120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #7134

Self-Regulated Learning and Blended Technology Instruction in a Flipped Classroom

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Introduction

The mission of the SMART LIGHTING Engineering Research Center (ERC) includes a key educational component, namely to *educate a diverse, world-class workforce that will be needed to grow the business of Smart Lighting*. The education program of the ERC addresses university and pre-college level education and outreach and has as a goal the development of innovative curriculum and instructional practices that will allow for transfer of new knowledge into the classroom. Although the major focus is on content related to the ERC, methods that apply to all STEM areas are under consideration in practices related to design, implementation, and assessment of student learning. One of the primary goals of the project is to investigate the viability of alternative approaches to instruction that will build on the constructionist/ constructivist approach to STEM education. To meet this goal, the instructional practice of *flipped classrooms* is being piloted in the Electronic Instrumentation course at RPI; specific content is provided via *online video lectures,* and class time is devoted to hands-on practice of concepts. The implementation of *flipped classrooms,* requiring self-regulated approaches to learning, is becoming more common; however, most students within the STEM domain are accustomed to the traditional teacher-directed classrooms. Although many students had prior experience with video lectures, their comfort levels are generally not high. A major focus of this development effort is to provide students with a scaffolding infrastructure so they can become more confident and successful in this new learning environment.

Starting in 2010, a series of pilot videos were developed and implemented. The purpose of the videos was to provide a method whereby instructors, advanced students, and external experts could provide material and context used to replace, supplement, or enhance traditional classroom and laboratory instruction. A key specification of the design and development of the videos was that they must be made available online, with plans for ubiquitous availability across classes, instructors, and sites. Each video lecture represented key components of content and context knowledge. The videos were designed to meet the needs of students through multiple methods of instruction, including those with limited access, repeated access, sequenced access, and general availability. Initial evaluations of pilot use in the classroom, conducted in Fall 2010, Spring 2011, and Fall 2011, provided formative feedback on students' uses and perceptions and assisted in development of materials.

In 2011-12, additional video materials were developed and all videos were uploaded to *YouTube*, thereby enabling student access to the videos anytime and anywhere. The video lectures for this course were used concurrently with multiple online PowerPoint slides, online handouts of notes for each experiment, and online reading materials from multiple websites.

This paper addresses formative information related to student and faculty perceptions of the use of video lectures (i.e., how they were used, as well as facilitators and barriers to use), collected during the Spring 2012 pilot.

Theoretical Background

In the 21st century, change and reformation to policies and instructional methods are a necessity for the field of education.[1] 21st century students require major change to traditional methods of teaching; engagement is promoted through instructional strategies of visual stimulation, experiential/authentic learning, technology integration, and community-based learning.[2] In 21st century education, constructivist, constructionist, and studio-based learning provide the key pedagogical foundation for successful instruction and student learning.[3] In these settings, an environment of techniques including problem-solving, critical thinking, experiential activities, inquiry, and collaboration foster learning.[4]

One of the more influential aspects of instruction in 21st century education is the use of technology.[5] A particular strategy involving technology is the use of web-based supports for students[6] including virtual laboratories, video lectures, tutorials, etc. for students to reference.[7,8] A more recent approach to learning via technology involves the inversion of traditional instruction (i.e., classroom lecture followed by homework) using the instructional practice of *flipped classrooms*.[9,10] The term *flipped classrooms* refers to the practice of using technology (e.g., videos, podcasts, etc.) to deliver lectures and important conceptual information to students outside of class on their own time; class time is reserved for "homework".[10-12]

This approach promotes the self-regulated learning necessary for constructivist and constructionist-based learning. Constructivist and constructionist-based approaches to learning are supported by empirical literature which demonstrates that to obtain competence, proficiency, or expertise in a domain it is necessary for the learner to practice until a level of familiarity, and ideally automaticity, in basic skills is reached.[13-16] Self-regulated learning dictates that students are in control of their own learning by setting goals for their learning, monitoring their own learning, and motivating themselves to learn[17,18] Self-regulated learning facilitates innovation, critical thinking, problem solving, and communication skills.[19] The class time in a *flipped classroom* model is reserved for such self-regulated active, hands-on experimentation and critical problem-solving to deepen and extend student learning.[19]

