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The inverted classroom : a literature review

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THE INVERTED CLASSROOM: A LITERATURE REVIEW

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Abstract

Teachers struggle to thoroughly educate students in science, technology, engineering and math (STEM) related fields. This literature review examines the current research on STEM education, learning theories, and the effects of an inverted classroom on student learning in STEM classes in order to determine the possible benefits of implementation at pre-collegiate levels. Lacking research at the high school level, this paper focuses on articles describing inverted, college level STEM classes. This study indicates that further research is needed at both the high school and college level to prove that inverted classes result in improved learning and student retention; it also provides recommendations for implementation of Project Lead the Way led research.

Table of Contents

Introduction

Despite a pressing need, the United States fails to adequately educate students and encourage them to pursue degrees in science, technology, engineering, and math (STEM) fields. Students find learning to perform experiments, program computers, or solve complex equations difficult. In 2006, Kuenzi, Matthews, and Mangan found the overall proportion of STEM degrees awarded is about 17% of all postsecondary degrees, while the country is facing the imminent retirement of the engineers and scientists of the Baby Boomer generation. The U.S. science and engineering workforce, made up of chemists, mathematicians, economists, engineers, and others, has doubled over the past twenty-five years (National Science Foundation, 2012). Creating a climate for improving STEM education to continue to fill these jobs will require collaboration and effort from educators and policy makers.

The United States Government Accountability Office found that in 2010, thirteen federal agencies invested over $3 billion in programs designed to improve STEM education and awareness (Scott, 2012). Despite this investment in STEM, the Business-Higher Education Forum (BHEF) found that fewer than half of all 12th graders meet college readiness benchmarks in math and science, and fewer than one third of college-bound high school seniors are interested in STEM careers (2011). While the percentage of degrees awarded in STEM fields is shrinking in the United States, other countries are growing. For example, China's expenditures in research and development rose in 2009, and 30% of all bachelor's degrees awarded were in engineering (National Science Foundation, 2012). In order to compete in today's increasingly technological world and fill science, technology and engineering jobs, the U.S. needs to increase student motivation and learning in STEM fields throughout their K-12 education and beyond.

This literature review will examine current research about teaching and learning in STEM classes, the learning theories associated with multimedia and active learning, and how the inverted classroom may be part of the answer to increasing the number of graduates in science, technology, engineering and math. Only 17% of high school graduates are interested in STEM careers and have the proficiency in math necessary for success at the college level (BHEF, 2011). Today's students have grown up in an increasingly digital world with instant access to more sources of information than ever before, yet they "are reluctant to move from a comfortable, spoon-feeding type of education to a more active role" (Phillips, 2005, p.9). The large lecture model continues its dominance in STEM education today even though the science of learning and instruction indicates that deeper learning occurs with active and collaborative instructional strategies (Fairweather, 2008).

The inverted classroom replaces the paradigm of passive lecture and repetitive, practice homework with a more active, hands-on learning experience using technology and project-based learning. According to Gannod, Burge and Helmick (2007), in an inverted classroom, laboratory and in-class activities replace typical lecture time; students watch lectures as homework via Podcasts, YouTube or other audio-video media and come to class prepared to practice. Toto and Nguyen (2009) have observed a related systemic problem in engineering education today:

> How do we convey the amount of information necessary to support an information rich education and yet also provide the applied experiences so

> essential to deepening that knowledge? A balance needs to be struck between communicating information and affording opportunities to apply the theory being learned (p. 1).

The research about inverted classrooms grows every day. Robin Kay (2012) completed a comprehensive review of video podcasting analyzing over 50 peer-reviewed articles, which included K-12 and undergraduate studies across a variety of subject areas. The United States government, Business-Higher Education Forum, and many others publish information about the status of STEM education every year. Research about teaching and learning to identify optimal pedagogies continues to grow as well. This paper is unique because it examines the current research on STEM education, the learning theories that support higher-level learning, and the effects of an inverted classroom on student learning in science, technology, engineering, and math related classes.

This review studies the inverted classroom through a science, technology, engineering and math lens. The results of the review will indicate whether the inverted classroom model in high school STEM classes warrants investigation and recommend strategies for implementation. The paper will attempt to answer the following questions:

- What is the status of STEM education in the United States?
- What can be learned from STEM education history and active learning theories?
- What effects do inverted classrooms have on learning and motivation versus traditional lecture?

- What aspects of teacher implementation of the inverted classroom in STEM classes have the greatest impact on learning?

Methodology

Google Scholar and UNI Rod Library databases including *Education Full Text, ERIC, Mental Measurements Yearbook, PsycArticles,* and *PsychInfo* facilitated locating the literature for review. Various key words and methods were used to find the information. Keywords included *flipped classroom, inverted classroom, video lecture, online classroom, screencasts, podcasts, high school, secondary, lecture, multimedia, STEM and STEM education.* After finding articles using keyword searches, more articles were found using the Google Scholar related articles feature. The reference lists of the articles were also mined for further possible resources.

Articles were chosen for review based on full text availability, title, abstract keywords, and publication source. For the purposes of this study, only articles written since 2003 were considered timely and relevant. The search returned over 100 possible articles for inclusion. Articles were then evaluated based on relevance to the topic and quality of content. The procedure used to analyze sources included careful reading and identification of information relevant to the research questions by color coding content within the documents. Two articles from before 2003 have been included because of their relevance to the topic. The articles both address active versus passive learning studies completed in 1998 and 2001.

Several articles were dismissed because they were not related to STEM classes, focusing instead on humanities classes or general information about the Internet and inverted classrooms. Two of the articles found included works in progress, which did not include conclusions. One of these articles was dismissed because a subsequent article describing the results was located. The other article was included because of a unique comparison with previous inverted classroom experience.

Performing inverted classroom experimental studies with truly random samples is virtually impossible because classes at the university level are self-chosen by students based on their major and schedule. In addition, many classes are taught only once per term, which means that experiments lack a control group. Therefore, the articles include data, which may be flawed, but they are still relevant and include information for analysis and discussion.

Although scholarly articles specifically describing the effects of the inverted classroom in high school STEM classes were sought, none were found. One may find numerous articles in newspapers, blogs and magazines about the number of secondary schools adopting the inverted classroom, but these articles lack peer review and hard data. Anecdotal evidence for implementing inverted classrooms abounds, but this analysis focuses on articles with quality research.

A total of thirty-five articles were chosen to be a part of this literature review based on this criteria. One non-peer reviewed article, an interview with inverted classroom teachers, is included. Comments from the *Project Lead the Way* teacher forums are also included. These represent valuable information about the teacher experiences with the inverted classroom even though they are not research-based.

Analysis and Discussion

The Status of STEM Education in the United States

As described in the introduction, the United States is falling behind other countries in efforts to educate and motivate students in science, technology, engineering and math. Students who begin STEM majors in college often migrate to other majors after finding their classes too difficult or boring; less than half of students who intend to major in STEM graduate with a STEM degree (BHEF, 2011). Baldwin described the STEM education situation as "not adequate to the task of preparing workers for our technologically-driven economy or developing a scientifically-literate citizenry" (2009, p.9).

