RESEARCH ARTICLE

Flipping an Introductory Science Course Using Emerging Technologies

David Green
University of Miami

Jennifer Sparrow
Penn State University

Abstract

Today's faculty members have tools available that enhance the learning experience of modern digital learners. Emerging technologies and innovative teaching practices update the STEM education learning process and facilitate student retention. In today's hybridized educational world, the classroom stretches far beyond the traditional four walls, and students should be producers of content, rather than merely passive acceptors of information. This article explains how several emerging technologies were implemented and tested in a General Education marine science course for non-majors, describes the role of technologies in "flipping" the classroom, and summarizes student feedback on the learning experience. Using the global marine system and specific case study locations, the course covered major oceanography disciplines, critical environmental issues, and socio-economic conditions of urbanized coastal regions. Environmental sustainability was the integrative theme, highlighting the importance of economic growth while emphasizing that environmental responsibility and social well being must be foregrounded in the context of an exponentially growing human population.

Flipping the classroom using emerging technologies supplemented a rigorous schedule of project-based learning, laboratory activities, field excursions, and civic engagement commitments. Pre- and post- SALG surveys (Student Assessment of Their Learning Gains) were used to gauge student perspectives on the course redesign. They demonstrated improvements in knowledge, skills development, and integration of learning. The combination of activity-based, student-centered learning and emerging technologies make today's STEM education classroom an exciting, interactive, and engaging experience by giving these sometimes reluctant students the tools they need to succeed in tomorrow's professional world

Introduction

A scientifically educated citizenry capable of innovation and leadership is a necessity for a functioning democracy. Many of today's learners, however, are ambivalent about science and science education, and they lack understanding of how science relates to their daily lives (Burns 2011; Burns 2012;

Green 2012). While today's learners have been surrounded by technologies in the classroom throughout their entire academic journey, many lack the skills necessary to apply their learning and to produce content and are still passive acceptors of information. Educators now have a responsibility and the opportunity to introduce "high-impact educational practices" into curricular redesigns (Kuh 2008). A host of innovative teaching strategies in STEM education have emerged (Springer et al. 1999; Vatovec and Balser 2009; Brown et al. 2010; Prunuske et al. 2012; Green 2012) that can engage reluctant students, increase critical thinking abilities, foster collaborative relationships in the classroom, and enhance communication skills (oral, written, and digital). Matching appropriate emerging technologies with effective teaching practices (Brill and Park 2008) and gathering feedback on these STEM course redesigns is imperative as we continue to enhance our curricula.

With the advance of academic technologies, many educators have embraced the "hybrid" course design (Garrison and Kanuka 2004; McGee and Reis 2012). Hybrid courses (or blended course designs) are those in which a significant amount of quality online content is used to engage students (McGee and Reis 2012) while providing new teaching opportunities for educators (McGee and Diaz 2007; Brown et al. 2010; Green 2012). Modern learners have been called "digital natives," while today's educators have been named "digital immigrants," but that terminology has generated some debate (Prensky 2001a and 2001b; Toledo 2007; Bennett et al. 2008). Although educators and learners may speak different languages in relation to technology and have different comfort levels regarding its use, it is easy to see the potential of hybrid course design for today's multi-tasking, quick information-seeking, and media-socialized students. Using emerging technologies facilitates activity-based learning and provides students with ownership of the learning environment (Brill and Park 2008; Strayer 2012; Prunuske et al. 2012). Connecting sound pedagogical strategies with suitable technology usage creates a learning environment that matches the needs of modern learners, while providing them with the skills they need to succeed in their professional careers.

Inverting the teaching sequence, or "flipping" the classroom, has gained significant attention in recent years (Lage et al. 2000; Milman 2012; Strayer 2012; Khan 2012; Prober and Khan 2013). Essentially, traditional lecture-type material is provided to students in video or online format before face-to-face sessions. Then, during the face-to-face meetings, students are engaged in social-learning scenarios that promote interactions, engagement, and skills development by applying their knowledge. The role of the instructor changes and, in many ways, resembles an "academic coach" during the learning process rather than an "information presenter." Figure 1 outlines the course design conceptual model used in this curriculum redesign, which employed web-based reusable learning objects that students used before class sessions, so that

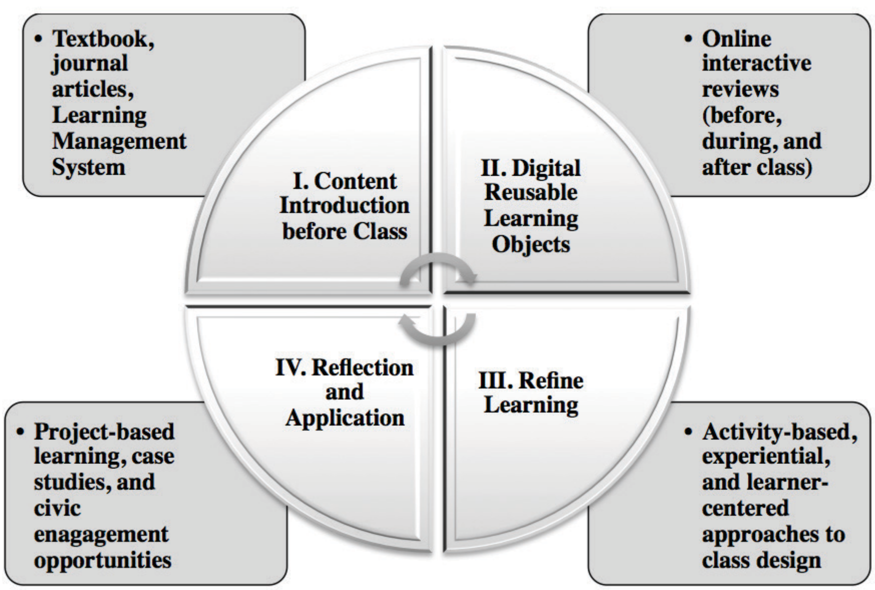


FIGURE 1. A conceptual model of the "flipped classroom" scenario used in the course redesign is depicted. Before attending face-to-face sessions, students are expected to read introductory content, which includes both traditional readings and interactive web-based activities. During face-to-face class sessions, students engage in learner-centered approaches, including activity-based labs and experiential learning opportunities. By implementing combinations of project-based learning, case study analyses, and civic engagement strategies, students apply their learning, demonstrate higher-order thinking skills, and produce content that ultimately benefits the needs of the regional community.

experiential and activity-based learning activities could be conducted during face-to-face sessions. Reflective exercises and activities, like project-based and service-learning activities, are high-impact learning opportunities that promote academic responsibility and civic engagement. Using emerging technologies to "flip the course" provided the curricular flexibility to implement these innovative teaching strategies.