Research has shown that the *flipped classroom* model is often implemented in STEM related fields.[20-23] Rodd & Newman reported positive outcomes related to the use of technology in STEM education; students who had access to technology supported, technology guided and technology reinforced learning had more positive attitudes toward learning the content, greater retention of direct content, and greater transfer to other areas.[24] The integration of technology using the *flipped classroom* model reinforced positive findings indicating student attitudes were more positive toward the class, and increases were shown in student understanding, engagement with the material, and content mastery.[20,21,25]

This study examines student and faculty perceptions of a *flipped classroom* approach in an undergraduate electronics engineering course. As is discussed in the following section, this is part of a larger study that addresses hands-on, active learning through the use of inexpensive, portable, student-owned instrumentation that has demonstrated enhanced student learning, especially at the higher levels of Blooms' Taxonomy.[26-30,33] This larger study is continuing and is expected to further establish that *flipped classrooms* do allow for the productive redistribution of student and faculty resources to increase overall learning.

Instructional Setting

Electronic Instrumentation

Most engineering undergraduates at RPI, outside of electrical and computer engineering, are introduced to electronics and instrumentation in a course that has traditionally been taken in the junior or senior year called Electronic Instrumentation. At the request of mechanical engineering students, who make up the bulk of this class, this course has recently been modified to be available to sophomores. The students wanted to have some basic electronics skills for their other courses, especially those with large design projects. The following course description shows the general range of topics addressed.

Electronic Instrumentation—A survey, application-oriented course for engineering and science majors. Topics include: transducers and measurement devices; DC and AC analog circuits including impedance, power, frequency response, and resonance; diodes, transistors and operational amplifiers; signal conditioning, noise, and shielding; digital electronics, A/D and D/A conversation; power supplies, rectifiers, and electromagnetic devices.

Physics II (Electricity and Magnetism) is a pre-requisite and Differential Equations is a co-requisite.

The course typically has two sections of 50-70 students each, meeting twice a week for 2 hours. There has also been a common two hour lecture once each week, but the lectures were recorded and the meeting eliminated to place total focus on hands-on activities in the classroom. The class meets in a large studio classroom in which there is power for student laptops at each two student station along with an LCD display for materials from the instructor's computer or a visualizer for written comments or images of equipment or experiments. In addition to the instructor, each section is staffed with 2-3 teaching assistants (depending on the class size).

Formal assignments include eight experiments for which the students work in teams of two. Each experiment also has an online homework assignment accessed through the universities Blackboard LMS. Homework is done individually and is automatically graded and added to the LMS grade book. There are also 4 design projects for which two teams combine. Class attendance is required. Any missed classes are made up during the 8-12 hours of open shop time that made available for any groups that require extra time for experiments or projects. Open shop time is shared with two other courses – Embedded Control[32] and Electric Circuits[31] that use the same studio classroom and staffed by at least one teaching assistant (TA) from each course. There are four traditional paper and pencil exams during the term.

Electronic Instrumentation was largely a multi-section lab course with a common weekly lecture prior to the late 1990s when it was completely modified as a studio course. A special, 36 seat studio classroom was built for it as part of the conversion of electrical and computer engineering courses to studio delivery. The classroom was outfitted with a full complement of lab equipment, audio-visual equipment, computers, etc. and cost about $10k per seat. The studio approach was a big success, drawing many visitors to the RPI campus to see how it was implemented. Most visitors left excited by the idea but discouraged by the high cost and the hard limits on individual section enrollments from the finite size of the studio classroom. When enrollments in mechanical engineering exploded a few years later, studio delivery tied to the existing classroom became unrealistic. Fortunately, the work by Millard and his colleagues on Mobile Studio for Electric Circuits was ready to be expanded to other courses.[31] Electric Circuits and Electronic Instrumentation were moved to the large studio classroom built for the Embedded Control class and both courses were fully converted to utilize Mobile Studio hardware and software rather than traditional laboratory instruments.[26-29]

A Mobile Studio (mobilestudioproject.com) is technology-based pedagogy based on inexpensive hardware/software which, when connected to a PC (via USB), provides functionality similar to that of electronic laboratory equipment (scope, function generator, power supplies, DMM, etc.) typically associated with an instrumented studio classroom. The Mobile Studio IOBoard is a small, inexpensive hardware platform for use in a home, classroom or remote environment. When coupled with the Mobile Studio Desktop software, the system duplicates a large amount of the hardware often used to teach Electrical Engineering, Computer Engineering, Physics and K-12 technology-related courses; in addition to a myriad of industrial and commercial utilizations.

