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Examining the Effects of Using Picture-Based Summaries in a Flipped Classroom Model

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Abstract

The flipped classroom model allows more student-centered learning to take place within the classroom, and allows the teacher-centered lecture to be moved outside the classroom as a video viewed as homework. Studies suggest that student-centered learning is more effective than teacher-centered lecture; however, there is a paucity of research in creating effective at-home video lessons in the flipped classroom model. In this quasi-experimental quantitative study a picture-based summarization technique was incorporated into the Cornell note-taking strategy for students to use while viewing the at-home lecture video in a set of grade nine biology classes. A control group (n = 26) used the traditional Cornell note-taking strategy concluded with a student-generated written summary while viewing the at-home lecture, and a treatment group (n = 29) used the Cornell note-taking strategy, but was given a set of teacher-generated pictures as a summary of the at-home lecture. Results of an independent sample t-test generated from pre and post assessments using multiple-choice items showed no significant difference in comprehension of content objectives. Results of paired samples t-tests show that both control and treatment groups improved significantly over the four-week study. Therefore, it can be concluded that the use of picture-based summaries does not improve comprehension more than traditional written summarization, however, both strategies have a similar effect. It is suggested that future studies examine multiple aspects of student understanding to determine the effectiveness of teacher-generated picture-based summaries of Cornell notes on student comprehension.

Keywords: Cornell notes, flipped classroom, picture-based summary, student-centered learning, teacher-centered lecture

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Literature Review

A common challenge to the modern American classroom is overcoming the achievement gap between the diverse learners contained in just a single classroom. In order to attain mastery some students simply need more time than others (Bloom, 1968), and many need to participate in more student-centered learning (Dewey, 1938). One possible solution to this quandary that is being used more widely is the flipped classroom model—a student-centered learning environment in the classroom coupled with teacher-centered, online learning at home (Bishop & Verleger, 2013). The flipped classroom model may offer a promising shift in teaching methodology, as it allows for an extension of at-home learning time for students that need it, and allows for a variety of student-centered learning strategies to take place within the classroom (Bishop & Verleger, 2013).

Rationale for the Flipped Classroom Model

Within the classroom environment, several studies of undergraduate learning in science courses suggest that student-centered lessons are more conducive to learning than teacher-centered lectures (e.g., Fujinuma & Wendling, 2015; Mazur ,1997; Missildine, Fountain, Summers, & Gosselin, 2013). For example, Mazur (1997) discovered that in an introductory science course, class-time could be more productive if students are engaged in discussion rather than listening to a lecture. Mazur organized his class so that students read assigned reading and lecture notes prior to class, then responded to a short quiz based on the reading at the start of class. Additionally, students were responsible for defending their answer choices to peers, so that following discussion, students had a greater success rate on quizzes (1997). In a similar study, Fujinuma and Wendling (2015) retained the teacher-centered lectures in an introductory college science course, but followed the lectures with two student-centered modules requiring skills such as group discussion, problem-based learning and peer teaching and assessing. Their results also showed marked improvement in scores on the course final exam from the previous year's course design using lectures followed by a single module of whole-class discussion with limited opportunities for students to practice learned skills (Fujinuma & Wendling, 2015). Additionally, the recent publication by the National Research Council (2012), that outlines the national standards for K-12 science practices also supports student-centered learning at the primary and secondary level by advising more active (i.e., student-centered) learning involving exploration, inquiry and engineering design and disparaging past direct instruction practices involving "long lists of detailed and disconnected facts" (p. 10).

Furthermore, an empirical study by Missildine and colleagues (2013) measured the success of in-class student-centered learning against direct instruction lecture. In the study, nursing students were taught using three models: lecture-only, lecture with recorded lecture available, and a flipped classroom model where students were able to apply concepts in a variety of interactive styles in class. Results of the study showed small, but significant differences in mean examination scores with highest mean scores for the flipped classroom model ($M = 81.89$), followed by the lecture with video support model ($M = 80.70$), and the lecture-only model ($M = 79.79$). The data supports some key concepts of Bloom's (1968) mastery learning in that students benefitted from reviewing material at their own pace (i.e., watching recorded lecture with the ability to pause and re-watch) and from student-centered class activities. This shows that the flipped classroom model benefits students that need additional support.