"Marine Systems" is an introductory general education science course for non-science majors that has traditionally been taught as a lecture-based course with embedded laboratory exercises. This paper describes a curriculum redesign that used a "flipped" course model, learner-centered approaches, and embedded service-learning opportunities, and it provides student perspectives on the learning process. The use of emerging technologies in the curriculum facilitated the course delivery, so that students developed an understanding of ecology and its relevance to their daily lives, increasing their civic engagement and awareness (fig. 2). The primary goals of this course redesign were

1. To enhance the educational experiences of non-major science students by engaging in learner-centered approaches and web-based techniques;
2. To demonstrate the potential pedagogical benefits of coupling emerging technologies with innovative teaching practices in a STEM education setting;
3. To assess student perspectives of their learning gains related to their adoption of emerging technology in a "flipped classroom" scenario.

Methods

The course redesign began by linking course objectives and learning outcomes to a "Guiding Question" which reads:

> "Given the current degree of human impacts on the marine world, how can tomorrow's generations of all inhabitants continue to benefit from the natural goods and services a healthy marine system provides, if we better understand *our* role as citizens *today*?"

From this follows the "Primary Course Objective" for this course:

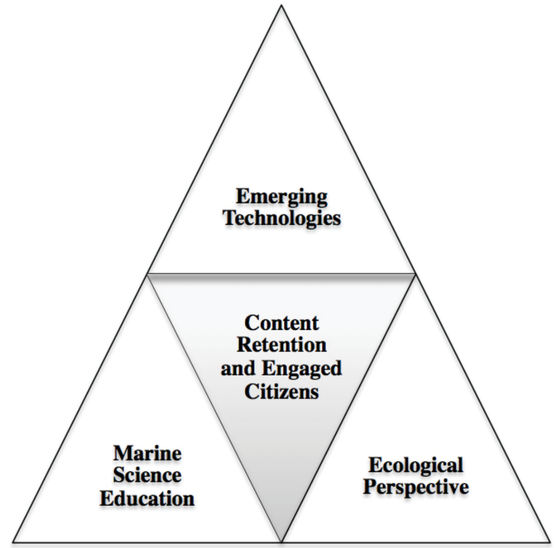


FIGURE 2. By using emerging technologies to facilitate the learning process, students gain an ecological perspective related to the marine science concepts they are introduced to. This helps them retain information and connect it to their daily lives, and, following successful completion of the course and civic engagement activities, they leave as engaged citizens.

> "Students will be able to positively influence both southwest Florida and global communities in making evidence-based decisions regarding human use and impacts of coastal and marine areas / resources."

Lastly, the specific learning outcomes and skills development objectives are

1. To enhance baseline scientific knowledge relating to marine systems and global sustainability by developing critical thinking skills;
2. To gain an understanding of the ecology of regional ecosystems, the natural goods and services provided by these ecosystems, and how human interactions disrupt natural functions;
3. To introduce the concept of environmental sustainability and provide opportunities for students to apply this concept to practical real-life situations in an urbanized society.

Learner-centered Approaches

A variety of learner-centered approaches (experiential learning and project-based learning) were used to enhance student practice, learning, and contributions to the learning environment (fig. 3). Combinations of classroom and field-based learning exercises were used to describe the scientific method, to help explain key oceanographic concepts, and to provide encounters with local estuarine ecosystems. Students were given ownership of academic exercises, while the instructor facilitated, guided, and reinforced crucial learning content. Table 1 explains the calendar of individual learning modules with associated major academic themes and objectives. Multiple sources of information including the textbook, scientific journal articles, lab exercises, and personal observations were used. The textbook provided background information, while journal articles examined current issues and explored topics such as ocean acidification, human impacts, overexploitation of marine resources, and global climate change. Learner-centered laboratory exercises applied textbook concepts and provided a collaborative, activity-based learning environment. A reflective journal provided opportunities for student observations and personal reflections on the learning process. Field excursions engaged student interest by exploring coastal ecosystems and assisted with the understanding of ecosystem structure and function, coastal development, and marine research. The capstone project reinforced all class activities by relating environmental sustainability to the socio-economic and environmental issues previously explored. Civic engagement opportunities helped students leave the course as engaged citizens who are willing to apply their knowledge to meaningful projects that benefit our local informal science education partners.

