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Flipped Instruction in a High School Science Classroom

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Abstract This paper reports on a quasi-experimental study examining the effectiveness of flipped instruction in a 9th grade biology classroom. This study included four sections of freshmen-level biology taught by the first author at a private secondary school in the Pacific Northwest. Using a block randomized design, two sections were flipped and two remained traditional. The quiz and posttest data were adjusted for pretest differences using ANCOVA. The results suggest that flipped instruction had a positive effect student achievement, with effect sizes ranging from +0.16 to +0.44. In addition, some students reported that they preferred watching video lectures outside of class and appreciated more active approaches to learning.

Keywords Flipped instruction · Active learning · Secondary Biology

Introduction

Although secondary biology is typically taught through lecture and note-taking (Lyons 2013), there is widespread consensus among developmental psychologists (e.g., Piaget 1964) and educational theorists (e.g., Vygotsky 1978) that learning is optimized when students construct and negotiate meaning (Cavagnetto 2010). This notion is incredibly important for educators designing learning environments aligned with principles of evidence-based learning. Instead of being the "sage on the stage," teachers should support students to negotiate, construct, and debate the meaning of important scientific concepts and language.

With this basic notion in mind, many scholars have investigated flipped instruction. When the primary content is delivered outside of class, there is time and space in class for active learning. Although flipped approaches to instruction have improved science achievement, most of the existing researches have been conducted in undergraduate settings (e.g., Arnold-Garza 2014; Critz and Knight 2013; Enfield 2013; Missildine et al. 2013; Strayer 2012; Talley and Scherer 2013; Tune et al. 2013; Wilson 2013). This study aimed to produce more knowledge about using flipping instruction in secondary settings, specifically high school Biology.

Background

Flipped Instruction

Flipped instruction is not one instructional practice. It refers to a wide variety of instructional techniques that have been implemented differently by different researchers and educators. Typically, in flipped classroom instruction, content dissemination (lecture) is moved outside of the classroom to create more time for active learning inside the classroom. The in-class, active learning may include discussions (Critz and Knight 2013; Talley and Scherer 2013; Tune et al. 2013), individual or small group projects (Arnold-Garza 2014; Enfield 2013; Strayer 2012), teacher-led demonstrations (Enfield 2013), situational discussions (Critz and Knight 2013; Missildine et al. 2013), games (Missildine et al. 2013), problem sets (Wilson 2013), weekly reflection (Talley and Scherer 2013; Wilson 2013), free work time (Arnold-Garza 2014), and laboratory

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investigations (Go Teach 2011). Throughout the literature review, several positive and negative themes emerged as well as some practical advice for those teachers who are considering the flipped classroom approach.

Students who are involved in a flipped classroom seem to have an increased appreciation for group work, innovation, and feel more empowered to use new technology to find information on their own. Strayer (2012), who taught two sections of introductory statistics at a US university, asked this research question: "How does the learning environment of an inverted introductory statistics classroom compare with the learning environment of a more traditional lecture-homework introduction to statistics classroom?" (p. 172). To answer this question, he flipped one of his sections and did not flip his other section of the same class. He used a mixed methods approach in this study. Strayer found "significant differences between the traditional and flipped classrooms" (p. 179). The data showed that students in his flipped classroom section were more open to and preferred cooperation and innovation as compared to students in his traditional section who did not like the idea of group work or new ideas. Similarly, Enfield (2013), who taught a multimedia class at California State University North, used a survey following his flipped classroom intervention and saw that 73.5 % of his students reported being "more confident in their ability to learn a new technology without taking a formal course" (p. 22).

Some studies have reported an increase in student achievement with flipped methods of instruction (Missildine et al. 2013; González-Gómez et al. 2016; Tune et al. 2013). Tune et al. (2013) measured the effectiveness of flipping a classroom in a graduate-level physiology course. They made the notes and recorded lectures available to both sections of students they taught. The students in the flipped section were required to watch the lectures before class and then attend class where there was a quiz on the lecture and then a classroom discussion with practice problems. The students in the traditional section had the option of either attending class or watching the recorded lecture; they also received practice problems for homework. The researchers found students in the flipped classroom scored an average of more than 12 % points above the students who were in the traditional classroom. Likewise, Missildine et al. (2013) found positive achievement results when they flipped their undergraduate nursing courses. Talley and Scherer (2013), who teach physiological psychology at a state university, flipped their classrooms and reported a 10 % increase in final semester grades with the flipped classroom versus the traditional classroom. Recently, González-Gómez et al. (2016) found positive effects for flipping a general science course in the undergraduate settings.