In 2010, the President's Council of Advisors on Science and Technology found that approaches to STEM education in kindergarten through twelfth grade emerged largely without a coherent vision or careful oversight of goals and outcomes across multiple governmental multiple governmental agencies (GAO, 2012). Increasing the number of STEM graduates will require the efforts of educators from Kindergarten teachers to college professors along with policy makers and business representatives (BHEF, 2011). Across a broad spectrum of society, there is a desire to improve STEM education in the United States. In an era of global competition and a technology-based economy, it is increasingly important that people be able to use their scientific knowledge on their jobs and in their role as citizens of a society where complex policy and resource questions increasingly have dimensions related to science and technology (Baldwin, 2009).

In March of 2011, the Government Accountability Office (GAO) released a report to Congress about the fragmentation, overlap and duplication of STEM education efforts at a national scale. The GAO found thirteen federal agencies that invested over $3 billion in programs in 2010, and while there were advantages to multiple agencies promoting STEM awareness and education, this indicates overlap and redundancies in the system. 83% of the STEM education programs overlapped with other programs by serving the same target groups or offering similar services. Although more than half of the agencies described in the GAO analysis reported STEM-related efforts, the majority of them did not use outcome measures that reflected their plans and reports. Because of the overlap and limited data available from the GAO on effectiveness and performance, there remains a concern about the United States' ability to produce citizens literate in STEM subjects.

Almost half of the STEM-interested 12th grade students did not acquire the requisite foundational problem solving skills in math or science during their K-12 education, requiring them to seek remediation to succeed in postsecondary institutions (BHEF, 2011). The challenge for STEM teachers increased due to the need to teach students of diverse backgrounds and interests (Baldwin, 2009). Problem solving requires a mastery of a variety of complex skills including analyzing visual diagrams, problem schematics, and free body diagrams; an ability to derive, manipulate, and solve mathematical equations, and an analytical thought process (Berger, 2007).

Many researchers described the challenging nature of physics, pre-calculus, chemistry, statics, computer science, programming, and other STEM classes (Boutell and Clifton, 2011; Crippen and Earl, 2007; Demetry, 2010; Dollar and Steif, 2009;

Furner and Gonzalez-DeHass, 2011; Kim and Kletskinilona, 2012; Musallam, 2011, and Toto and Nguyen, 2009). Specifically, when learning to program, students may "grasp the basic pieces, but they fall down in their logical thinking" (Boutell and Clifton, 2011, Para. 1). According to Crippen and Earl (2007), problem solving has long been held as an important part of mathematical and scientific literacy and that regardless of the problem type, developing these skills is complex.

Students may feel nervous or anxious learning STEM subjects. Many people are familiar with math anxiety: "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Furner & Gonzalez-DeHass, 2011, p. 228). Kim (2011) described science anxiety in much the same way and went on to discuss how this anxiety can interfere with attitudes about science and science knowledge. Educators need strategies to overcome this anxiety and motivate students to pursue STEM fields even though they are difficult.

Wai, Benbow and Steiger (2010) suggested that increasing the STEM educational dose by providing advanced placement STEM classes, math fairs, science fairs, and tutoring relates to an increase in real-world STEM accomplishments. Wai, Benbow and Steiger's conceptualization of educational dose encompasses accelerating, enriching, and STEM educational opportunities. *Project Lead the Way* (PLTW) provides an opportunity to increase the STEM educational dose in middle and high school. PLTW's goals include maximizing the pool of potential engineers and maximizing the success of students "through effective program design and classroom instruction" (Walcerz, 2007, p. 11).

Project Lead the Way

In accordance with Wai, Benbow and Steiger's educational dose theory, Walcerz (2007) found that approximately 60% of PLTW seniors "stated the intention of studying math, science or engineering" in college (p. 23). This is significantly higher than the average of all high school seniors. Walcerz described how PLTW provides career and college information about STEM fields throughout the curriculum, and over 90% of PLTW seniors feel confident about the types of majors and jobs they intend to pursue because of their PLTW experience.

The PLTW *Pathway to Engineering* courses in high school uses a hands-on, real-world problem-solving approach to learning (Bottoms & Anthony, 2005). Students spend more than half of their class time engaged in activities, but the main method for conveying information remains the power point lecture. PLTW provides two weeks of training for new teachers and detailed curriculum. According to Bottoms and Anthony, PLTW also trains teachers how to teach in a project based format, how to engage students in projects and problems requiring rigorous mathematics and science knowledge and skills, and how to assess students' mastery of materials.

STEM Education History and Active Learning Theories

Changes in the understanding of how people learn and technology growth can lead to changes in how and what is taught. Wanting to improve student learning in STEM-related fields is not new. The move away from lecture-based instruction has been in the works for over a hundred years, beginning as early as 1880 (Turner, 2012). According to Turner's study, prior to 1880, high school physics was taught using the lecture/demonstration model in which students were passive receptors to the concepts presented. Turner found that by 1910, thirty years later, students were using new textbooks and laboratory equipment to participate in experiments, and schools were unable to buy the equipment for the old lecture method.

Kim (2011) referenced Dewey's 1940s work on students participating in the methods of science instead of studying the outcomes of science. Kim also referred to Schwab's work in the 1960s indicating the need for change in science education and also emphasizing inquiry. Bligh's 1972 work on lectures indicates that they "can be used to teach information, including the framework of a subject, but an expository approach is unsuitable to stimulate thought or change attitudes" (Phillips, 2005, p.3).

The large lecture paradigm persists because it is a cost-effective and proven method of conveying large quantities of information to many people, but the true cost "is the lost opportunity for more meaningful and more enduring learning" (Foreman, 2003, p. 12). Baldwin (2009) describes the overall status of teaching in STEM fields as a "source for concern;" STEM educators, who have little formal teaching training, teach how they were taught, and rarely implement strategies based on learning theory or cognitive science research (p. 10). Baldwin described how reform efforts at the undergraduate level are sporadic and rely on individual faculty or small groups who integrate hands-on and active learning into their lectures.

Fairweather (2008) argued that the greatest gains in learning may come from encouraging STEM faculty to implement "*any* form of pedagogy that increases student engagement" (p. 10). PLTW's hands-on, active, engaging activities in the pre-engineering classes at the high school level have demonstrated results in increased motivation for students to continue in STEM-related fields as indicated by the intention of 60% of students to major in STEM fields (Walcerz, 2007).

Hake produced a landmark study in active versus passive learning in 1998 including six thousand underclassmen in his survey of mechanics test data for introductory physics. Hake found that students in the interactive engagement classes generally had higher averages on the Force Concept Inventory and Mechanics Baseline tests than students in traditional lecture classes. He suggested that problem-solving capabilities are "actually *enhanced*" when concepts are emphasized, which is consistent with previous studies finding that inquiry-based learning provides better results on solving synthesis and analysis problems (p. 68). Although his findings were positive, Hake suggested the need for further research.