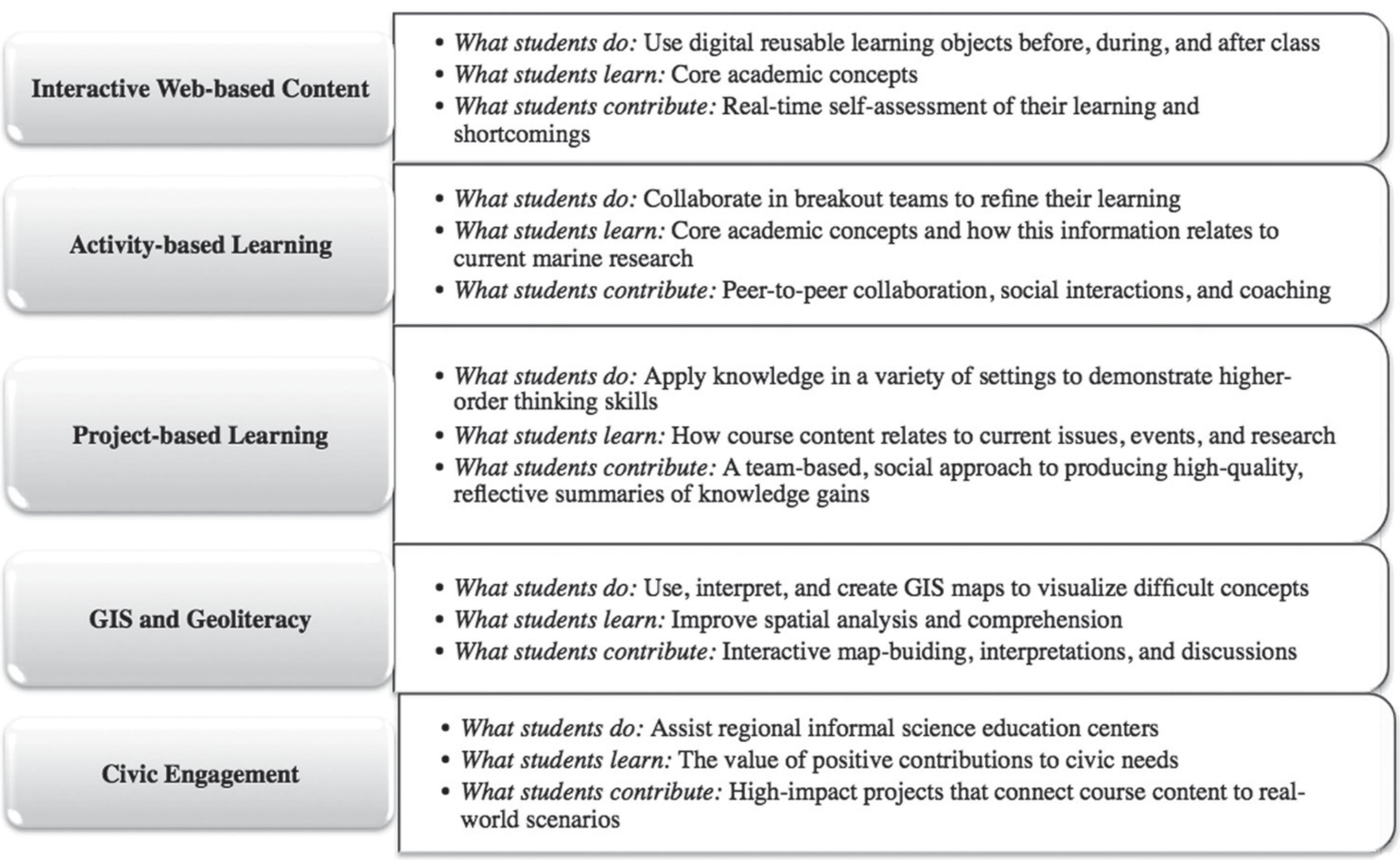


FIGURE 3. Mapping teaching strategies used within the course design to student practice, learning, and contributions to the learning environment.

TABLE 1. Calendar of "learning modules" that explains major academic themes and objectives.

MODULE	THEME	OBJECTIVES
1	Introduction to course	To build a foundation for the course To introduce concepts related to environmental sustainability
2	Thinking like a scientist	To enhance scientific research skills and evidence gathering To review the scientific method To increase communication, collaboration, and critical thinking skills
3	Marine Geology	To understand Earth's dynamic past
4	Marine Chemistry	To introduce seawater properties, ocean acidification, and biogeochemical cycles
5	Physical Oceanography	To explain the coupling of marine and atmospheric processes
6	Marine Ecology	To explain ecosystem structure and functions To provide interactions with regional ecosystems
7	Current issues and human impacts on the marine world	To understand exponential human population growth and consequences for natural goods and services To explore issues related to global climate change and likely impacts To explore environmental sustainability and marine conservation plans To increase geo-literacy skills
8	Civic engagement	To relate course content to students' daily lives To provide service to regional informal science educators To enhance coastal areas for future

Virtual "Oceanographic Research Cruise" Capstone Project

Teams of students "virtually participate" in an oceanographic research expedition that visits a particular location of geological importance on the planet. The task reads: "You have been assigned positions aboard an oceanographic vessel exploring the far reaches of the planet! Your crew will arrive at a marine destination to use as your case study. At this location, your crew will explore and research the factors shaping the region as related to the information you learn in this class. At the end of your 'research cruise,' crews will present at our 'Oceanographic Exploration and Research Collection Symposium!' Collectively, we will explore the globe in its entirety, learning about the marine systems worldwide! You will incorporate concepts related to physical and chemical oceanography, marine geology, and marine ecology into your learning adventure!" The final project is submitted via a student-created webpage that summarizes the team's virtual research expedition. The primary intention is to apply course content and learning in a social setting to a specific location that is unique to each team of students.

Ecosystems Visit Field Study and Formal Lab Report

In class, small groups of students chose a theme to investigate for a field research project. At this point, students brainstormed the parameters of the theme and arrived at a research question, formulating a testable hypothesis and designing an experiment to test their hypothesis. The instructor facilitated discussions and helped students choose gear that was needed for the field studies. Each student group created their own study and all groups worked their way through the scientific method during this project. At a field location, students collected their data and replicated their studies in multiple locations. Students created a formal lab report (complete with Excel graphs, figures, and tables) that summarized their research. Major academic concepts covered in this project included

1. Natural Goods and Services

2. Ecosystem Structure and Function
3. Water Quality
4. Limiting Factors
5. Beach Profiles
6. Flora and Fauna Analyses
7. Estuarine Ecosystems Ecology
8. Intertidal Zone, Beaches, and Dunes Evaluation
9. Coastal Urbanization and Habitat Loss
10. Environmental Sustainability
11. Land Ethic and Wilderness Values
12. Marine Conservation

Students were given ownership of this exercise from start to finish, and they explored the natural world the way a scientist would by applying their previous learning to real-world research opportunities.

Human Impacts Project

Breakout groups were formed, and each group was assigned a topic related to a human impact on the marine environment. Phase I ("Background Explorations—A Literature Scavenger Hunt") included a literature review, where each group located peer-reviewed journal articles related to their topic. From this research, the breakout group synthesized a definition of the impact, explained why it is a problem in the context of an exponentially-growing human population, and described how future decisions should be made differently to improve the situation related to the negative human impact. During Phase II of the project ("From Jigsaw to Podcast"), new groups were formed so that each new group contained students who researched a different human impact during the first phase (similar to a "jigsaw" method of teaching). Students now assumed the role of "expert" for their original topic and they had to teach the new group about that human impact. Once the students had explained their synthesis from Phase I, the new group created an educational podcast script that was three minutes in length and appropriate for an audience of middle-school-aged children. To create the script, students had to summarize all of the human impact topics represented in their new group by answering the following questions:

1. What is the size of the current human population and what is meant by exponential population growth?
2. What are examples of modern-day human influences on the marine world?
3. How and why are these human impacts a problem for the marine world under the context of an exponentially growing human population?
4. Explain what humans can do differently in regard to future decisions made about ocean impacts.

This project helps students critically examine scientific research, use higher-order thinking skills, and produce educational content for a younger generation.

High-impact Learning Opportunities: Service-learning Projects and Civic Engagement

Partnering with regional informal science education centers, students assisted with tasks that met community needs by participating in field-based service-learning projects. These projects allowed students the opportunity to visualize previous human impacts on coastal ecosystems and mitigate the damage. Using "prompt" questions, students reflected on their experience in a written deliverable that connected their service-learning experiences to their learning in the course and personal development. In previous iterations, students also delivered oral presentations with the regional partners in attendance. Serving the needs of the community and learning how to take a leadership role in civic engagement are the primary goals of this high-impact project.

Matching Emerging Technologies to Course Outcomes

A main focus of this course redesign was to match the use of appropriate technologies with non-traditional pedagogical strategies (table 2). Careful thought was given to the choice of technology in the course delivery and to desired outcomes. A description of the chosen technologies follows.