Another positive finding in the research literature was enhanced discussion between students and instructors. Tune et al. (2013) found that they were better able to engage students in discussion, and that students asked more specific questions about key material and more follow up questions as compared to students in a traditional classroom (p. 319). This increased discussion may support better instruction. With this in mind, Critz and Knight (2013) reported better understanding student errors in thinking due to the increased class time spent on discussions, as well as being able to identify struggling students earlier and thus providing more timely interventions.

In one aspect of the flipped classroom, there is some conflicting data. Arnold-Garza (2014), Critz and Knight (2013), Enfield (2013), and Wilson (2013) found that after implementing the flipped method of instruction, student perception of the class and the teacher was positive. However, this was not always the case; Tune et al. (2013) reported that students were not overly enthusiastic about [the flipped classroom]. By the end of the course, some students changed their view of this teaching style, while others held fast to their dislike even though they said this format helped them to learn. The researchers noted "It is curious that some students still retained unfavorable views of the course format while simultaneously reporting that this format facilitated their ability to learn" (p. 320). Likewise, Missildine et al. (2013) reported similar results in that student satisfaction was lower in the flipped classroom as opposed to the traditional classroom. Additionally, Arnold-Garza (2014) found that 45 % of students who took the flipped version of library instruction indicated they would still have liked to use class time to explain key concepts.

One other reported difficulty of flipped instruction stems from technological constraints. Some educators complained that creating and editing the online video content was time-consuming and difficult (e.g., Critz and Knight 2013; Enfield 2013). In addition, one researcher (Enfield 2013) pointed out that the sharing and consumption of videos can be very cumbersome with slow Internet connections. While the flipped classroom research is still, most of the empirical researches have been conducted in undergraduate or graduate setting. This study was designed to investigate the impact of flipped instruction in secondary biology settings.

Active Learning

Inherent in most visions of flipped instruction is the increase in active learning strategies. While there are many definitions of active learning, Springer (1997) summarized active learning by advocating that "classroom experiences [need] to be more similar to actual career situations. Students generally are given greater opportunities to learn from one another and to work in small groups on authentic problems" (p. 1). He then stated that "small-group teaching and learning innovations have been identified by a number of labels including cooperative learning, collaborative learning, active learning, and problem-based learning" (p. 1). According to McCormick et al. (1999), active learning is encouraged by the National Science Foundation and "includes student involvement in discussion, hands-on activities and small collaborative learning groups" (p. 3). More recently, Bandiera and Bruno (2006) stated that active learning involves "interaction between teacher and student, comparison of their respective knowledge and conceptions, and a regulation, of the teaching/learning process, through feedback" (p. 130). They go on to say that cooperative learning is a subset of active learning.

Likewise, Stalheim-Smith (1998) argued that "active learning is not a spectator sport" (p. 3). She goes on to quote a 2000-year-old proverb "I hear and I forget, I see and I remember, I do and I understand" (p. 3). Tacit in these arguments is the notion is that traditional learning (lecture) is more passive. Bergtrom (2011) argued that instructors rely too heavily on lecturing instead of helping students construct knowledge, which is more appropriate if you considering constructivist theories of learning. Instead, instructors should "facilitate the process of organization while students learn actively by making connections and thinking more critically about course content" (p. 33).

There is extensive support that active learning increases student science achievement, especially at the undergraduate level. Freeman et al. (2014) performed a meta-analysis of 225 studies that investigated active learning in the science, technology, engineering, and math fields (STEM). The researchers reported a mean, weighted effect size of 0.47 in favor of the active learning for undergraduate STEM courses. The authors noted that "increases in achievement hold across all of the STEM disciplines and occur in all class sizes, course types and course levels" (p. 8412). They also noted that this same trend can be seen in K-12 education although the effect size is not as pronounced (0.39 for exam scores, and 0.24 for concept inventories). Along with supporting increased academic achievement, Freeman et al. also noted that active learning decreased the rate at which students failed courses.