In 2001, Terenzini, Cabrera, Colbeck, Parente, and Bjorklund compared traditional lecture and discussion courses to courses implementing active and collaborative instructional approaches by surveying 480 engineering students from different universities. Their research indicated that students in active and collaborative settings report more interaction with other students and faculty, more detailed feedback from instructors, and more encouragement to challenge ideas presented. Students in Terenzini, et al.'s study reported advantages in a variety of learning outcome areas considered important by industry and the Accreditation Board for Engineering and Technology (ABET). This research, although also positive, raised reliability issues due to the subjective nature of the survey.

Adding to this research in 2011, Deslauriers, Schelew, and Wieman compared two large-enrollment physics classes taught by either traditional lecture or by interactive teaching methods for one unit of the course. As designed by Deslauriers, et al., the interactive class approached the unit by including pre-class reading assignments and quizzes, in-class questions with discussion, small-group active tasks, and targeted in-class instructor feedback. The interactive class was designed to have the students spend all of their time in class engaged in deliberate scientific thinking. 90% of students enjoyed the interactive instructional style, and 77% claimed that they would have learned more if the whole class had been in the interactive style. The authors found that the students in the active learning section did more than twice as well on the test as did those in the lecture session. The large number of students involved and the comparison of not only student opinion but test data as well increased the reliability of these results.

STEM Education Practices

Among the eight promising practices in STEM education Froyd (2008) analyzed throughout the literature, promising practice two, small group work, and promising practice six, in-class activities, were rated as strong with respect to both implementation standards and student performance standards. Promising practice six, designing in-class activities to engage students in active learning, has the strongest support in terms of student performance standards. Froyd's promising practice two, organizing students in small groups, supports interactive engagement by using a variety of proven learning activities including problem-based and project-based learning, capstone design projects, and inquiry-based learning.

In *Challenging the Primacy of Lectures: The Dissonance Between Theory and Practice in University Teaching*, Rob Phillips (2005) summarized the dissonance between learning environment supported by theory and research and the current practice in Table 1 included below (p. 7). Phillips described the need for collaboration among all educators to improve the pedagogical choices at the course and departmental level.

	Espoused Theory	Theory-in-Use
Pedagogical philosophy	constructivist	instructivist
Approach to learning	deep	surface
Approach to teaching	student-centred	teacher-centred
Subject design	outcomes-based	content-based

Table 1: Components of the Learning Environment in the Espoused Theory and the Theory-in-Use

Borrego, Froyd and Simin Hall (2010) surveyed engineering departments in the United States in order to assess the diffusion of engineering education innovations. They described several difficulties in compiling an inclusive and accurate list of potential respondents and the challenge of encouraging them to respond, "which is indicative of the broader challenges of improving engineering education" (p. 191). Their overall response rate was 16%, with only 12% of the surveys providing usable data. Among the innovations included in the survey, 87% of responders were aware of student-centered pedagogies and 71% reported adoption of student-centered pedagogies. The results for student-active pedagogies were the least valid, but through the peer review process Borrego, et al., found that many reviewers felt that it was "perhaps the single most important means of improving engineering education" (p. 194).

The Inverted Classroom Effect on Learning

As described above, there are instructors providing more learning experiences for students in STEM classes than just the typical lecture. This includes educators implementing the inverted classroom model. The inverted classroom uses web-based lectures, videos or screencasts to present lecture material in advance of class so more in-class time can be used for authentic and engaging learning activities (Day, Foley, Groenweg & van der Mast, 2004). The application of the inverted classroom retains the best qualities of the lecture model and the best qualities of the student-centered active learning model (Toto & Nguyen, 2009).

In her literature review of using video podcasts in education, Kay found that there were four types of videos created by instructors: lecture-based, enhanced, supplementary and worked examples (2012). Half of the studies in her review examined students' attitudes toward video podcasts, and over 85% of the findings were positive. Kay also found that student learning behaviors and student performance supported using video podcasts in higher education. Throughout this paper, these different types of videos in relation to STEM education will be discussed.

Post-secondary educators implementing inverted classroom video lectures have attempted to demonstrate that they provide at least the same level of learning as in-class lectures while providing more time in class for hands-on learning and feedback, which should result in improved student learning. Edgar Dale's *Cone of Learning* also suggests that active participation leads to more learning and that lectures are the least effective way to learn (Day, Foley, Groeneweg, and van der Mast, 2004). Day, et al. also argued "web lectures fall in a learning effectiveness category significantly better than do traditional classroom lectures" due to the ability to pause and review the videos (p. 2). Teachers implementing this type of video are employing Kim's lecture-based videos.

Some instructors oppose a change from the live lecture format because they like to interact with students; however, Kaner and Fielder (2005) claimed "the non-lecture activities we can develop in our classrooms provide far more time and opportunity for interaction than live lectures" (2005, p. 5). Although Kaner and Fielder provided a list comparing live and recorded lectures, they "are not convinced that one is better than the other...By making the lecture part of the homework [though], we effectively double the teaching time available in the course" (p. 6). Many teachers are reluctant to implement inquiry-based, active or student-centered activities in classes because of time limitations (Kim, 2011). The inverted classroom provides that time.

Carlisle (2010) described the results of the inverted classroom on three introductory Java classes taught by three different professors. Professor 1 created the video lectures, and surveys indicated that Professor 1's students watched the videos most often and had the strongest feeling that the videos helped them learn the material, and data showed they performed better on the programming test. Carlisle described all sections of students rating the in-class lab activities as most helpful over reading, video, and class lecture. The absence of a control group receiving traditional lecture instruction, the subjective nature of surveys, and the small sample population cast some doubt on the conclusion that the video lectures improve student learning. Carlisle suggested further research with larger classes.

Gannod, Burge and Helmick (2007) found that the increased contact with students allows teachers to identify who is struggling and who is excelling, which allows teachers to focus attention on struggling students and correct misconceptions immediatel . Their data also showed student response was positive concerning the video lectures, and students acquired the necessary programming skills. Gannod, et al. did not compare student learning to previous semesters. In their research, with and introductory course for senior undergraduate Computer Science students, Day, Foley, Groeneweg and van der Mast (2004) included questions comparing student performance in previous classes to the inverted pilot course, but they did not come to any conclusions indicating that "the pilot study produced more questions than answers" (p. 9).

Ideal Learning

Foreman (2003) identified qualities of the ideal learning situation; it is customized and constructive; provides immediate feedback; motivates students to persist, and builds enduring conceptual structures. Gannod, Burge and Helmick (2007) argued that the inverted classroom model addresses the qualities described by Foreman and the characteristics of the current generation of learners as described by Frand. Among the student characteristics highlighted by the authors served by video lecture were "zero tolerance for delays" and "doing is more important than knowing," (Gannod, et al., 2007, Learners and the Inverted Classroom).

Berger (2007)described video podcasting as a transformative tool, which allows students to pull only the content they need and want and effectively address some of the needs of the current generation of learners. The immediate feedback during in-class activities and instantaneous availability of videos satisfy Frand's description of Millennial Generation learners, Foreman's ideal learning situation and Phillips' espoused theory of learning. So too, does the active construction of learning during the in-class activities.