Reusable Learning Objects (RLOs): Traditional lecture sessions were replaced with web-based digital Reusable Learning Objects (RLO's) that were created by the instructor. These highly-interactive presentations with audio, animated figures, text, pictures, and illustrations

TABLE 2. The course redesign focused on matching appropriate emerging technologies with use in the curriculum and to Course Outcomes, so that non-traditional teaching strategies could be employed.

Emerging Technology	THEME	OBJECTIVES
Reusable Learning Objects	Replaces traditional lectures Real-time assessment	To use innovative teaching strategies that engage today's modern learner
GIS Mapping Software	Labs and discussions	To promote geo-literacy by using maps to facilitate comprehension and visualization of difficult concepts
Podcast Creation	Student-produced content to share with younger students	To enhance digital communication skills while learning about current human impacts
Webpage Design	Student-produced content summarizing the application of their knowledge as part of a capstone project	To enhance digital communication skills while applying knowledge to a particular case study location in a collaborative, team-based approach
Online Literature Reviews and Database Searching	Active searches of literature databases to support projects and assignments	To introduce the importance of peer-reviewed literature, the scientific method, and appropriate evidence-gathering strategies that help increase critical thinking skills
Twitter™ Discussions	Engages students outside of the classroom, between face-to-face sessions	To facilitate a social, interactive experience for students outside of the classroom
eTexts, Smartphones, and Tablet Computers	Makes all course content available to students at all times and places	To engage students in the learning process by using entertainment devices as pedagogical tools for content delivery

supplemented the curriculum and enhanced the experience of students by providing an interactive learning environment with real-time assessment and feedback.

GIS Mapping Software: A variety of Geographic Information Systems (GIS)-based learning opportunities were embedded within the course design. Students interpreted patterns they observed and improved their spatial analysis skills. They created their own maps of coastal ecosystems and water quality summaries by using handheld Global Positioning System (GPS) receivers and cloud-based GIS mapping software.

Podcasting: A podcast is an audio or video file that is broadcast over the internet. Following in-depth research on human impacts on the marine world, students created three-minute educational podcasts that are sharable with a younger audience.

Web 2.0 Tools (Weebly, Prezi, Blogs, etc.): Students used free Web 2.0 tools to create their own presentations and webpages. Using these tools, students went from passive acceptors of knowledge to active producers of learning content, which helped them utilize higher-order thinking skills.

Online Database Literature Searches: Students are expected to evaluate evidence and find reputable sources of scientific information. Peer-reviewed literature database searches were required throughout the course and exposed students to discipline-appropriate writing styles and the importance of the peer-review process.

A. FALL 2011 - "UNDERSTANDING" **B. SPRING 2012 - "UNDERSTANDING"**

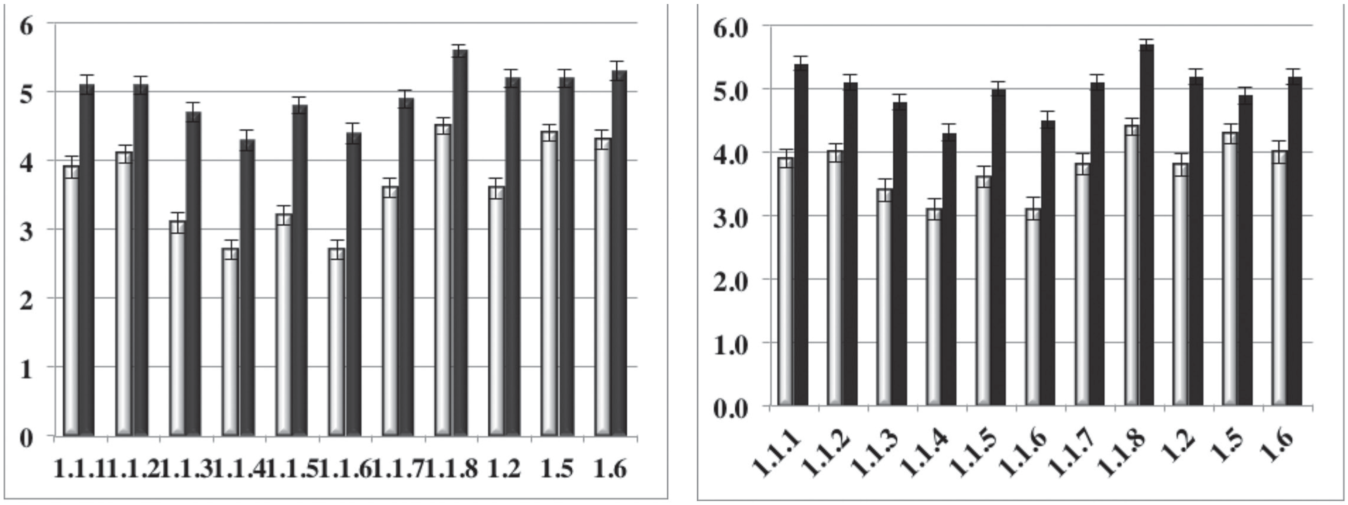


FIGURE 4. Pre- and Post- SALG survey results from two semesters comparing "Understanding of Core Academic Concepts." Question numbers on the x-axis can be cross-referenced with the actual questions in Table 3. Students responded with a 1–6 score, as illustrated on the y-axis (1 = N/A; 2 = Not at All; 3 = Just a Little; 4 = Somewhat; 5 = A Lot; 6 = A Great Deal). Mean and SE are reported ($n_{Fall\ 2011\ Pre}$: 69; $n_{Fall\ 2011\ Post}$: 59; $n_{Spring2012\ Pr}$e: 60; $n_{Spring2012\ Post}$: 58).

Twitter™ Discussions: Twitter™ is a social networking system designed for quick comments and interactions. Students engaged in out-of-classroom discussions that followed face-to-face sessions and introduced upcoming class topics.

eTexts, Smartphones, and Tablet Computers: A variety of hardware choices by students facilitated the learning process. Our classroom was not conceptualized as a four-walled room with desks, but instead reached far beyond the traditional setup and allowed for real-time explorations of internet content and just-in-time teaching moments related to current events. While all course components are currently available for use on a tablet or computer via the learning management system, not all students own such a device, and any hardware choice by the student was acceptable.

