerpt of the analyzed data that describes specific examples of perceptions that belonged to the category. This appendix presents one or more additional excerpts of the analyzed data for each of the perception categories.

#### **Next Step in Solving Problem Cannot be Identified or Performed**

An excerpt from the transcribed conversations in which the student was unable to identify or perform the next step in solving a problem appears below.

Instructor: Yes, sir?

Student: So with number 43 you come out with  $6 = 6$ . Would that be an identity?

Instructor: An identity? So what's the solution set?

Student: The solution set? Well, that's what I had a problem with. I kept getting  $6 = 6$ .

Instructor: Well,  $6 = 6$ , which means it doesn't really matter what the value of  $x$  is, the equation is going to be true as long as the equation is defined.

Student: OK.

Instructor: Right?

Student: OK, so as long as  $x$  is not equal to 3 or -3.

Instructor: Right. If  $x$  is 3 or -3 then it's not defined. So any number except those.

Student: So it would be an identity?

Instructor: Right, so it would be an identity. That's what an identity is right? It's true for all values of  $x$  for which the equation is defined.

Another excerpt from the transcribed conversations in which the student was unable to identify or perform the next step in solving a problem appears below.

Instructor: Yes, ma'am?

Student: Both of us keep getting  $2y + x = 5$ , and it's supposed to be  $2x + y = 5$ .

Instructor: Oh, so number 81, can I see the problem in the book, number 81, perpendicular to  $x - 2y = 3$  and containing the point, what's the point? (-3, 1). OK, so you figured out the slope first, um, got the  $-2y = 3 - x$  divided by the -2, so  $y =$  (pause). So your slope is a positive  $1/2$ , that looks correct. So the slope of the perpendicular line is?

Student:  $-1/2$ .

Instructor: No, it's the negative reciprocal.

Student: So it's -2?

Instructor: It's -2.

Student: OK, so that's what we plug into this formula?

Instructor: Right.

Student: OK, thanks.

Another excerpt from the transcribed conversations in which the student was unable to identify or perform the next step in solving a problem appears below.

Instructor: Yes, ma'am?

Student: Whenever I (*pause*). Like how would I evaluate this?

Instructor: You can factor out an  $i$ . If you factor out an  $i$  then what you have left is a negative square root of 2, plus two square root of 2, and that's going to be one square root of 2.

Student: OK.

Another excerpt from the transcribed conversations in which the student was unable to identify or perform the next step in solving a problem appears below.

Instructor: Yes, sir?

Student: When we're graphing this, I get that it's a parabola, but how do we tell the width of the parabola when we're graphing it?

Instructor: The width? Well, I mean it's going to have to go through these points, right? So (0,1), (1,0), (2, -3), right?

Student: OK.

Instructor: And actually, this looks like it's one side of the parabola. I mean,  $x$  can be negative, right? So if you throw in the negative values you're actually going to get like nine points here. If you draw a curve through those nine points you'll get a parabola. Yeah, this is the

correct approach.

Student: OK.

### **Overall Strategy for Solving Problem Cannot be Determined**

Another excerpt from the transcribed conversations in which the student needed help in determining an overall strategy for solving the problem appears below.

Student: OK. In the example in the video you did, where is it?  $y$  is the absolute value of  $x$ . How would you (*pause*). Would it be like basically the same thing?

Instructor: Similar. Usually you pick your  $x$  and figure out what the  $y$  is. In this case it might be easier to pick your  $y$  first. You can stick anything in there for  $y$ , right? Stick in -2, -1, 0, 1, 2. Stick in anything there for  $y$ . If you stick in -2 for  $y$  then what is your  $x$ ?

Student: Um, -2? or 2?

Instructor: Which one is it? What's the absolute value of -2?

Student: 2.

Instructor: Yep. What's the absolute value of -1?

Student: 1.

Instructor: Yep.

Student: OK.

Another excerpt from the transcribed conversations in which the student needed help in determining an overall strategy for solving the problem appears below.

Student: Can you explain to me how I would do this one? I forgot.

Instructor: Well, this is an equation involving fractions. Whenever you have an

equation involving fractions, what you can do to get rid of the fractions is to multiply by the least common denominator. And here there's only one denominator, right? So your least common denominator is the  $y - 0.333$ . So multiply both side of the equation by  $y - 0.333$ . And over here it's just going to cancel, right? And over here you can distribute the 3.

### **Operation With Fractions Cannot be Performed**

An excerpt from the transcribed conversations in which the student indicated that he or she was unable to perform an operation with fractions appears below.

Student: I didn't get the right answer on this.

Instructor: 49?

Student: Yes, sir.

Instructor: So  $1/2 + 2i$ ,  $1/2 - 2i$ , so  $1/4$ , minus  $i$ , plus  $i$ , minus  $4i$  squared, yeah  $1/4 + 4$ . That's the correct answer.

Student: Is that right? It said  $17/4$ .

Instructor: Well, how do we add these two together? What do we need to add fractions? We need a common denominator, right?