The flipped classroom model was first developed to allow absent students to view missed lectures, but these recorded lectures also helped other students that were able to use it as study review (Tucker, 2012). This model allowed for much-needed flexibility in order to address the wide range of learners present in the typical American classroom. At the school under study, differences in ethnicity, socioeconomics, disability and primary language spoken in the home are reported factors associated with wide achievement gaps on state tests (School Accountability Report Card, 2015). Despite these differences, most students do perform better when given enough time to learn the concepts. A flipped model practitioner noted that he was able to spend more in-class time with struggling learners, while high-achieving students had the freedom to work more independently (Tucker, 2012). Moreover, a meta-analysis of 108 studies of mastery learning programs (i.e., programs that allow students more time to review targeted concepts until mastered) showed positive effects on student performance in upper elementary grades through college, especially for generally lower-performing students (Kulik, Kulik, & Bangert-Drowns, 1990). Additionally, a study by Shaw and Molnar (2011) showed that when medical students had access to online lecture podcasts, students that had English as a second language (ESL) benefitted dramatically by scoring an average of three-and-a-half standard deviations higher with lecture podcasts than with in-class lecture only. Shaw and Molnar (2011) suggested that the ability of students to pause the video lecture to review at a slower pace, if needed, likely contributed to the improved scores.

Building on Mazur's practical knowledge that students benefit from student-centered learning, Newmaster, LaCroix and Roosenboom (2006) concluded that students report higher engagement in learning when they are involved in authentic learning experiences (e.g., projects where students have choices in the study subject or real-world projects that are applied to benefit their own community) that elicit an intrinsic motivation to discover an outcome. Furthermore, Hannafin and Land (1997) cite criticisms that traditional teacher-centered techniques fail to teach students skills that are transferable to real-world applications. They surveyed a number of student-centered learning environments that incorporated technology into the curriculum. Successful models were able to use technology in simulations and applications that allowed students to construct ideas to utilize critical thinking skills. Their conclusions also suggest, however, that some learning goals, especially introductory basic skills, may be more appropriately taught using strategies that separate knowledge and application of knowledge. Therefore, traditional teacher-centered lecture may be most appropriate to introduce basic concepts in the at-home portion of the flipped classroom model and student-centered lessons involving application of knowledge may be most appropriately applied to the in-class portion of the flipped classroom model (Bergmann & Sams, 2012; Hannafin & Land, 1997).

Although execution of the flipped model may vary, recommendations are for the at-home video lesson to be between three and five minutes (and strongly recommend against exceeding 15 minutes) to retain student engagement (Bergmann & Sams, 2012) as student viewing habits wane as the video length increases (Guo, Kim, & Rubin, 2014; Kim et al., 2014). Additionally, a short video lesson would enable a student that requires multiple viewings for comprehension and retention to review the video multiple times in a realistic time frame. This narrow time frame to present basic concepts presents a challenge for teachers accustomed to delivering lectures that take up a class period. Strategies that effectively assist students in comprehension and transferability to the in-class student-centered lesson that can be integrated into a short at-home video segment have not previously been explored. Because students were already expected to take notes during lecture in the high school classes under study, effective note-taking strategies of this at-home lesson were the focus of this study.

Effectiveness of Note-taking Strategies on Student Performance

High school students in this study and those around the nation have been explicitly taught note-taking strategies as research has shown that note-taking supports their learning (Faber, Morris & Lieberman, 2000; Kobayashi, 2006; Peper & Mayer, 1986). In a study by Peper and Mayer (1986) high school juniors were either assigned to take notes during a lecture or to listen to a lecture without taking notes. Whereas results showed that students that do not take notes are better at recalling individual facts verbatim from the lecture, students that do take notes excel in more complex assessments of comprehension (Peper & Mayer, 1986). Results supported the generative hypothesis of note-taking. That is, students that take notes are better able to make connections between prior knowledge and lecture content and are better able to apply the concepts to problem-solving tasks. Similarly, a study of ninth grade students explicitly trained in the Cornell note-taking strategy showed a significant improvement in scores compared to those not trained in a note-taking strategy (Faber et al., 2000). Although there are a multitude of note-taking strategies, for the purposes of this study the focus will be on the Cornell note-taking strategy, as that is the preferred note-taking method at this study's school site.

Cornell notes. The Cornell note-taking strategy, described by Pauk and Owens (2005), involves taking notes in a wide column on the right side of a notebook page, then reviewing notes to identify main ideas in order to generate questions or cues in a narrow column to the left of the notes, and finally, generating a final summary at the end of notes. The left cue column and summary can be used to review main ideas and concepts frequently. To further support students in generating cues and questions in the left column, the students in the classes under study were explicitly taught to refer to *Costa's levels of questioning* (1985). This strategy was developed for use with Cornell note-taking by the Advancement Via Individual Determination (AVID) program based off of the Model of Intellectual Functioning by Costa (1985) that separates questions into leveled categories (e.g., level one prompts knowledge recall, level two prompts analysis of the subject, and level three prompts for application of the subject).