SALG Survey and Data Analysis (Methods)

A Pre- and Post- Student Assessment of Learning Gains (SALG) survey was conducted to gain anonymous student perspectives on the course redesign. Students from single course, in each of two different semesters, was included in this analysis. Surveys included questions related to Knowledge, Skills, and Integration of Learning. Mean scores with Standard Errors were calculated for each question and compared across semesters. Table 3 displays the questions used in the SALG surveys. Because students withdraw from classes during the semester, the pre- and post- surveys have slightly different sample sizes. Results from the SALG surveys allowed for omnibus comparisons and cross-semester evaluations. Students were given an opportunity for free-write responses, as well, though those comments are not included in this manuscript.

Results

During the Fall 2011 semester, 77% of students self-reported GPA's > 3.01 and 92% stated they were non-science majors ($n_{Fall\ 2011\ Pre}$: 69; $n_{Fall\ 2011\ Post}$: 59). During the Spring 2012 semester, 52% of students self-reported GPA's > 3.01 and 95% stated they were non-science majors ($n_{Spring2012\ Pre}$: 60; $n_{Spring2012\ Pos}$t: 58).

Students responded to questions designed to measure their own perception of their understanding of core academic content (table 3—"Understanding" section). Across semesters, similar trends emerged. Students entered the course at or near the "Somewhat" comfortable level with their understanding of core academic concepts in all measured categories; students in both classes left the course

TABLE 3. An overall summary of the SALG Survey questions ($n_{Fall\ 2011\ Pre}$: 69; $n_{Fall\ 2011\ Post}$: 59; $n_{Spring2012\ Pre}$: 60; $n_{Spring2012\ Post}$: 58). Students chose from the following responses for each question:
1: N/A 2: Not at All 3: Just a Little 4: Somewhat 5: A Lot 6: A Great Deal

Number	Question	N Pre total	Mean Pre total	N Post total	Mean Post total
	UNDERSTANDING				
1	Presently, I understand...				
1.1	The following concepts that were explored in this class				
1.1.1	Sustainability	129	3.900	117	5.249
1.1.2	Natural Goods and Services	129	4.053	117	5.100
1.1.3	Marine Geology	129	3.240	117	4.750
1.1.4	Marine Chemistry	129	2.886	117	4.300
1.1.5	Physical Oceanography	129	3.386	117	4.899
1.1.6	Chemical Oceanography	129	2.886	117	4.450
1.1.7	Marine Biology / Ecology	129	3.693	117	4.999
1.1.8	Human impacts on the marine environment	129	4.453	117	5.650
1.2	The relationships between those main concepts	129	3.693	117	5.200
1.3	How ideas we explored in this class relate to ideas I have encountered in other classes within this subject area	129	3.953	117	4.550
1.4	How ideas we explored in this class relate to ideas I have encountered in classes outside of this subject area	129	3.707	117	4.602
1.5	How studying this subject helps people address real world issues	129	4.353	117	5.051
1.6	How civic engagement activities help connect course content to real-world scenarios	129	4.160	117	5.250
1.7	Please comment on how civic engagement activities (podcast scripts for middle schoolers, Bunche Beach salt flats service and reflection) impacted your learning.	.	.	.	.
	SKILLS				
2	Presently, I can...				
2.1	Find articles relevant to a particular problem in professional journals or elsewhere	129	4.200	117	5.200
2.2	Critically read articles about issues raised in class	129	4.300	117	5.000
2.3	Identify patterns in data	129	4.247	117	5.000
2.4	Recognize a sound argument and appropriate use of evidence	129	4.347	117	4.950
2.5	Develop a logical argument	129	4.553	117	4.999
2.6	Write documents in discipline-appropriate style and format	129	4.200	117	4.999
2.7	Work effectively with others	129	5.353	117	5.350
2.8	Prepare and give oral presentations	129	4.493	117	5.050
2.9	Read and interpret maps	129	4.600	117	5.050
2.10	Use GPS handheld devices to collect data	129	4.233	117	4.649
2.11	Interpret GIS images	129	2.879	117	4.448
2.12	Explain the skills this class helped you develop.	.	.	.	.
	ATTITUDES				
3	Presently, I am...				
3.1	Enthusiastic about the subject	129	4.474	117	4.301

TABLE 3 (CONTINUED). An overall summary of the SALG Survey questions ($n_{Fall\ 2011\ Pre}$: 69; $n_{Fall\ 2011\ Post}$: 59; $n_{Spring2012\ Pre}$: 60; $n_{Spring2012\ Post}$: 58). Students chose from the following responses for each question:
1: N/A 2: Not at All 3: Just a Little 4: Somewhat 5: A Lot 6: A Great Deal

Number	Question	N Pre total	Mean Pre total	N Post total	Mean Post total
3.3	Interested in taking or planning to take additional classes in this subject	129	3.467	117	3.651
3.4	Confident that I understand the subject	129	3.753	117	4.600
3.5	Confident that I can do this subject	129	4.653	117	4.600
3.6	Comfortable working with complex ideas	129	4.253	117	4.601
3.7	Enthusiastic about activity-based learning	129	4.821	117	4.800
3.8	Enthusiastic about project-based learning	129	4.353	117	4.650
3.9	Willing to seek help from others (teacher, peers, TA) when working on academic problems	129	4.914	117	4.900
3.10	Please comment on your present level of interest in this subject.	.	.	.	.
3.11	Please explain how project-based learning impacted your learning in this class.	.	.	.	.
	INTEGRATION OF LEARNING				
4	Presently, I am in the habit of...				
4.1	Connecting key ideas I learn in my classes with other knowledge	129	4.407	58	4.700