Classroom Learning Environment

During the standard studio delivery stage of Electronic Instrumentation, a very extensive set of online materials was developed and made accessible through the course website. For each experiment and project, these include copies of PowerPoint slides used in lectures, handouts describing all required tasks and background reference materials addressing both review of materials from previous courses and reference information on components and equipment. In addition to this required reading, optional materials are also provided as supplements. General information not associated with particular assignments (e.g. how to use a protoboard, how to identify circuit components, troubleshooting and debugging, etc.) is also included. Detailed information on the questions on each of the four exams, including copies of formula sheets and many examples from past tests are also found on the course website. All of these materials are available throughout the semester and can be used as examples to help with learning. Both the course website and the materials found there are continuously improved based on feedback from students and staff. (See http://www.ecse.rpi.edu/courses/S12/ENGR-4300/ElecInst.html for an example of the course website from Spring 2012.)

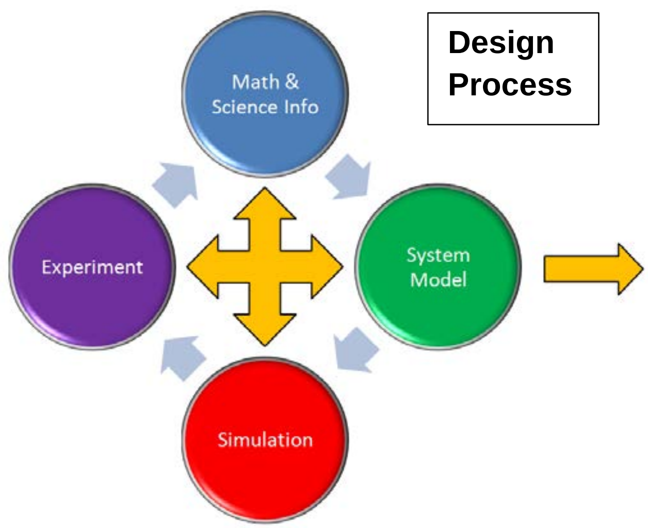
One of the critical requirements for the student teams is to obtain staff signatures verifying completion of key tasks in each experiment and project. For experiments, each write up document includes a checklist page listing all tasks and identifying 3-6 representative tasks for which the team must show their work to a TA or instructor who must sign on the signature line provided. There are two purposes for this checklist. First, once students have described what the experiment write up requires of them and provided the evidence that they have successfully completed each task, they are given feedback on whether or not they have done the right experiment, collected accurate data, etc. so that they have useful information to include in their experiment report. Second, the checklist provides evidence that the students have done their own work. For example, if a team is asked to produce a plot of data for some experiment or simulation, they can only receive a signature if the experiment or simulation is actually running.

They are then asked to change some conditions and explain the result. Project write ups in general do not include checklists so students are required to generate their own and obtain verification of any data they wish to use in their reports.

In addition to obtaining staff signatures on checklists, the bulk of student-staff interaction involves troubleshooting and debugging. The course website includes a continually changing document that lists the main issues faced by student teams doing the hardware and/or software experiments that make up the assignments. This document helps with many problems, but most of the students in this class have limited experience with electronics and measurement and, thus, require some assistance from the TAs or instructor. This interaction is rich with opportunities for learning and is, more often than not, enjoyable for everyone involved as problems are collectively tracked down and solved.

In 2011-12, based on an overwhelmingly positive vote of the students, the pilot use of the online videos in the two sections of Electronics Instrumentation was fully implemented. In this setting, students were provided with a series of online video lectures to be viewed, as assigned, outside the classroom; scheduled instructional time was used for organized hands-on lab and project work. The online videos were uploaded and available for student use through the course Blackboard LMS site (Fall 2011) and then also via YouTube (Spring 2012), thereby enabling student access to the videos anytime and anywhere.