Videos do not always supplant lectures. Some instructors are making videos to supplement and clarify classwork, which correspond to the supplementary type of videos Kay examined. Pinder-Grover, Green, and Millunchick (2011) created videos for a large-enrollment Materials Science Engineering course. The videos answered questions from class, demonstrated homework strategies and provided quiz solutions. The instructor created so-called "muddiest point" videos when at least 30% of students indicated a desire for clarification on a topic as reported using an online survey (p. 6). The authors found a positive correlation between the use of the various types of videos and final course grades.

Stephenson, Brown and Griffin (2008) compared three different modes of delivery in three human genetics class with fifty-eight students: the traditional lecture, e-Lectures and virtual lectures. E-lectures were similar to traditional lectures except the students could stop, start and replay the lecture at any point while virtual lectures were largely text based with interactions, self-assessment questions and a hierarchical navigation structure. E-lectures are an example of the enhanced type of video that Kay (2012) described in her literature review. The survey conducted by Stephenson, et al. indicated that the students favored traditional lecture, but test scores indicated that each was equally effective in terms of mean scores. However, when broken down by question type according to Bloom's Taxonomy, the three methods demonstrated differences. In the comprehension domain, students in the virtual lecture and e-lecture groups scored better than those in the traditional lecture, but the traditional lecture was as effective or more effective in knowledge, application, analysis and evaluation. This research is intriguing because the results would indicate that traditional lecture classes provided the same level of learning as an inverted class. However, Stephenson, Brown and Griffin did not replace lecture time with in-class active learning activities.

Berger (2007) incorporated video podcasts into a *Strength of Materials* class at the University of Virginia with an average enrollment of fifty-five students. The podcasts delivered included video problem solving, roundtable discussions and exam review, examples of Kay's (2012) worked example videos. 40% of Berger's class responded to the feedback survey, and the results indicated that the video problem solutions were extremely useful for students as they attempted to do similar problems for homework. Berger acknowledged the limitations of this study and suggested the next step is to assess podcasting's impact on student understanding and retention through comparison with a control group.

Aspects of Teacher Implementation

Several aspects of teacher implementation impact student learning in the inverted classroom. Pre-planning and setup are necessary for in-class labs. Toto and Nguyen (2009) found that students prefer class activities in which they are active immediately, activities that "'keep everyone busy' and 'require more participation from the students'" (p. 4). Gannod, Burge and Helmick (2008) implemented more activities with less depth per assignment in the inverted classroom; each smaller learning activity addressed a specific outcome, therefore teachers and students have immediate feedback about pitfalls and incorrect assumptions.

Subject matter knowledge is also very important; "among those who teach math and science, having a major in the subject taught has a significant positive impact on student achievement" (Kuenzi, Matthews, and Mangan, 2006, p. 9). Teachers who lack expertise in a specific area of the content may ask a specialist or industry professional to guest lecture via video. Gannod, Burge and Helmick (2007) indicated that the inverted classroom lends itself well to guest speakers by avoiding scheduling conflicts and off-topic anecdotes.

While guest lectures are an important addition to the inverted classroom, there is some evidence that videos created by the instructor may be more effective than those created by someone else (Carlisle, 2010). Students feel more connected to their instructor than to an unknown lecturer. Carlisle also suggested that scripting the video in advance of recording and using high quality audio devices result in videos students are more likely to watch. Pinder-Grover, et al. (2011) listed four aspects for developing quality screencasts: "content preparation, recording, editing and production, and publishing" (p. 5). They believed the success of the resource hinged on identifying the learning goals for students and preparing content based on these ideals.

Mayer's ten principles of multimedia instructional design, grounded in theory and based on evidence, should inform the design of video lectures in order to reduce extraneous processing, manage essential processing and foster generative processing (2008, p. 760). Table 2 summarizes Mayer's ten principles, their definitions and intended impact on learning. Multimedia instructional videos are a passive medium in that they require no behavioral or social activity on the part of the learner. Hence, they do not promote constructivist learning. Mayer and Moreno (2002) believe though that active construction of learning can be accomplished by not only presenting words and pictures, but also by "helping the learner to process the presented material in meaningful ways" (p. 117).

Principle	Definition	Impact
Coherence	Reduce extraneous material	Reduce Extraneous Processing
Signaling	Highlight essential material	
Redundancy	Do not add on-screen text to narrated animation	
Spatial contiguity	Place printed words next to corresponding graphics	
Temporal contiguity	Present corresponding narration and animation at the same time	
Segmenting	Present animation in learner-paced segments	Manage Essential Processing
Pre-training	Provide pre-training in the name, location and characteristics of key components	
Modality	Present words as spoken text rather than printed text	
Multimedia	Present words and pictures rather than words alone	Foster Generative Processing
Personalization	Present words in conversational style rather than formal style	

Table 2: Summary of Mayer's Ten Evidence-Based and Theoretically Grounded Principles for Multimedia Design

Kay and Kletskinilona (2012) also used Mayer's principles in their research on using problem-based video podcasts to teach Calculus. When creating the 59 problem-based videos, they implemented seven key features including segmenting, context, key elements, clear visuals, highlighting, conversational tone, and short duration. 87% of students rated the videos useful, and the highest rated features of the videos were "quality of explanations, control over when to study, and writing quality" (p. 623). Crippen and Earl created videos of worked examples including self-explanation prompts which "seems to produce a difference in performance, problem solving skill and self-efficacy" (2007, p. 818). Crippen and Earl determined that the amount of information in worked examples alone may overwhelm students, but including self-explanation prompts, examples of how to engage in an iterative personal dialog, help increase motivation and performance.

Musallam (2010) studied the use of videos in a high school AP Chemistry class using Mayer's pre-training, segmenting, and personalization theories along with a holistic introduction to the primary content prior to class. This was not a true inverted classroom because the videos were for pre-training, not to replace lecture, but there was a significant difference between the pre-training group and the no pre-training group upon conclusion of pre-training and instruction. Musallam found that students in the pre-training group reported less mental effort, experiencing less intrinsic cognitive load, and scored higher on the Chemical Equilibrium Concept Assessment.

Dollar and Steif (2009) reorganized an engineering statics course to include a highly interactive, web-based resource for student use. In addition to videos, the Open Learning Initiative (OLI) Engineering Statics course included digital images, manipulative objects, interactive and non-interactive simulations and walkthroughs. The OLI course provided immediate feedback to the learner and student feedback for instructors. Using the OLI course freed substantial class time to use for activities that addressed identified misconceptions and gaps in knowledge. For this approach to work, including feedback from students about their learning using the OLI course, the researchers emphasized to students the contrast between traditional lecture-based classes and the blended learning environment.

Sugar, Brown and Luterbach (2010) examined thirty-seven screencasts, videos of the activity on a computer screen, for common structural and instructional strategies.

The framework they found, based on their analysis of professional and professor-made videos, includes strategies similar to Mayer's ten principles. Their analysis found three common structural elements: bumpers, screen movement, and narration. They also discovered five instructional strategies: provide overview, describe procedure, present concept, elaborate content, and focus attention (p. 10). See Appendix A for *Figure 1. Screencasting framework and corresponding instructional strategies*, which represents a summary of their framework.