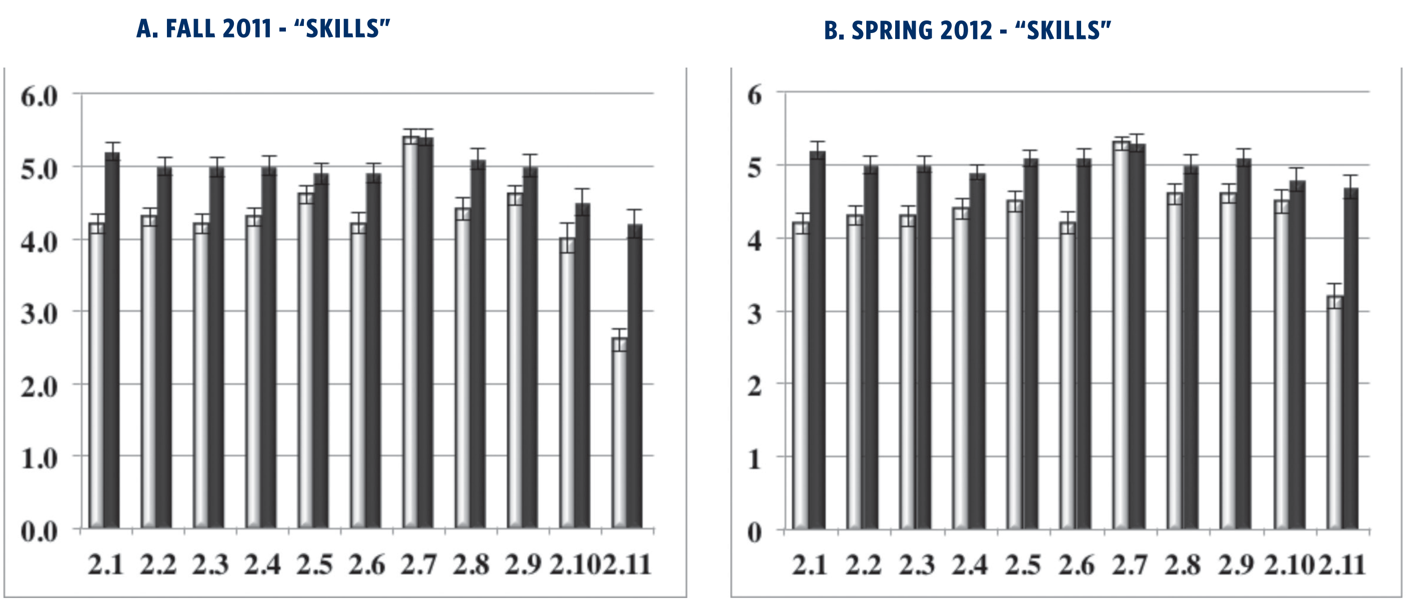
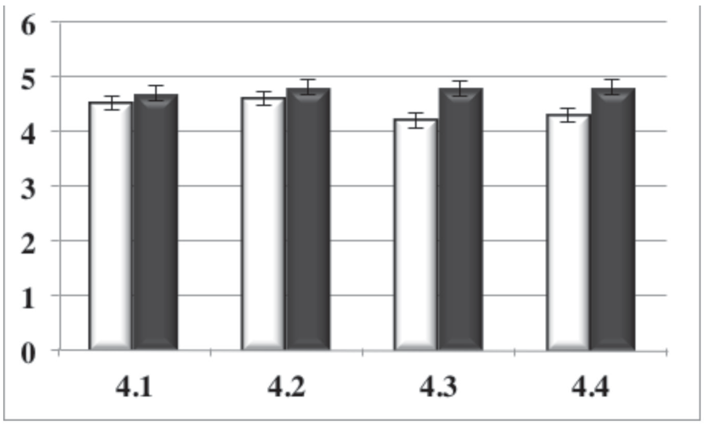


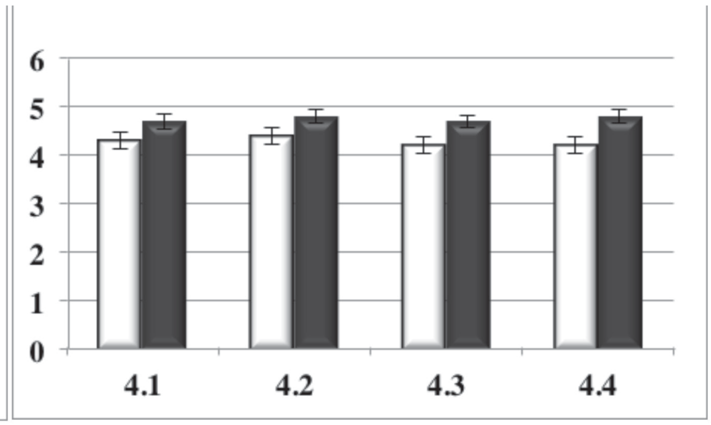
FIGURE 5. Pre- and Post- SALG survey results from two semesters comparing "Skills Development." Question numbers on the x-axis can be cross-referenced with the actual questions in Table 3. Students responded with a 1–6 score, as illustrated on the y-axis (1 = N/A; 2 = Not at All; 3 = Just a Little; 4 = Somewhat; 5 = A Lot; 6 = A Great Deal).
Mean and SE are reported ($n_{Fall\ 2011\ Pre}$: 69; $n_{Fall\ 2011\ Post}$: 59; $n_{Spring2012\ Pre}$: 60; $n_{Spring2012\ Post}$: 58).

FIGURE 6. Pre- and Post- SALG survey results from two semesters comparing "Integration of Learning." Question numbers on the x-axis can be cross-referenced with the actual questions in Table 3. Students responded with a 1–6 score, as illustrated on the y-axis (1 = N/A; 2 = Not at All; 3 = Just a Little; 4 = Somewhat; 5 = A Lot; 6 = A Great Deal). Mean and SE are reported ($n_{Fall\ 2011\ Pre}$: 69; $n_{Fall\ 2011\ Post}$: 59; $n_{Spring2012\ Pre}$: 60; $n_{Spring2012\ Post}$: 58).

A. FALL 2011 - "INTEGRATION OF LEARNING"



B. SPRING 2012 - "INTEGRATION OF LEARNING"



feeling "A Lot" to "A Great Deal" more comfortable with their own understanding of core academic concepts (fig. 4).

Students responded to questions designed to measure their own assessment of "Skills Development" (table 3—"Skills" section). Across semesters the data indicated that students entered the course at or near the "Somewhat" comfortable level with their perceptions of skills development; students in both classes left the course feeling "A Lot" to "A Great Deal" more comfortable with their own perceptions of skills development (fig 5). One specific skill ("Work Effectively with Others") displayed no change in the pre- and post- surveys in either the Fall 2011 or Spring 2012 semesters (fig. 5).

Embedded within this course were opportunities for civic engagement, GIS exercises to enhance geospatial analysis skills, and collaborative learning experiences for students. The omnibus dataset (table 3) reveals that students showed a strong increase in their understanding of how civic engagement activities help connect course content to real-world scenarios ($Mean_{Pre}$ = 4.160 vs. $Mean_{Post}$ = 5.250). GIS and geoliteracy skills were enhanced as students demonstrated a strengthened skillset related to their abilities to interpret GIS images to identify patterns ($Mean_{Pre}$ = 2.879 vs. $Mean_{Post}$ = 4.448). Student attitudes remained neutral toward activity-based learning ($Mean_{Pre}$ = 4.821 vs. $Mean_{Post}$ = 4.800). However, student perspective related to project-based learning displayed an increase ($Mean_{Pre}$ = 4.353 vs. $Mean_{Post}$ = 4.650).