In addition to improving overall academic performance, active learning may reduce gender disparities. Lorenzo et al. (2006) believe that active learning can help to reduce this gender gap. They looked at longitudinal data from students at Harvard University, enrolled in a calculus-based introductory physics class for non-majors between the years of 1990 and 1997. The courses were taught by five different instructors with differing approaches that changed from traditional to most interactive between 1990 and 1997. The researchers classified each approach as traditional, partially interactive, and fully interactive. Using this classification scheme, the researchers found "consistent results for each approach regardless of the instructor" (p. 119). This means that differences seen in scores may be due to the teaching method. While traditional (lecture) courses caused the gender gap to remain constant, courses that utilized more active approaches to learning were correlated with higher achievement for females.

There is also some evidence that active learning supports positive attitudes to science. For example, in the context of a quasi-experimental study, Springer (1997) gave the students a survey that assessed their perceived ability and interest in science. Students who participated in active learning courses reported higher perceived ability and interest in scientific concepts. To support this claim, Springer noted that the average student (50th percentile) in the active learning group reported a greater ability to relate concepts and applications than 91 % of the students in the control group (Springer 1997). While there is evidence that active learning supports improved attitudes and academic achievement, the vast majority of this research has been conducted in undergraduate settings. This study was designed to investigate the impact of flipped instruction and active learning in secondary biology settings.

Research Methods

This current study utilized a quasi-experiential design. The first author taught four sections of 9th grade biology at a private high school in the Pacific Northwest region in the USA. Students were assigned to treatment and control groups using a block randomized approach. First, the four classes were classified as high or low using first quarter (average) student achievement scores. Based on these scores, 3rd and 5th periods were designated as the high achieving classes (87.7 and 90 %, respectively), and 6th and 7th periods were designated as the low achieving classes (85 and 81 %, respectively). Then, with the flip of a coin, 5th and 6th periods were assigned to the treatment group (flipped instruction), and 3rd and 7th periods were left as the control (lecture) group.

For the flipped classroom, the first author created video lectures by using a smart board, air pad, and Screencast-O-Matic software, as well as a webcam to record lectures on scientific concepts. Then, the first author uploaded these videos to YouTube and posted a link along with a short quiz to Moodle (an online interface for students and teachers that all students had access to). These Moodle quizzes were typically three true/false or multiple-choice questions. Students were responsible for watching four lectures per week and taking one quiz per lecture. These quizzes were scored by Moodle and automatically entered into the online gradebook.

The traditional classroom method of content delivery was an interactive lecture. That is, the first author (classroom teacher) was live and in person writing notes on the board while asking questions of the students, having students repeat information back, and perform calculations in their notebooks. While we did not track content delivered via in-class lecture, it was very similar to the online lectures. From time to time, however, student questions and comments prompted the instructor to cover content that was not in the online videos. Students in the traditional classroom were held accountable for lecture and textbook information via the textbook questions and worksheets, where the correct answer was often a direct quote from the textbook or the lecture explaining the central scientific concept. For each chapter, students completed three content-specific assignments. These assignments were graded by the first author and entered into the grade book.

Because lectures were viewed outside the classroom for the flipped method of instruction, this allowed for students to participate in more active learning, such as projects, laboratories, and interactive forms of learning. In the traditional classroom, because class time was used for direct instruction, activities meant to deepen knowledge consisted of worksheets, and end-of-chapter questions that were completed at home. In general, the flipped classroom incorporated more active learning activities but some laboratories and activities were used in both conditions. Table 1 shows activities by topic for the flipped versus traditional method of teaching.

During the course of the intervention, data were recorded in two ways. Quantitative data were collected via four assessments throughout the unit (pretest, quiz 1, quiz 2, posttest). The assessments were made using a program called Exam View Assessment Suite that accompanies the biology textbook (Miller and Levine 2010), which includes a range of multiple-choice and fill-in-the-blank questions. The pretest consisted of 15 multiple-choice questions and six fill-in-the-blank questions. The photosynthesis quiz consisted of 10 multiple-choice questions. The cellular respiration quiz consisted of 17 multiple-choice questions. The end-of-chapter test consisted of 45 multiple-choice questions 11 fill-in-the-blank questions, two short answer/essay questions that were aimed more at conceptual understanding, and two fill-in-the-blank questions asking about the balanced equation for cellular respiration and photosynthesis. On the posttest, there was an even distribution among test questions about general energy ideas, photosynthesis, and cellular respiration. In addition, the first author collected some informal qualitative data before, during, and after class.