Student: That'd be 4 over 4.

Instructor: No. It's not 4 over 4. It's equal to what? It'd be 16 over 4.

Student: Oh, OK.

Instructor: So we got 1 over 4 plus 16 over 4. So there's your 17 over 4.

### Careless Mistake Cannot be Located

Another excerpt from the transcribed conversations in which the student asked for help in locating a careless mistake appears below.

Instructor: Yes, sir?

Student: Am I on the right track? I'm not sure if I did that right.

Instructor: Well, you're adding the real parts, and then you're adding the imaginary parts, and here your imaginary part is going to be a negative square root of 2 and a 2? Let's look at number 17. It looks like a negative square root of 2 and a 2 square root of 2, right? It looks like you're missing a square root of 2.

Student: I copied the wrong number down.

### Definition is Unknown or Unclear

An excerpt from the transcribed conversations in which the student asked a question that reflected either a lack of knowledge or lack of understanding of a particular definition appears below.

Instructor: Can you tell me where the function is increasing and decreasing?

Student: What do you (*pause*). I don't understand.

Instructor: The values of  $x$  where it's increasing and decreasing.

Student: Oh (*pause*). It's increasing at -1.

Instructor: Mmm (*pause*). No, it's going to be increasing wherever it's going uphill, which is going to be over here, for values of  $x$  over here, it's increasing. And for values of  $x$  over here it's going to be decreasing, right? Uphill is increasing and downhill is decreasing.



Student: OK, so what do I write then?

Instructor: Well, you want the values of  $x$  for this portion of the graph. Starting here, all the values of  $x$  for that portion of the graph. So which values of  $x$ ? This is 1, so which values of  $x$  correspond with that portion of the graph?

Student: 1 to positive infinity?

Instructor: Exactly. That's where it's increasing.

### **Mathematical Notation is not Understood or Cannot be Used Properly**

Another excerpt from the transcribed conversations in which the student did not understand or was unable to properly use mathematical notation appears below.

Student: I have a question. OK, the solution set, whenever you use the brackets, or the squiggly (*pause*), I forgot what they're called, what is that for? Like right there. Is that absolute value?

Instructor: Well, that's set notation. The curly brackets indicate that it's a set. So this is the set containing the solutions 1 and 9.

Student: OK, so when do you know when you have to use it or not?

Instructor: Well, actually whenever the book says solve an equation, that's what it's asking for. It's asking for the set of all solutions.

Student: So like on number 19, we're going to have to (*pause*).

Instructor: Well, once you solve it, you find  $x = 11$ , which is actually an equation. That's an equation. The solution set is the set containing 11.

Student: 11 by itself, right?

Instructor: Right, it would be the set containing 11. That's probably what they have in the back of the book. It's the set containing 11.

Student: OK.

## APPENDIX N

### Extra Sum-of-Squares F-Statistics Calculated During Backward Elimination

The procedure of backward elimination was followed to iteratively select variables to be removed from the tentative models formulated in Chapter 4. This appendix contains tables that show the  $F$ -to-remove (the extra-sum-of-squares  $F$ -statistic) calculated for each variable for each iteration of the procedure.

Table N1 shows the  $F$ -to-remove statistics calculated during backward elimination of perceived learning contribution variables during the analysis performed for addressing the second research question. Backward elimination resulted in the removal of all variables except one from the tentative model.

Table N1

*Extra Sum-of-Squares F-Statistics Calculated During Backward Elimination of Perceived Learning Contribution Variables*

Variable	Iteration									
	1	2	3	4	5	6	7	8	9	10
plcvv	0.856	1.834	2.320	2.164	1.397	1.562				
plcnt	0.509	1.187	3.234	3.105	2.824	3.084	1.549	1.106	1.048	
plcps	0.001									
plcvv x plcnt	1.131	2.684	3.789	3.835	3.067	3.053	1.500	2.446	4.504	4.371
plcvv x plcps	0.390	1.277	1.290	1.356	0.587					
plcnt x plcps	0.444	1.541	1.645	1.474	0.817	1.690	0.876	0.104		
plcvv x plcnt x plcps	0.643	2.780	2.811	2.658	1.925	1.715	0.774			
plcvv <sup>2</sup>	0.176	0.182	0.192							
plcnt <sup>2</sup>	0.019	0.019								
plcps <sup>2</sup>	0.687	0.763	0.857	0.779						

Table N2 shows the *F*-to-remove statistics calculated during backward elimination of level of engagement variables during the second analysis performed for addressing the third research question. Backward elimination resulted in the removal of only one variable from the tentative model.

Table N2

*Extra Sum-of-Squares F-Statistics Calculated During Backward Elimination of Level of Engagement Variables in Tentative Model*

Variable	Iteration	
	1	2
<i>loevv</i>	5.439	13.967
<i>loent</i>	1.144	28.488
<i>loeps</i>	5.540	5.455
<i>loevv</i> <sup>2</sup>	4.741	11.411
<i>loent</i> <sup>2</sup>	0.175	

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## **VITA**

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