Helping students integrate their new knowledge is an important goal in a general education course and is a key factor in matching teaching strategies to student practice, learning, and contributions to the learning environment (fig. 3). Students were asked if they were in the habit of connecting key ideas they learn in their classes with other knowledge, of applying what they learn in classes to other situations, of using systematic reasoning in their approach to problems, and of using a critical approach to analyzing data and arguments in their daily lives (table 3—"Integration of Learning" section). Learner perspectives showed an increase in each of these four categories related to the student integration of learning (fig. 6 and table 3 – "Integration of Learning" section).

Discussion

Spatially and technologically, tomorrow's classroom will be very different from today's, and the academic tools used in it may not yet even exist (McGee and Diaz 2007; Green 2012; Bolduc-Simpson and Simpson 2012). Yet we currently have many opportunities to engage modern learners with a variety of innovative strategies (Kuh 2008) and learner-friendly technological devices. We must continue to evaluate and assess the incorporation of emerging technologies into curricula redesigns, to ensure their academic soundness and their effectiveness in increasing student engagement. Entry-level STEM courses, like the one described in this article, provide us with the opportunity to transform the science education experience for reluctant learners (Green 2012).

Brundiers et al. (2010) stated the importance of embedding "real-world learning opportunities" into general education courses with an environmental sustainability focus. Overall, students responded favorably to project-based learning in this course redesign. When performing their own assessments, students clearly indicated an increased confidence in their learning gains. Increased skills development (critical thinking, communication, collaborative learning, and social interactions), which contributes to career and professional readiness, was demonstrated, as was an increase in integrating course content by connecting information gained in this course to other knowledge. Likewise, students perceived an increase in their ability to connect their knowledge gains from this class to other situations. In using the scientific method as a guide, students verified that they now are beginning to use systematic reasoning in their approaches to problem solving. Consistent with previous studies, students associated with this course redesign began to understand how civic engagement activities help connect course content to real-world scenarios that made course material relevant to them (Jacoby 2009; Green 2012).

While this course redesign was successful in many ways, it is important to recognize that not every student responds favorably to an inverted classroom design supported by technology. Most students are accustomed to note-taking during a traditional lecture, and any alteration to this structure makes some students uncomfortable. While these changes may not excite a student (as indicated in SALG Attitudes question about activity-based learning), other data presented in this paper show that learning did indeed take place. It is equally important to recognize that not all students learn in the same way, and some may not respond positively to non-traditional teaching strategies. This, however, is true of any teaching method, and it remains the responsibility of the instructor to adjust, assist, and guide each individual learner in the classroom, as needed. The instructor must also remember that learning happens at different paces, and that some students respond slowly to independent learning strategies that differ from their traditional classroom experiences, especially if they lack self-motivation. There are access issues with technology that must be understood by the instructor (i.e. costs, lack of ownership, etc.). Some students lack digital skills, and we must not assume that all have the same knowledge and experience when it comes to using digital tools, software, and hardware. Indeed, Toledo (2007) states that not all students are interested in a technologically-immersed learning environment, regardless of age or exposure. While the challenges listed here are not prohibitive, they must be understood for a successful course redesign aimed at increasing student engagement in the learning process.

In this study, emerging technologies proved to be an effective complement to the curriculum. Student responses generally showed an increase in learning and an increased confidence in subject matter as a result of the flipped classroom model that used emerging technologies as a teaching supplement. Classrooms tended to be lively, with animated students who were actively producing content. This is a much different scene from a traditional classroom with slideshows, dimmed lights, and quiet students taking notes. Thanks to the increased opportunities for one-on-one interactions during the face-to-face class time, struggling students were identified early in the learning process and assisted with their skills development and knowledge gains. This is consistent with Prunuske et al. (2012), who stated that they were able to spend more classroom time assisting students with higher-order learning development.

Using an inverted classroom delivery model required that the role of the instructor be modified into that of an academic facilitator, one who actively guides, rather than one who spouts information from the front of the room. Because self-motivated students were essential to the success of the course, there were challenges. "Borderline chaos" was tolerated in this active-learning scenario, yet the student energy was harnessed and used in a positive manner. Typically, breakout groups of students worked independently while the instructor circulated through the classroom. As a result, there was less reliance on slideshows and formal lectures. Instead, discussions, interactive exercises, and activity-based learning opportunities were emphasized, to promote student engagement and concept retention. Students must still be provided with proper guidance that includes "cognitive presence, teacher presence, and social presence" (Garrison and Cleveland-Innes 2005). Extra time and care should be given by the instructor to explain the new teaching methods, why they are important to the students, and what the learning outcomes are. Innovative teaching methods aside, best practices in teaching must be continued, which means that, regardless of pedagogical strategies, traditional study skills still need to be emphasized for proper learner development. (Brill and Park 2008; McGee and Reis 2012).

Many students have some underlying interest in the course on the first day, yet these same students may have had earlier experiences in science classes that alienated them. Some arrive with preconceived notions about what science is and isn't. This interrupts their learning until the instructor can find ways to break through these barriers and reach the learner. Connecting textbook material with real world scenarios, case studies, and interactive exercises promotes stronger interest in the learning process and provides students with ownership of the class. Service-learning projects make students feel a sense of pride and accomplishment by directly serving the needs of regional organizations. Reaching reluctant learners and exciting them about science is an embraceable challenge that can be accomplished through the right mix of teaching methods and curricula design (Strayer 2012).

Learner-centered approaches to teaching were employed that relied upon innovative web-based techniques. By matching appropriate emerging technologies with learning outcomes in a STEM education classroom for non-science majors, reluctant students were reached and excited; these students were able to connect course content to other classes and to their daily lives, making their experience relevant and worthwhile. Gaining insight from students about the academic experience by understanding their perspectives is important as faculty experiment with new teaching strategies. To promote best practices in teaching, assessing learning gains and demonstrating student successes is an important follow-up for faculty members who experiment with non-traditional teaching methods and approaches. The incorporation of emerging technology into the course redesign allowed students to engage in a variety of learner-centered approaches designed to increase their knowledge, skills, and integration of learning. While students were neutral in their feelings toward activity-based learning, they displayed an increase in their enthusiasm toward project-based learning, which indicates that a successful social and collaborative learning environment was established with this course redesign. Student spatial skills were enhanced through the use of GIS mapping exercises and academic content was connected to their daily lives via a service-learning project at a coastal salt marsh, indicating student uses of higher-order thinking skills (Bloom 1956; Fink 2003). Our current students are our future decision-makers and leaders. It is vital to give them the tools they need to be well-rounded professionals who are educated and technologically advanced, and who approach their lives with ecological perspectives. As faculty members, it is our responsibility to ensure the teaching strategies we employ are as advanced and innovative as possible. Taking the time to understand the student perspective on innovative course redesigns can enable us to enhance the learning environment for all and might just help us save some of those reluctant science students.