These question-generation, summarization, and review techniques employed in the Cornell note-taking strategy have been shown to be effective in supporting student comprehension (King, 1992; Kobayashi, 2006). A study comparing note-taking strategies of college students during lecture by King (1992) provided evidence that students that self-generate questions based on lecture notes and students that process notes by composing a written summary both perform better on a test of lecture comprehension and a test of retention than students that only compose and review notes.

The recorded video of the teacher's lecture slides in the flipped classroom model could provide additional support for students that have difficulty generating their own notes (Kiewra, 1985). In a review of several studies evaluating students' performance when taking and reviewing notes Kiewra (1985) evaluated alternative strategies to support comprehension of lecture by demonstrating that providing the teacher's lecture notes to students can be a helpful support. Variables compiled by the study included whether the students were given the teacher's lecture notes for review, students self-generated notes based on the lecture or students used both strategies prior to a test. In the compiled studies, the students reviewing the teacher's notes generally perform better than the students reviewing their own notes. Yet, the students using both sets of notes for review perform better than both of the other groups. In the flipped classroom model students may benefit in this way by completing their own notes of the lecture, while also having a video recording of the teacher's lecture slides and voice recorded elaboration on the slides to review prior to a test (Shaw & Molnar, 2011).

Although the Cornell note-taking strategy appears to be supportive in student comprehension of lecture, a study by Jensen and Finley (1996) demonstrates that traditional teaching methods, such as lecture may not be effective in allaying student misconceptions. The flipped classroom model could further compound this problem by not having a teacher present that can respond to students (Bell & Cowie, 2001). Bell and Cowie (2001) describe an interactive process of assessing and providing feedback to student misconceptions that arises during the natural progression of student-teacher exchanges during a lesson. These "interactive formative assessments" are generally unplanned, and occur when a teacher is able to recognize that students lack sufficient background knowledge to understand an aspect of the lesson. In general, studies on effectiveness of feedback on misconceptions have been mixed, but it may have an effect on student learning (Shute, 2008), so strategies that attempt to minimize misconceptions of the at-home lecture should be targeted.

An alternate comprehension strategy that may alleviate student misconceptions of the lecture is a summarizing strategy that has been used with the reading of text (Leopold, Sumfleth, & Leutner, 2013; Mayer, Bove, Bryman, Mars, & Tapangco, 1996). Summarizing strategies assist students in extracting and understanding the important elements from a text (Mayer et al., 1996). For example, in a study with college science students Mayer and colleagues (1996) demonstrated that a visual picture-based summary of a scientific process with brief captions (e.g., pictures with captions of the steps in the process of lightning) were even more effective toward comprehension than providing the visual picture-based summary and captions along with an explanatory text of the process. In a follow-up study, Leopold and colleagues (2013) tested high school science students to determine if students performed better with the visual picture-based or a written summary. In this study, students read texts and then were asked to review a series of expert pictures (i.e., a series of pictures that correspond with discrete ideas or steps in order to explicate an overarching concept created by the instructor or researcher) that summarized the text. Results indicate that the students showed a higher level of comprehension of descriptive texts when instructors provided students a visual picture-based summary as opposed to a predetermined written verbal summary (i.e., summary of text composed by the teacher or other expert), or directing students to generate a summary themselves (e.g., a picture-based or written verbal summary; Leopold et al., 2013). The pictures allowed students to form mental images of the concepts that allowed transfer of the knowledge to novel problems better than their counterparts that created their own summaries. The students generating their own summaries may have experienced a greater mental burden by having to make multiple decisions regarding the importance and relationships between various concepts impeding their ability to form a clear mental image of the concepts (Leopold et al., 2013). Summarizing text is a concise strategy that is adaptable to various educational contexts and curriculum. Furthermore, this approach along with the Cornell note-taking strategy may be beneficial for students in a flipped classroom.

Purpose of the Current Study

In sum, although the flipped classroom model has been successful at incorporating in-class student-centered learning and the ability to review lecture material at a self-pace at home, lack of feedback during the teacher-centered recorded lecture may lead to student misconceptions (Bell & Cowie, 2001; Jensen & Finley, 1996). The focus of this study will be on the improvement of the Cornell note-taking strategy of the at-home lecture component of the flipped classroom model in order to maximize comprehension of the lecture content and minimize these misconceptions. Research suggests that teacher-generated picture-based summarization of text presented to students supports their comprehension of text (Leopold et al., 2013; Mayer et al., 1996), therefore, this study uses a novel application of this strategy to the summary portion of the Cornell note-taking strategy in order to improve comprehension of lecture content.