Motivating students to watch videos or engage with other online resources has a big impact on learning. Without the videos, students miss vital pieces of information necessary to complete the in-class activities. Day, Foley, Groeneweg, and van der Mast (2004) found that motivating students with small homework, short assignments related directly to the video, encouraged them to watch the video, and students found these quite useful. To motivate students to watch and engage with their video lectures, Boutell and Clifton (2011) assigned short quizzes and short code writing assignments with answers built into the lecture.

Demetry (2010) examined the difference between asking students to read lecture notes and watch video lectures as homework. In order to increase attention to higher-level thinking and the development of lifelong learning skills, Demetry modified the class structure by including video lecture and higher-level team-based application problems. In addition to these strategies, smaller class sizes and the presence and interaction of the teacher may be necessary to realize the benefits of the inverted classroom (Gannod, Burge, and Helmick, 2008).

Tucker interviewed middle and high school teachers currently implementing the inverted classroom. Johnathan Bergmann, a high school chemistry teacher, commented, "it's not the instructional videos on their own, but how they are integrated into an overall approach, that makes the difference....students can't just 'watch the video and be done with it'" (2012, p. 82). Andrea Smith, middle school math teacher, explained "crafting a great four- to six-minute video lesson poses a tremendous instructional challenge: how to explain a concept in a clear, concise, bite-sized chunk...not to just teach the procedure...but also to represent the important underlying conceptual ideas" (p. 82).

The Project Lead the Way teacher forums also provide anecdotal evidence of the benefits of the flipped classroom. Kurt Borchardt (2012) wrote "make sure you emphasize to your students that it's not your typical YouTube experience (fun, entertaining). They need to be taking notes, thinking (ahhhh), pausing and replaying" (PLTW DE Forum). Roger Jaffe (2012) added about inverting his AP Statistics class "I've increased the number of days that I'm working with students rather than lecturing by 30-40% and the level of students' work and understanding is so much better than last year. I'll be doing the same thing with my DE class over the summer for next year and I'm really looking forward to it" (PLTW DE Forum). See Appendix B for these comments in context and related inverted, also called flipped, classroom experiences. These opinions are valuable reflections on the impact of the inverted classroom on teaching and learning, and they echo much of the related research.

Conclusions and Recommendations

Content-crammed STEM classes need to provide more time for guided hands-on learning and practice in order to recruit and retain students. Several instructors at the college level are implementing the inverted classroom model to demonstrate that at home video lecture and in-class activities offer better learning experiences (Carlisle, 2010; Day, Foley, Groeneweg, & van der Mast, 2004; Gannod, Burge and Helmick, 2008; Toto and Nguyen, 2009). This conclusion addresses how the inverted classroom addresses problems facing STEM education recruitment and retention.

The Status of STEM Education in the United States

The United States is falling behind other countries in recruiting students to STEM fields. Wai, Benbow and Steiger's (2010) research suggested that increasing the STEM educational dose by engaging students in advanced placement STEM classes, like *Project Lead the Way*, relates to an increase in real-world STEM accomplishments. Recruiting and retaining students in these classes may increase the number of students who continue in STEM-related fields in college. Deslauriers, Schelew, and Wieman (2011) suggested that instruction based on research in cognitive psychology, including in-class activities and discussions, increases student attendance and engagement.

STEM Education History and Active Learning Theories

The research to date demonstrated that although educators have been working to improve learning in STEM fields for years, many instructors continue to use the large lecture as the primary form of engagement with students. Baldwin (2009), Fairweather (2008), and others argue that teachers must move away from lecture-based lessons toward student-centered, active learning . The inverted classroom model provides the time for activity in class and the delivery of content necessary for student success.

The Inverted Classroom Effect on Learning

Research by Foreman (2008) and Gannod, Burge and Helmick (2003) described the ideal learning situation for the millennial generation that encompasses current high school and college students. These students benefit from the hands-on, active learning activities that the inverted classroom provides. The immediate feedback and correction of misconceptions in the inverted classroom also plays to their strengths and assists their learning. If students complete work in class, teachers do not have to wonder if students failed to complete activities because they did not understand or because they just did not want to complete the activities outside of class.

Traditionally, instructors lectured with little regard to students' note-taking abilities and varied learning styles. Video lectures allow students to pause, rewind, and get closer to see details of pictures, charts, and demonstrations. Of the research analyzed, (Berger, 2007; Carlisle, 2010; Day, Foley, Groeneweg, and van der Mast, 2004; Gannod, Burge and Helmick, 2008; Kaner and Fielder, 2005, and Toto and Nguyen, 2009) all had encouraging results from their use of the inverted classroom. Student response to videos, in-class activities and attainment of curricular goals were positive. Therefore, it is possible to conclude that the inverted classroom may benefit student learning at other levels of instruction as well.

Aspects of Teacher Implementation

In order to see the benefits described, teachers must implement some of the strategies discussed in the literature. The videos must be short, high quality and accompany a task for students to complete. Instructors designing video lectures should use Mayer's ten principles of multimedia instructional design in order to reduce cognitive load and provide the most beneficial learning environment (Mayer, 2008). Teachers who create screencast demonstrations will find Sugar, Brown and Luterbach's framework a helpful guide (2010).

In-class activities should depend on learning derived from the videos in order to maintain the motivation to watch the videos as well as expand on the information in the videos. The instructor may also need to create additional activities to utilize all of the instructional time. Supplementary videos clarifying common misconceptions, demonstrating worked problems and providing self-explanation may also improve learning and reduce math and science anxiety (Musallam, 2011). The *Project Lead the Way* curriculum provides high-quality activities and practice problems; see Appendix C for an example comparison between a typical and inverted Principles of Engineering class. This example includes lecture-replacement videos as well as worked problem examples. It also includes the potential to move the assessment review time out of the classroom and onto the screen.

Recommendations

Project Lead the Way offers a unique opportunity for research of this kind. Several teachers are already implementing the inverted classroom in Principles of Engineering and Digital Electronics classes. See Appendix B for a summary of PLTW forums, which illuminate the excitement you can find amongst these educators. Hundreds of master teachers and affiliate professors country-wide can work together to create high-quality scripts and resources for teachers to use in their own classes. Teachers who choose to participate will provide students with informed consent forms in order to collect survey data about student attitudes (see Appendix D for example). PLTW collects data from end of curriculum assessments, which can be mined to compare students who participated in inverted classrooms to similar students in traditional classrooms. PLTW also collects data on how many students go on to study STEM fields in college, which could also be used to determine if the inverted classroom increases motivation to pursue these types of careers.

An action-research project in high school and middle schools offering *Project Lead the Way* classes would increase understanding of the implications of the inverted classroom at the pre-collegiate level. As Day, Foley, Groeneweg, and van der Mast describe, "research in an educational setting is extremely complex...design-based research has become an accepted blend of empirical and formal education research" (2004, p.4). Therefore, in order to determine the effects of the inverted classroom in a high school setting, an educational design experiment is appropriate.