Acknowledgements

A SENCER Post-Institute Implementation Award and an FGCU General Education Council Course Redesign Faculty Award helped fund this project. The authors wish to thank Douglas Spencer, Jessica Rhea, Mike Savarese, Donna Henry, Elspeth McCulloch, Aswani Volety, and the "Tablet Computer Teaching Cell" at FGCU. Terry Cain, Lee County Parks and Recreation, and the Conservation 2020 Program assisted with civic engagement projects and field excursion logistics. Finally, many thanks to the "Students-as-Partners" who make this work possible and worthwhile! This study was completed at Florida Gulf Coast University before the lead author moved to the University of Miami.

About the Authors

David Green is an Instructional Designer for the Academic Technologies department at the University of Miami, where he is responsible for consulting with, guiding, and supporting faculty in the design and delivery of technology-enhanced courses and co-curricular activities. He is responsible for helping to design, develop, and implement the "Cane Academy," which is a new initiative at the UM Miller School of Medicine to "flip the classroom" using short instructional videos coupled with companion assessment exercises. As a SENCER Leadership Fellow, he authored a SENCER Model Course and has retrofit multiple university-level classes using the SENCER approach to pedagogy, assessed student response and engagement to the course redesigns, and helped recruit new faculty members to the program.

Jennifer Sparrow is the Senior Director for Teaching and Learning Technology (TLT) at Penn State University. TLT works to help PSU faculty take advantage of information technology to enrich the educational experiences of their students and to champion the creative and innovative uses of technology for teaching, learning, and research. She was previously Senior Director of Networked Knowledge Ventures and Emerging Technologies at Virginia Tech. For more than 15 years, she has championed the use of technology to engage students in the learning process. She has a passion for working with faculty to explore new technologies and their potential implementations in teaching and learning. She loves working with faculty who are willing to push the boundaries of the leading edge of technology in teaching, learning, and research. Her current projects involve the convergence of technologies and learning spaces to create interactive and engaged learning opportunities. Jennifer's conversations around technology focus on increasing digital fluency for students, faculty, and life-long learners.

References

Bennett, S., K. Maton, and L. Kervin. 2008. "The 'Digital Natives' Debate: A Critical Review of the Evidence." British Journal of Educational Technology 39 (5): 775–786.

Bloom B.S. 1956. Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain. New York: David McKay Co., Inc.

Bolduc-Simpson, S., and M. Simpson. 2012. "Social Places in Virtual Spaces: Creating a Social Learning Community in Online Courses." Distance Learning for Educators, Trainers, and Leaders 9 (3): 33–42.

Brill, J.M., and Y. Park. 2008. "Facilitating Engaged Learning in the Interac-tion Age: Taking a Pedagogically-disciplined Approach to Innovation with Emergent Technologies." International Journal of Teaching and Learning in Higher Education 20 (1): 70–78.

Brown, M., M. Auslander, K. Gredone, D.P.J. Green, B. Hull, and W. Jacobs. 2010. "A Dialogue for Engagement." EDUCAUSE Review 45 (5): 38–56.

Brundiers, K., A. Wiek, and C.L. Redman. 2010. "Real-world Learning Opportunities in Sustainability: From Classroom into the Real World." International Journal of Sustainability in Higher Education 11 (4): 308–324.

Burns, W.D. 2011. "But You Needed Me: Reflections on the Premises, Purposes, Lessons Learned, and Ethos of SENCER—Part 1." Science Education and Civic Engagement: An International Journal 3 (2): 5–12.

———. 2012. "But You Needed Me: Reflections on the Premises, Purposes, Lessons Learned, and Ethos of SENCER—Part 2." Science Education and Civic Engagement: An International Journal 4 (1): 6–13.

Fink, L.D. 2003. Creating Significant Learning Experiences. San Francisco: Jossey Bass.

Garrison, D.R., and H. Kanuka. 2004. "Blended Learning: Uncovering Its Transformative Potential in Higher Education." Internet and Higher Education 7 (2): 95–105.

Garrison, D.R., and M. Cleveland-Innes. 2005. "Facilitating Cognitive Presence in Online Learning: Interaction Is Not Enough." The American Journal of Distance Education 19 (3): 133–148.

Green, D.P.J. 2012. "Using Emerging Technologies To Facilitate Science Learning and Civic Engagement." Science Education and Civic Engagement: An International Journal 4 (2): 18–33.

Jacoby, B. 2009. Civic Engagement in Higher Education: Concepts and Practices. San Francisco: Jossey-Bass.

Khan S. 2012. The One World School House: Education Reimagined. New York: Twelve.

Kuh, G.D. 2008. High Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter. Washington, D.C.: Association of American Colleges and Universities.

Lage, M.J., G.J. Platt, and M. Treglia. 2000. "Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment." The Journal of Economic Education 31 (1): 30–43.

McGee, P., and V. Diaz. 2007. "Wikis and Podcasts and Blogs! Oh My! What Is a Faculty Member Supposed To Do?" EDUCAUSE Review 42 (5): 28–40.

McGee, P., and A. Reis. 2012. "Blended Course Design: A Synthesis of Best Practices." Journal of Asynchronous Learning Networks 16 (4): 7–22.

Milman, N.B. 2012. The Flipped Classroom Strategy: What Is It and How Can It Be Used?" Distance Learning for Educators, Trainers, and Leaders 9 (3): 85–87.

Prensky, M. 2001a. "Digital Natives, Digital Immigrants Part 1." On the Hori¬zon 9 (5): 1–6.

———. 2001b. "Digital Natives, Digital Immigrants Part 2: Do They Really Think Differently?" On the Horizon 9 (6): 1–6.

Prober, C.G., and S. Khan. 2013. "Medical Education Reimagined: A Call to Action." Academic Medicine 88 (10): 1407–1410.

Prunuske, A.J., J. Batzli, E. Howell, and S. Miller. 2012. "Using Online Lectures To Make Time for Active Learning." Genetics Education 192: 67–72.

Springer, L., M.E. Stanne, and S.S. Donovan. 1999. "Effects of Small-group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-analysis." Review of Educational Research 69 (1): 21–51.

Strayer, J.F. 2012. "How Learning in an Inverted Classroom Influences Cooperation, Innovation, and Task Orientation." Learning Environments Research: An International Journal 15: 171–193.

Toledo, C.A. 2007. "Digital Culture: Immigrants and Tourists Responding to the Natives' Drumbeat." International Journal of Teaching and Learning in Higher Education 19 (1): 84–92.

Vatovec, C., and T. Balser. 2009. "Podcasts As Tools in Introductory Environmental Studies." Journal of Microbiology and Biology Education 10: 19–24.