Method

Research Question

Does the presentation of picture-based summaries of Cornell notes of video-recorded lecture affect grade nine honors biology students' comprehension of evolutionary biology concepts in a flipped classroom model?

Hypothesis

Based off of the research by Leopold and colleagues (2013), the researcher hypothesized that content comprehension would be higher in students presented with picture-based summaries of video-recorded lecture compared to students generating written summaries of video-recorded lecture in grade nine biology flipped classrooms.

Research Design

A quantitative experimental design was used. A pre-test of selected questions of evolution content from the *Computer Test Bank for Prentice Hall Biology* (Miller & Levine, 2003) was administered to honors biology students in two classes prior to a unit on evolution. One classroom was designated a control group that generated verbal written summaries of video-recorded lectures assigned as homework, and a second class was designated a treatment group that was given teacher-generated picture-based summaries of the video-recorded lectures assigned as homework. During the four week study both groups were exposed to three identical video-lectures of three topics in evolution—only the summarization strategy differed between groups. Both groups completed the same classroom activities for the duration of the unit. A post-test of content comprehension identical to the pre-test (i.e., selected questions from the *Computer Test Bank for Prentice Hall Biology,* Miller & Levine, 2003) was given at the end of the unit to determine differential growth in evolution content comprehension between control and treatment groups.

Independent variable. The independent variable in this study was the presentation of picture-based summaries, as implemented in the study be Leopold and colleagues (2013), of four video-lectures to students in a flipped classroom model. Picture-based summaries were defined as a series of pictures that corresponded with discrete ideas or steps in order to explicate an overarching concept (Leopold et al., 2013). Video-lectures were defined as video recordings of Microsoft PowerPoint slides with voice overlay of lecture that corresponded to the slides in a presentation not to exceed 15 minutes. A flipped classroom model, as defined by Bergmann and Sams (2012), provided lecture to students in the form of up to 15 minute video-recorded lectures that were viewed as homework by students, and used class time for activities including, but not limited to, practice problems that were generally used as homework in traditional classrooms.

Dependent variable. The dependent variable in this study was content comprehension. In this study a unit on evolution was taught and four video-lectures, each on different topics within evolution, were the focus of content evaluated for comprehension. Content comprehension was defined as scores on a test of 12 selected multiple-choice items (i.e., three questions measuring each of four video-lecture topics) from Computer Test Bank for Prentice Hall Biology (2003).

Setting & Participants

The Central California public secondary school served an agricultural-based city with mainly Hispanic (66%) and White (26%) students. The secondary school had a student population of approximately 2,500 students. Approximately 16% of students were English Learners (School Accountability Report Card, 2015). All students at this school had school-issued computer laptops, school-issued Google Classroom accounts to receive and submit digital assignments, and Wi-Fi hotspots were loaned to students from the school library if they did not have internet access in the home. For this study the convenience sample consisted of the two periods of grade nine (i.e., students aged 14 to 15 years) honors biology classes taught by the researcher. One period of 29 students was randomly assigned to the treatment group and the other period of 26 students to the control group.

Treatment group. A grade nine honors biology class of 29 students, 17 females and 12 males, served as the treatment group. Of the 29 students, 25 were concurrently enrolled in a class qualified as Gifted and Talented Education (GATE). Furthermore, 13 students belonged to households where Spanish was the language spoken at home and 16 students belonged to households where English was the language spoken at home.

Control group. A grade nine honors biology class of 26 students, 16 females and 10 males, served as the control group. Of the 26 students, 20 were concurrently enrolled in a class qualified as GATE. Eight students belonged to households where Spanish was the language spoken at home, 16 students belonged to households where English was the language spoken at home, and two students belonged to a household where a language other than Spanish or English was spoken in the home.

Measures

Pre-test and post-test questions were selected from *Computer Test Bank for Prentice Hall Biology* (2003) that aligned with the objectives from the three video-lectures given. The pre-test and post-test (see Appendix A) were identical and separated in time by the four weeks used to complete this study. The tests consisted of 12 multiple-choice items with four answer choices per item with one correct answer per item. The objective from the four video-lectures was assessed with three questions each. Items from the pool of questions tied to the objectives of interest from *Computer Test Bank for Prentice Hall Biology* (2003) were selected by the researcher as most relevant to each video-lecture. Another biology teacher at the school also selected items from the pool of questions that she identified as the most relevant to the lecture. Differences in question selection was addressed by discussion in order to reach consensus. The students were given approximately 20 minutes to complete each test.