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Appendix A

From Sugar, Brown and Luterbach, 2010, p. 11

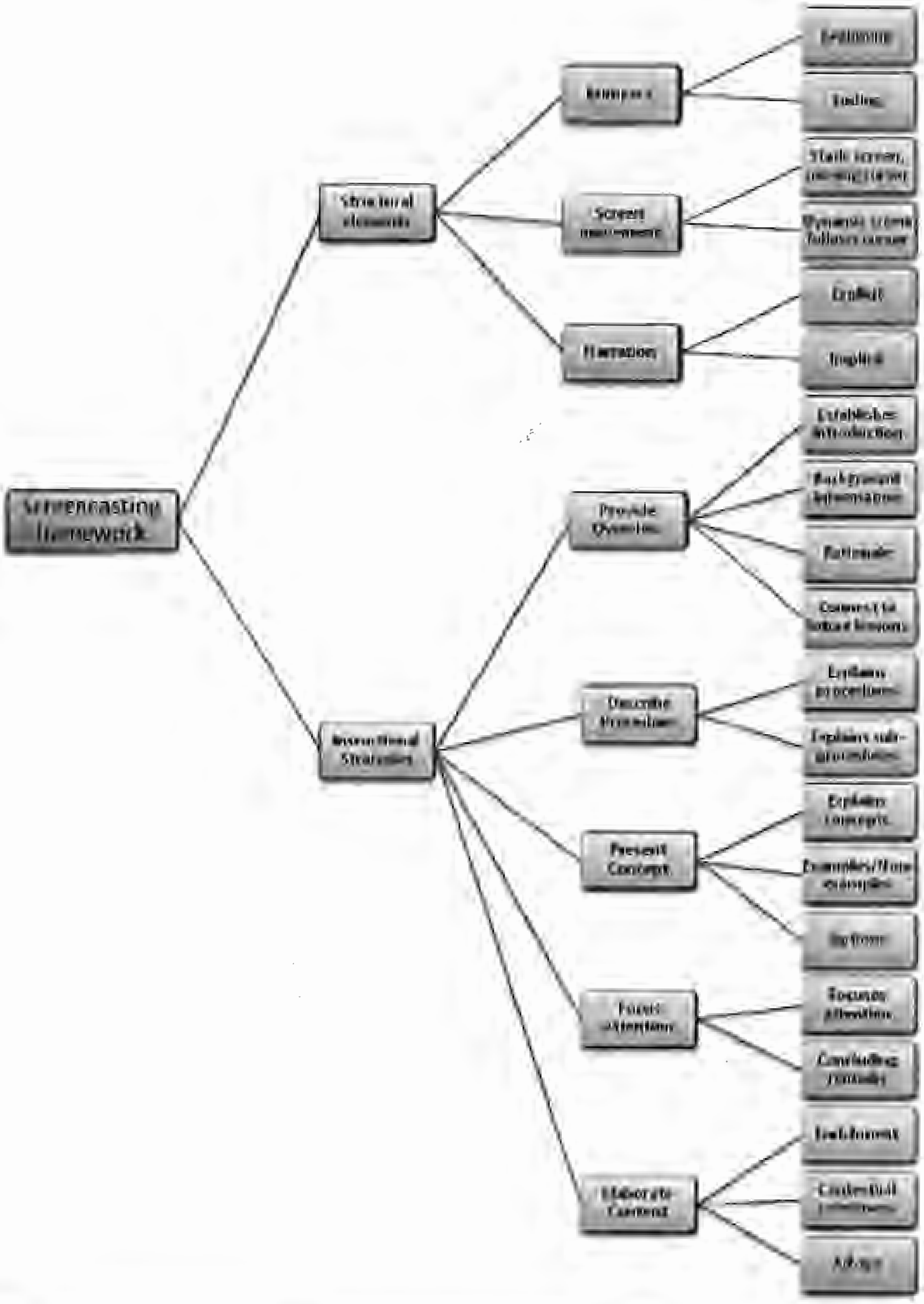

Figure 1. Screencasting framework and corresponding instructional strategies.

Appendix B

Digital Electronics Forum "flipped classroom" search:

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Brett Kisker - Tuesday, 22 May 2012, 06:23 PM

If this is happening, I want in on it as well. I'd be more than happy to create some videos over time.

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Bakari Holmes - Tuesday, 22 May 2012, 05:46 PM

I'm also game for helping create videos. Maybe we should have a folder in the dropbox for "flipped" videos and resources. I also plan on starting to use your videos this next school year, Kurt. I will be slowly working on making my own starting this summer for DE first, then IED, then POE.

Cheers,

Bakari

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Thomas Spencer - Tuesday, 22 May 2012, 05:35 PM

Please add me to the list as well. The e-mail address that I use most is tc_spencer@yahoo.com.

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Andrew Woods - Tuesday, 22 May 2012, 04:53 PM

I would also like to help Flip the DE classroom. June is a bit busy for me with AE training, I could make a few videos if you could tell me the topics and the learning outcomes.

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom by Vanessa Stratton - Tuesday, 22 May 2012, 03:43 PM

I would love to collaborate to flip DE! Kurt, I use your videos now as review and my students really appreciate them. I am going to use part of June to really sit down and plan how to flip Units 1 and 2. I will post what I come up with (as far as a syllabus, student/parent contract etc. but maybe we can start a Dropbox with resources just for the 'flipped' DE.

EDD I teach basically flipped so the students are working collaboratively in class but I am also going to spend some time making this a smooth, clear process for my students.

Vanessa Stratton
Santa Rosa Academy

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Brett Kisker - Monday, 21 May 2012, 02:28 PM

What would be really nice is if PLTW could set up a student-accessible space on their website for us to put these videos. Youtube is currently blocked for students in my school district, and it takes all sorts of extra steps to get them to be viewable by students (even at home). If I could just go through PLTW to host my PLTW videos, it would be awesome.

Oh, and it would mean that I could be much less concerned about using PLTW-copyrighted materials.

Anyone out there at national HQ listening???

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Kurt Borchardt - Monday, 21 May 2012, 01:40 PM
Summary_of_videos_made_to_date.docx

I've posted this on the forum before, but another time can't hurt. Attached is a document with youtube links to all the movies I've made. I do have a few more videos that I'm going to make in the next few weeks, I'll post an update once I'm done.

The vids want to make are: electrical components 101, 555 timer design, and understanding advanced boebot code. If anyone is game for making these videos, I'll be more than glad to use your videos! I'm game for collaborating with y'all!

Kurt

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom by Matt Lockwood - Monday, 21 May 2012, 12:52 PM

Kurt, could you post a link to your videos? I'm intersted to see what your videos look like.

I love the idea of flipping DE and my other PLTW classes. My thought is why we are not working collaboratively in this endeavor? We could really do some major flipping if we divided the work amongst many teachers and then create wiki or youtube channel with all the videos in one location. Many hands make light work.

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Kurt Borchardt - Sunday, 20 May 2012, 06:06 PM

I strongly suggest the students take notes in a bound journal on the first day of class, beyond that, I don't force the students to any type of note taking style. The reverse instruction lends itself to GREAT note taking for *most* students. What I've experienced is the students that take poor notes (with reverse instruction) have a host of academic skills issues (poor organization, etc...), but I find it's easier to figure out my "problem children" cause they stand out more (than with the classic lecture style of instruction).