All of the quantitative data were analyzed using SPSS. Although 75 students were assigned to conditions, the analytic sample included 69 students who were present for the pretest, both quizzes, and posttest. To estimate the difference between conditions, the data were analyzed using an analysis of covariance procedure (ANCOVA), which adjusted for pretest differences.

Results

The pretest, quiz, and posttest results are presented in Table 2. The quiz and posttest data reported in Table 2 have been adjusted for pretest differences. As shown, students in the traditional method of instruction performed better on the pretest (ES $= -0.52$). On all posttests, however, students in the flipped instruction group showed increased levels of achievement. This was true for the photosynthesis quiz (ES $= +0.30$, $p = 0.18$), the cellular respiration quiz (ES $= +0.44$, $p = 0.05$), and the posttest (ES $= +0.16$, $p = 0.47$). For this intervention, there was consistent evidence that students in the flipped classrooms performed better on assessments of scientific knowledge. While two of the three effect sizes were not statistically significant, this is not surprising considering the small sample size for this intervention. Figure 1 graphically displays each student's pretest score versus posttest gain score, by condition.

The qualitative results suggest that students may have benefited from the active learning strategies, which required them to construct and negotiate meaning with their peers. During one active learning session, a group of female students represented the carbon atoms in glucose by creating a chain of human beings. Once the analogy was decided, one girl (B.R.) informed the group "we need six students because glucose has six carbon atoms, and in the first stage they need to split into two groups of three." In another active learning session, one group of students explained photosynthesis using a rhyme set to the tune of jingle bells and another group composed an iPhone movie about cellular respiration that included a fight scene because "glucose is being broken down."

In addition, there is some anecdotal evidence that students enjoyed the flipped method of instruction. The statements about flipped instruction were typical comments provided by students. Before the flipped classroom officially began, two students (BR. and L.M.) who were finished with the test early asked whether they could go out in the hall and watch the YouTube videos that were posted for homework that weekend. When they came back into the classroom they exclaimed "that was actually kinda cool."—L.M. "Thanks for doing that"—B.R. This same sentiment was echoed the next day in 5th period as P.D. came in chanting "flipped classroom, flipped classroom."

T.C. "I think it's really cool."

G.A. "Me too."

Table 1 Learning activities for flipped and traditional methods

Learning activities	Flipped classroom	Traditional classroom
Content delivery		
12 online video lectures	X	
12 in-person lectures		X
Learning tasks		
Textbook questions		X
Textbook worksheets		X
Photosynthesis laboratory	X	X
Calorimetry preparation sheet	X	X
Calorimetry laboratory	X	X
Carrying molecules activity (red/green light)	X	
Students act out photosynthesis	X	
Waterweed simulator (www.biologycorner.com)	X	
Artistic representation of photosynthesis	X	
Artistic representation of cellular respiration	X	
Cellular respiration word search	X	X
Creatine ethical dilemma	X	X
Review guide final test	X	X
Assessments		
Moodle reading quiz	X	
Content assignments		X
Pretest (chapters 8 and 9)	X	X
Photosynthesis quiz	X	X
Cellular respiration quiz	X	X
Posttest (chapters 8 and 9)	X	X

Table 2 Test and quiz scores, by condition

	n	*M*	SD	ES	*F*	*p*
Pretest				−0.52		
Flipped	40	6.95	2.37			
Traditional	29	8.10	2.58			
Photosynthesis quiz				0.30	1.85	0.18
Flipped	40	15.98	4.46			
Traditional	29	14.65	4.39			
Cellular respiration quiz				0.44	4.17	0.05
Flipped	40	24.37	6.46			
Traditional	29	21.42	7.10			
Posttest				0.16	0.53	0.47
Flipped	40	107.92	28.37			
Traditional	29	103.25	31.36			