To summarize, a self-regulated learning environment was promoted through use of the Mobile Studio; in the most in depth approach, students were conducting experiments, running simulations, solving traditional paper and pencil problems, watching video lectures, and reading online background materials.[30] All major concepts were presented in the context of the engineering design process so that the students could see each new system addressed as an example of how engineers typically do their jobs. Every new idea was then presented three times (from fundamental simplified theory, from simulation, and from experimentation) and students were asked to develop a practical system model that would permit them to design other systems for specific applications.



Students in this approach worked in teams whose members self-assigned responsibilities for each activity (experiments and design projects) and the instructor and teaching assistants checked on the preparation and performance through a task checklist completed for each activity. Assessment of the success was based on the final system model that students developed. As part of this process, students also were asked to document at the end of the course, their perceptions of instructional support and outcomes related to content and affective learning outcomes.

Method

Participants in this study included engineering students (n=70) enrolled in Electronics Instrumentation course at RPI in the Spring semester of 2012. The sample was comprised of primarily mechanical engineering students in their third/fourth year of study. Over three-quarters of the students were male (83%). Three-quarters of the students self-reported their ethnic origin as White.

Surveys were administered to students during class time at the beginning and end of the semester. Pre-course surveys were used to assess student demographics, learning style preferences,[36] and both pre and post-course surveys assessed attitudes toward learning via online videos (e.g., frequency of use, perceptions of use, benefits and barriers toward use). Interviews of students and faculty (conducted post-course) assessed overall perceptions of students' experiences and perceptions of the flipped classroom and use of online videos as lectures. Independent observations were conducted throughout the semester to document student interactions and student regulation of projects and experiments.

Results

Student Perceptions and Use of the Video Lectures

Online video lectures were primarily seen as a tool to strengthen and expand on students' conceptual understanding of course material, and not as an introduction to, or precursor of new material (see Table 1). For example, students predominantly used the online videos to review information for upcoming tests and quizzes and to clarify concepts. Approximately one-third of the students (32%) reported using the video lectures to extend their learning above and beyond what they learned through the hands-on activities (e.g., *"extended topics,"* "[online lectures] *provided some examples for calculations/problems"*).

Table 1
Frequency of Online Video Use*

Statement	% Post Spring 2012 All (n=68)	% Post Spring 2012 Matched (n=57)
Students used online videos to review when studying for quizzes/tests.	63	65
Students used online videos to clarify conceptual information.	40	40
Students used online videos to extend learning.	32	32
Students used online videos to guide them through lab assignments.	15	16
Students used online videos to assist in writing lab reports.	13	14
Students used online videos to prepare for upcoming labs.	13	9

**Numbers represent percentages of participants who responded "often"/"most of the time."*

Responses revealed that students occasionally used the video lectures for guidance in the completion of assignments and laboratory reports. Students reported that they rarely (less than

10%) watched the online videos prior to the corresponding lab as a way to prepare for the assignment.

Overall, more students (53%) perceived that the use of online videos did not make the course more difficult than a traditional lecture-based course; however, the majority of students (72%) consistently reported from pre- to post- that they preferred to attend a formal lecture rather than watch online videos (see Table 2). Similarly, approximately two-thirds (68%) of the students reported that they were not comfortable using the video lectures for learning. These responses support students' self-reported lack of use for transfer or conveyance of new information. Student responses may reflect prior experiential bias (i.e., expectations of STEM content delivery from prior courses supporting a pre-conception of a direct instruction approach from a learner-acknowledged "expert"), or previous experiences with video learning pedagogy (i.e., previous courses used the tool for rehearsal, supplemental or enhanced learning goals, not for primary mode of transferring new content).

Table 2
Perceptions of Online Video Usage*

Statement	%			
	Pre	Post	Pre	Post
	All (n=70)	All (n=68)	Matched (n=57)	
I prefer a formal weekly lecture instead of online videos.	75	72	80	72
Taking a course using online videos (will be) was more difficult than taking a traditional lecture-based course.	44	47	46	47
I (will be) was comfortable when using online videos for learning.	41	32	40	32
Taking a course with online videos (will allow) allowed me to self- direct my learning.	38	32	38	30
Taking a course with online videos (will allow) allowed for increased interaction with the instructor during class/lab.	28	22	33	21
Taking a course with online videos (will provide) provided more opportunity to learn content during class/lab.	28	21	27	20
I am the type that learns well with online videos.	29	19	27	19
The skills I developed through online video resources are valued by companies I am likely to work for.	21	17	24	16