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by David McCarroll - Friday, 18 May 2012, 05:31 AM

Hi Kurt. One of your replies is on my question on the same topic a few weeks back. I've already looked at some of your videos. They are great, and thanks for sharing.

One question I have is: how do you handle taking notes/journals? I want the kids to keep the journals in the classroom. It cuts down on lost journals, etc... But then, if they don't take them home, they can't take notes in them. What do you do for the note taking?

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by William Brooks - Thursday, 17 May 2012, 03:33 PM

Sorry to bother you. Do you put the power points from PLTW on the video's and discuss them or do you recreate your videos from scratch? Thanks

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom -> Re: Flipped Classroom
by Kurt Borchardt - Thursday, 17 May 2012, 02:43 PM

Search for my posts about reverse instruction. I've posted most of the videos I've made on a MS Word document.

I flipped DE during the 3rd quarter last year, did flipped instruction all of this year. I'm NOT going back to the ol' fashioned way. Amazing instruction method.

Only thing, **MAKE SURE YOU EMPHASIZE TO YOUR STUDENTS THAT IT'S NOT YOUR TYPICAL YOUTUBE EXPERIENCE (FUN, ENTERTAINING).** They need to be taking notes, thinking (ahhhh), pausing and replaying. You'll have some student say "I watched the video" but be mostly clueless in class. The mere fact of watching the video means as much as "I was in class when you gave the lecture." The clueless ones typically pick up the pace, or drop the class. You can't be a slacker and "get by" with this method...those that don't watch the lessons stand out like SORE THUMBS!!!

Other than that, make sure that your activities are ***IMPOSSIBLE*** unless they watched the video - especially the first few weeks - the students will quickly learn that they need to do the homework. Roughly 95% of my students do the homework now....WAY higher than the "traditional" method of instruction.

I also find I have WAY more time to work with struggling students, and I can allow those that work fast, to work at a fast pace.

Making the vids can be time consuming, but once it's set up, you just spend more time getting creative with your student activities. There are oodles of ways to get creative, when you do reverse instruction, you'll see what I mean. One brief example, when you're absent, you can give a video lesson / instruction for your sub to show the class. Damn cool stuff.

Kurt Borchardt

Show parent
See this post in context

Digital Electronics Forum -> Flipped Classroom
by William Brooks - Thursday, 17 May 2012, 01:39 PM

Has anyone experimented with or incorporated any of these new Flip Classroom concepts with the PLTW curriculum?

Just curious as to how successful you were.

See this post in context

Digital Electronics Forum -> Sharing Units with Math and Science -> Re: Sharing Units with Math and Science

by Roger Jaffe - Wednesday, 18 April 2012, 02:29 PM

And I agree! I flipped my classroom for AP Statistics this year and it's been a phenomenal success! I've increased the number of days that I'm working with students rather than lecturing by 30-40% and the level of students' work and understanding is so much better than last year. I'll be doing the same thing with my DE class over the summer for next year and I'm really looking forward to it.

Principles Of Engineering Forum "flipped classroom" search:

Principles of Engineering Forum -> Flipping POE -> Re: Flipping POE

by Jon Jasinski - Monday, 12 September 2011, 01:37 AM

If done correctly (and I am by no means a flipping expert..........pun intended) a flipped classroom could be more efficient than a strict "lecture-activity-lecture-activity" classroom. The key would be to deliver the right amount of information at the right time so you don't interrupt the "experience." Students learn from experience, not me. Lecture is inherently a passive experience, and I'm sure many of us try to avoid it for that reason. The reality is they are never getting as much as we think they're getting out of a lecture. That's why PLTW is project based; let's interrupt that flow as little as possible and let students learn. Granted, that's easier said than done and takes major planning, but there is a lot of potential if we can get out of our own way.

I tried something different with 1.1 simple machines this year. 5 groups are each building a different simple machine and then rotating through to complete the investigation. That in itself wasn't new. I screencasted mini-lectures using screencast-o-matic.com, one for each simple machine and uploaded them to youtube. They are unlisted, so you can only find them if you have the link (which I included below, feel free to use). I have 6 computers in my classroom, so immediately before a group works on a specific setup (or the night before), they watch the mini-lecture. This provides an uninterrupted exploratory experience for a few days with no formal lecture. I'm free to answer questions, assess, critique, and go beyond. It took me about an hour to record, upload, and link them from my wikispace. It was really quite simple. Press record, talk through the PPT, then upload.

- Mechanical Advantage
- Levers & Moments
- Wheel and Axle
- Pulleys
- Inclined Plane

- Wedge
- Screw

Principles of Engineering Forum -> Flipping the Classroom -> Re: Flipping the Classroom

by Allison Fitzwater - Monday, 7 May 2012, 01:26 PM

Thanks for the assistance! I flipped my Physics class this year and the students LOVED it. Since the classes have about the same demographic...*fingers crossed* I hope it works for next year. The Camtasia software does make flipping a bit easier...and a Bamboo tablet from Wacom (about $80) makes all the difference I'll post videos as I make them next fall.

Show parent

See this post in context

Principles of Engineering Forum -> Flipping the Classroom -> Re: Flipping the Classroom

by Allison Fitzwater - Tuesday, 8 May 2012, 12:29 PM

A flipped classroom inverts the nature of lecture and homework. Lectures are given as homework (a video, reading or link) and then problem sets and labs are done during class time. It's just a twist on the traditional teaching method. I like it because the kids can take as long as they want with the notes and then I am available during class time to answer questions about problem sets or take more time in lab. So far my kids love it, mostly because it makes sense. For more info try http://flipped-learning.com/

Show parent

Appendix C

Principles of Engineering Lesson 2.1 Statics

A Comparison of Schedule and Activities for Typical versus Inverted Classroom

Each day begins with a discussion of questions from the previous evening's video. Each video would also include a short activity or quiz for students to complete in order to implement appropriate instructional strategies to motivate students and engage them in their learning. The teacher will circulate throughout the classroom during work time to answer questions and provide feedback, stopping the class if necessary to provide whole class instruction for misconceptions.

As you can see, the curriculum does not provide time for review and assessment. Although Day 14 of the inverted classroom column includes time for review in class, teachers could generate review videos based on student questions, which would use class time more efficiently. Therefore the lesson would end with assessment on the fourteenth day, which is the amount of time provided by the curriculum.