ES standardized mean difference effect size; quiz and posttest means were adjusted for pretest differences

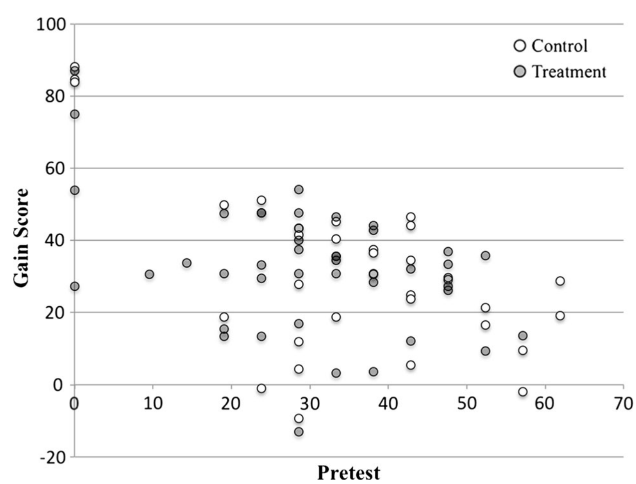

Fig. 1 Pretest versus gain score, by condition. *Note* For this figure, pretest and posttest data were both rescaled to 100 points

L.R. "Who watched the videos?.… I did."
N.S. "I watched the videos again this morning to prepare for class and I saw that the next videos were posted."

Likewise, some of the students in the traditional classroom talked about what they heard was happening in the flipped classroom:

T.C. "I love it when we get to do labs."
J.F. "Is the flipped class doing this lab?"
Me: "Yes"
T.C. (said longingly) "They do more labs than we do."
B.M. "Will we ever get to do the flipped classroom?"

Me: "Yes, in second semester everyone will do the flipped classroom."
B.M. "Oh good"

This suggests that students in the traditional classroom were aware and slightly envious of the students in the flipped classroom. In particular, students specifically mentioned that the flipped classes were getting to do more laboratories. Lastly, another positive aspect of the flipped classroom was that students did not miss lectures if they were absent. If a student missed class, it was easy to get them caught up on the content by watching the videos on their own schedule and time.

Discussion

The generalizability of this study is bounded due to students not being randomly assigned to their classes. Instead, preexisting, intact classes were randomly assigned to conditions. Second, this study was also limited by the small sample size. Third, this study was limited by technological constraints. The school web interface, which promised to track student video usage, was not working properly.

Despite these limitations, flipped instruction with additional active learning does show promise to support student achievement and interest in science. Based on the students' comments, they enjoyed flipped instruction and many of the active learning tasks. On both quizzes and the final posttest, students in the flipped condition outperformed students in the traditional method of instruction. While only one of the three assessments demonstrated statistically significant gains, this is not surprising considering the small size of this intervention study.

This study has implications for the teaching of science in secondary settings. The main implication is that active learning can occur without sacrificing the usual rigor associated with the discipline. If secondary science teachers want to inspire the next generation of scientists, we need to instill a passion for science. This will not happen if students are always passively taking notes during direct instruction and lecture. Flipped instruction provides a way to disseminate high-quality scientific information while providing a space for students to grapple with complex concepts and negotiate meaning. In the future, a curriculum may consist of a series of online videos, digital texts, and accompanying in-class activities. This does not negate the need for science teachers to be masters of their content; rather, it provides a more efficient way to cover critical content while providing the spaces for students to struggle, discover, and negotiate scientific meanings.

It is important to note that both teachers and students need to know how to use technology for the flipped classroom to work well. Teachers need to be technology savvy, by making their own videos or by finding appropriate videos for their content online and helping students access them. Students need to be technology savvy in that they need to be able to access videos and other online content, such as digital quizzes. This may require one-to-one technology or more class time devoted to username/password management, as well as how to navigate online resources.

This study has some implications for future research. It would be valuable to conduct this same study with a larger sample size. Future studies would also be improved by identifying a way to keep track of student video watching and to analyze whether video consumption was correlated with achievement. While the flipped method of instruction shows promise, more studies are needed at the secondary level to ensure the reliability of the robustness of this claim.

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