**Numbers represent percentages of participants who responded "Strongly Agree"/"Agree" on a 6 point Likert-type survey.*

Students (79%) did not perceive use of the online lectures to allow for increased interaction with the instructor; nor as a means of providing more opportunity to transfer content from theory to practice. When queried, they specifically noted a need for time to verify their learning via questioning usually provided through instructor contact (e.g., *"could not ask questions when watching," "Might forget…questions by class time."*). Observers noted, however, that the instructor and the teaching assistants were present during the scheduled hands-on practice time and were effective in using this time to address student queries or comments. On the other hand, early one-third (30%) of the students did report that the use of the video lectures enabled self-directed learning (e.g., *"helped to go at my own pace as needed," "can pause/redo," "it allowed* *me to go through the lecture again if I didn't understand,"* and *"I could choose what I needed to review and when."*).

Student Approaches to Learning

The student survey measured each student's approach to learning, specifically their preferences towards accessing the information they learn (externally through sensing or internally using intuition), the way they perceive information (visually or verbally), how they process information (actively or through reflection), and the way they progress towards understanding (sequentially or globally).

Data revealed that students in this pilot were primarily sensing (75%), visual (86%), and sequential (66%) learners (see Table 3). This finding indicates that students in Electronic Instrumentation preferred to learn using their physical senses (i.e., through hands-on experience and explicit instruction); visually through diagrams, demonstrations or modeling, pictures, graphs, etc.; and sequentially by developing understanding through linear, logical steps (i.e., knowing the big pictures and developing understanding of the details from the big picture).

Observation of the structure of the online lectures supported the sequential approach to learning as the individual video lectures presented information in a step-by-step manner, logical to the learning of the content; however, the links to access the video lectures on YouTube were not listed in sequential order, nor were they noted by title, thereby potentially creating confusion when students attempted sequential access (e.g., *"takes too long to find relevant information"*).

Table 3
Student Approaches to Learning

Learning Approach	Percentage of Students	
	All (n=69)	Matched (n=57)
Sensing	74	75
Intuitive	26	25
Visual	87	86
Verbal	13	14
Active	47	44
Reflective	53	56
Sequential	63	66
Global	37	35

Visual learners were supported by the use of video lectures based on the amount of textual, graphical, and pictorial information presented; however, students expressed concerns about the design and delivery of information. For example, students noted, *"they* [online lectures] *are too slow," "videos need to be shorter* [and] *more relevant,"* and *"The videos for this course are long and contain multiple parts which seemed unnecessary."* These comments may reflect the needs of a combined sequential/visual learner.

Students with a predominately sensing approach to learning also may have been affected by the use of video lectures in the class. For example, some students expressed frustration in using only *online video lectures* and not having any in-class lectures (e.g., *"I felt like I was thrown into a lab and had no idea what it was on or the concepts,"* and *"have* [videos] *be an aid—not* [the] *sole source of learning."*

Benefits and Limitations in Learning with Online Videos

Open-ended items on the student post-survey gathered students' perceptions on the benefits and limitations of using *online video lectures*, as well as suggestions and modifications for use of the videos in future classes. Students indicated specific benefits to using video lectures for learning; the most dominate of these was unrestricted access to the lectures which served as the foundation for the additional noted advantages such as the promotion of knowledge rehearsal, the allowance for more hands-on practice of concepts, and the facilitation of self-paced learning. Students' comments included, *"It allowed me to go through a lecture again if I didn't understand," "helped clarify concepts when studying," "I watched them before tests," "I had more time to practice concepts in class," "more time spent learning by doing,"* and *"they allow me to learn on my own time."*

Table 4
Benefits and Limitations of Video Lectures

	Student Responses
Benefits	• Helped when studying for tests/quizzes • Unlimited access • Work at own pace • Provided more class/practice time • Extended the topic
Limitations	• Lost motivation/attention • No way to ask questions • No feedback from professor
Suggestions	• Use only lectures • Provide lectures and videos • Make videos more exciting/shorter/provide more examples • Make videos mandatory

A specific limitation to using the online lectures for learning noted by many students was lack of immediate feedback or interaction with the instructor (e.g., *"No one to ask questions to," "could not ask for clarification," "could not ask questions immediately, but instructor is very good at responding quickly"*). Students' and teaching assistants' comments also relayed mixed levels of comfort in the changed classroom structure from a more traditional set up to a more self-regulated approach to learning. The implementation of *"flipped classrooms,"* requiring self-regulated approaches to learning, is becoming more common; however, most students within the STEM domain are accustomed to the traditional teacher-directed classrooms. Although, many students had prior experience with video lectures, their comfort levels were not high.