		Typical Classroom	Inverted Classroom
Last day of previous lesson	Homework		Watch Introduction to Statics video
Day 1	In class	Introduce concepts, key terms and essential questions Introduction to Statics Power Point	Introduce concepts, key terms and essential questions Small teams research building and bridge failures online and report back to class, discuss the importance of statics for building safe structures (put the lesson in context)
	Homework		Watch Centroids video
Day 2	In class	Centroids Power Point Begin Activity 2.1.1 Centroids	Complete Activity 2.1.1 Centroids with support from teacher and peers
	Homework	Finish Activity 2.1.1 Centroids	Watch Structural Members video
Day 3	In class	Structural Members Power	Complete Activity 2.1.2 Beam

		Point Begin Activity 2.1.2 Beam Deflection	Deflection with support from teacher and peers
	Homework	Finish Activity 2.1.2 Beam Deflection	Watch Free Body Diagram video
Day 4	In class	Free Body Diagram Power Point	Complete Activity 2.1.3 Free Body Diagrams with support from teacher and peers
	Homework	Activity 2.1.3 Free Body Diagrams	Watch Force Vectors video
Day 5	In class	Force Vectors Power Point	Complete Activity 2.1.4 Calculating Force Vectors with support from teacher and peers
	Homework	Activity 2.1.4 Calculating Force Vectors	Watch Moments video
Day 6	In class	Moments Power Point	Complete Activity 2.1.5 Calculating Moments with support from teacher and peers
	Homework	Activity 2.1.5 Calculating Moments	Watch Calculating Truss Forces video
Day 7	In class	Calculating Truss Forces Power Point Begin Activity 2.1.6 Step-by-Step Truss System	Work on Activity 2.1.6 Step-by-Step Truss System with support from teacher and peers
	Homework		Finish Activity 2.1.6 Step-by-Step Truss System using guided practice video
Day 8	In class	Finish Activity 2.1.6 Step-by-Step Truss System	Complete Activity 2.1.7 Calculating Truss Forces with support from teacher and peers
	Homework	Activity 2.1.7 Calculating Truss Forces	Watch Project 2.1.8 Truss Design video and brainstorm truss designs
Day 9	In class	Introduce Project 2.1.8 Truss Design	Begin Project 2.1.8 Truss Design
	Homework	Brainstorm truss designs	Begin project calculations and documentation
Days 10 - 13	In class	Project 2.1.8 Truss Design	Project 2.1.8 Truss Design
	Homework	Project calculations and documentation Review for Lesson Quiz Submit review questions	Project calculations and documentation Review for Lesson Quiz using videos and worked examples Submit review questions
Day 14	In class	Project 2.1.8 Truss Design	Submit Project 2.1.8 Truss Design Review for Quiz using student generated questions
	Homework	Complete documentation and continue review	Review for Quiz

The curriculum document provides 14 days for this lesson. It does not include time for review or assessment.			
Day 15	In class	Submit Project 2.1.8 Truss Design Review for Quiz using student generated questions	Lesson Quiz
	Homework	Review for Quiz	Watch Introduction to Materials video
Day 16	In class	Lesson Quiz	Introduce concepts, key terms and essential questions for Lesson 2.2 Discuss relationship between materials and statics Begin Activity 2.2.1 Product Analysis
	Homework		Continue Activity 2.2.1 Product Analysis

Appendix D

Based on consent forms found in Musallam (2011).

Informed Consent

Project Lead the Way

[Head Researcher's Name Here]

Consent to be a research subject

Purpose and Background

Project Lead the Way (PLTW) is doing a study on the effects of the inverted classroom in high school and middle school pre-engineering classes. An inverted classroom moves the lectures out of class as homework in order to provide more time in class for hands-on activity and teacher support. Education literature indicates that the subjects covered in PLTW classes are complex for students and that performance and interest in engineering is low. I am being asked to participate because I am a Project Lead the Way student.

Procedures

If I agree to be a participant in this study, the following will happen:

1. I will participate in class throughout the school year (this agreement does not prevent you from dropping the class according to your school's procedures).
2. I will complete the End of Curriculum Assessements
3. After procedural steps 1 and 2, I will answer a survey about my learning experience in this class.

Risks and/or Discomforts

1. It is possible that some of the questions on the survey may make me uncomfortable and impact your perceived sense of confidence and self-worth in the class. I am free to decline to answer any questions I do not wish to answer or to stop participation at any time.

2. Participation in research may mean a loss of confidentiality.

Student records will be kept confidential. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.

Benefits

There will be no direct benefit to me for participating in this study. The anticipated

benefit of this study is a better understanding of how the inverted classroom model affects learning and motivation in engineering.

Costs/Financial Considerations

There will be no financial costs to me as a result of taking part in this study.

Payment/Reimbursement

There will be no payment or reimbursement for me as a result of taking part in this study.

Questions

I have talked to [teacher's name] about this study and have had my questions answered. If I have further questions about the study, I may call him/her at [phone number here]. If I have any more questions or comments about participation in this study, I should first talk with the researcher, [head researcher's name and contact information]. If for some reason I do not wish to do this, I may contact the IRB, which is concerned with protection of volunteers in research projects. [Provide contact information for IRB, which reviewed research proposal].

Consent

I have been given a copy of the "Research Subject's Bill of Rights" and I have been given a copy of this consent form to keep. PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to be in this study, or to withdraw from it at any point. My decision as to whether or not to participate in this study will have no influence on my present or future status as a student at [school name here].

My signature below indicates that I agree to participate in this study.

____

Subject's Signature Date of Signature

____

Signature of Person Obtaining Consent Date of Signature

PARENTAL CONSENT FOR RESEARCH PARTICIPATION

Purpose and Background

Project Lead the Way (PLTW) is doing a study on the effects of the inverted classroom in high school and middle school pre-engineering classes. An inverted classroom moves the lectures out of class as homework in order to provide more time in class for hands-on activity and teacher support. Education literature indicates that the subjects covered in PLTW classes are complex for students and that performance and interest in engineering is low. Your son/daughter is being asked to participate because he/she a Project Lead the Way student.

Procedures

If your child agrees to be a participant in this study, the following will happen:

4. Your child will participate in class throughout the school year (this agreement does not prevent you from dropping the class according to your school's procedures).
5. Your child will complete the End of Curriculum Assessements
6. After procedural steps 1 and 2, your child will answer a survey about his/her learning experience in this class.

Risks and/or Discomforts

3. It is possible that some of the questions on the survey may make your child uncomfortable and impact his/her perceived sense of confidence and self-worth in the class. He/she free to decline to answer any questions he/she does not wish to answer or to stop participation at any time.

4. Participation in research may mean a loss of confidentiality. Student records will be kept confidential. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.

Benefits

There will be no direct benefit to your child for participating in this study. The anticipated benefit of this study is a better understanding of how the inverted classroom model affects learning and motivation in engineering classes in middle school and high school.

Costs/Financial Considerations

There will be no financial costs as a result of taking part in this study.

Payment/Reimbursement

There will be no payment or reimbursement as a result of taking part in this study.

Questions

I have talked to [teacher's name] about this study and have had my questions answered. If I have further questions about the study, I may call him/her at [phone number here]. If I have any more questions or comments about participation in this study, I should first talk with the researcher, [head researcher's name and contact information]. If for some reason I do not wish to do this, I may contact the IRB, which is concerned with protection of volunteers in research projects. [Provide contact information for IRB, which reviewed research proposal].

Consent

My son/daughter has been given a copy of the "Research Subject's Bill of Rights" and I have been given a copy of this consent form to keep. PARTICIPATION IN

RESEARCH IS VOLUNTARY. My child is free to decline to be in this study, or to withdraw from it at any point. His/her decision as to whether or not to participate in this study will have no influence on my present or future status as a student at [school name here].

My signature below indicates that I agree to allow my child to participate in this study.

____

Subject's Parent Signature Date of Signature

____

Signature of Person Obtaining Consent Date of Signature