Students noted specific ways they would change the use of the online lectures in the future including, *"Have some small amount of in-class lecture as well as just to give a review on some topics," "I found it challenging to learn this way … I would add real lectures,"* and *"The videos are nice, but a 30-45 minute lecture before each experiment would be very helpful in addition."* The teaching assistants also noted the initial barrier of implementing a tool like the online lectures in a self-regulated format (e.g., "*It is up to the students to watch or not watch, whereas in lecture they are there. With the video lectures they either watch or they don't…and in a lot of cases, they don't"* and "*A lot of students won't do it when they are home…they will do the work they are going to do. A lot of students, because of time scheduling and priority, it is put off. Somewhat of a traditional lecture would actually be better"*); however, the teaching assistants indicated the benefits of using online lectures to self-regulate learning (e.g., *"Easy to access, they can do them on their own time, if there is a part they already understand they can skip over."*).

It may be necessary to implement strategies to transition students from one form of instruction to another to allow for adjustment to new learning techniques. Until students become familiar with and have indicated a higher level of confidence in their ability to participate in a "*flipped classroom"* and with self-regulated procedures, a blended approach may be necessary by requiring and monitoring the students' use of the tools. Students indicated that lack of guidance on when to use the videos or instructor monitoring of video use were drawbacks to using online lectures for learning. Students suggested requiring students to watch the online lectures *"should be homework," "make them mandatory,"* or *"have students take a pre-lab online quiz to ensure we understood the videos"* would further instill the importance of the online lectures to students.

Students also noted that a barrier to the use of the online lectures was the format of the video and information being presented. The students recommended, "[the videos] *be more exciting," "create bookmarks in each video, so if we are looking for one specific topic…we can find that part in the video,"* and *"use them for a quick primer on topics."* These comments indicate a willingness to use the process, but also identified the students as more sophisticated users of technology then previous classes.

CONCLUSIONS

The NSF funded Smart Lighting Engineering Research Center at RPI is investigating the use of alternative approaches to instruction that will build on the constructionist or constructivist approach to STEM education. This includes the design and piloting of the instructional practice of *"flipped classrooms"* in an electronics course at RPI in the Spring semester of 2012. In this setting, transfer of key concepts was provided outside of class via online video lectures with class time devoted to hands-on practice of concepts. Students viewed the online lectures as a resource that reinforced and expanded their conceptual understanding of the course material but did not see the videos as a key way of transferring new content. Many noted that unrestricted access to the online lectures facilitated knowledge rehearsal, increased hands-on practice, self-regulated learning, and help in preparing for assessment. Students found the use of the *online video lectures* to be most helpful when studying for quizzes and tests, particularly noting the capability of re-watching the videos and reconstructing what they wanted/needed to cover.

Specific limitations or concerns to using the online videos included the delivery of information, the structure of the listing of the videos on YouTube, and the lack of interaction between student and instructor. Half of the students indicated they did not find learning from online lectures more difficult than learning from traditional lectures; however, the majority of students were consistent with their preference for traditional lectures, and were not comfortable using the online lectures for learning.

Blended instructional strategies such as supplementing the online lectures with a brief 10-minute review period at the beginning of each lab and/or including 2 to 3 questions for students to answer as they watch the videos and then bring to lab for brief discussion may be beneficial in providing students with some of the structure they are used to while continuing to promote and transition to self-regulated learning in the *flipped classroom*.

Acknowledgment: This work was supported primarily by the Engineering Research Centers Program of the National Science Foundation under NSF Cooperative Agreement EEC-0812056 and the NSF Division of Undergraduate Education under DUE-0717832.

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