Validity. The measure of student comprehension demonstrated validity as the authors of *Computer Test Bank for Prentice Hall Biology* (2003), were experts in the field of biology; each having earned a Ph.D. in biology, had research published in scientific journals and taught biological science classes at the university level (Miller & Levine, 2003). *Computer Test Bank for Prentice Hall Biology* (2003) aligned with the textbook *Prentice Hall Biology* (2002), which listed a number of expert consultants, reviewers, and activity testers. *Prentice Hall Biology* (2002) and supporting materials had validity for use with grade nine biology students as they were adopted by the school district for use in biology classes in which this study was conducted. Items in *Computer Test Bank for Prentice Hall Biology* (2003) were aligned to specific objectives from the textbook that the video lessons were based upon.

Reliability. Internal consistency was addressed by assessing each objective tied to each video-lecture with multiple items. The tests created from *Computer Test Bank for Prentice Hall Biology* (2003) had three items per objective for each of the four objectives for a total of 12 items. The Computer Test Bank for Prentice Hall Biology (2003) had an answer key that was used to score the pre-test and post-test multiple-choice items with 100% accuracy, avoiding scoring bias on the part of the researcher.

Intervention

Students in both the control and treatment groups received four flipped classroom model lessons on concepts of evolution over the course of four weeks. Students in the control group viewed a video-recorded Microsoft PowerPoint slide presentation that was accompanied by voice-recorded lecture that was accessed from the internet as a homework activity. While watching the video students took Cornell-style notes (based on procedures from Pauk & Owens, 2005) and were prompted at the end of the video to complete a written summary (as per Cornell-style notes protocol) by composing a sentence to summarize each slide of notes.

Students in the treatment group viewed the same video-recorded Microsoft PowerPoint slide presentation that was accompanied by voice-recorded lecture that was accessed from the internet as a homework activity. As students viewed the lecture they used the Cornell-note-taking system (based on procedures from Pauk & Owens, 2005) to create notes, but without the component of a written summary. At the conclusion of the lecture, the video instructed the students to review the main ideas by viewing a series of pictures. Each picture in the series was shown next to the slide of notes they represent (e.g., Leopold et al., 2013; Mayer et al., 1996). Picture-based summaries were distributed to students in the treatment group and they were directed to place these summaries at the bottom of the note-taking pages as a substitute for the standard Cornell-note-taking summary. The students were directed to study the picture-based summary to prepare for assessments as they would in standard practices of the Cornell-note-taking system (Pauk & Owens, 2005).

Procedures

Procedures closely followed the expert-generated picture-based summary portion of the study by Leopold and colleagues (2013) and Mayer and colleagues (1996) with the exception of using lecture as the content material, rather than text as content material. In this four-week study, students were first given the pre-test, followed by instructions and modeling of the expected note-taking and summary procedures. Both groups were given a video-lecture lesson assigned as homework on a topic in evolution each week for four weeks; however, the treatment group used the picture-based summary intervention following each video-lecture, and the control group used written verbal summaries. At the end of four weeks students were a post-test containing identical items to the pre-test to assess improvement in content comprehension.

Data collection. During the first week of the experiment students in both groups were given the 12-question pre-test. Later that day students in both groups were given written instructions for viewing the at-home video, how to create notes and do the summary activity. Special instructions for viewing the at-home video were to use the pause function of the video and "rewind" function to allow time to complete notes and review concepts that are not understood on the first viewing (Bergmann & Sams, 2012). The procedures were reviewed with students prior to allowing the students to play a sample video lecture on their student-issued computer laptops in class. Students were encouraged to ask questions if they did not understand the procedures.

For the homework assignment during the first week students watched the video-lecture that was assigned to their school-issued Google Classroom account and accessed through a program called EDpuzzle that monitors viewing activity for each student. At the end of the video students were prompted to complete the summary activity applicable to the control or treatment group. During the next class students received credit for completing the notes as instructed and a multiple-choice quiz on the material was administered. An activity that builds off the concepts reviewed in the video was done in the classroom setting for both groups that week. One video-lecture lesson per week in other topics in evolution was assigned during weeks two, three, and four. A unit test in evolution was given in week four to both groups that contains the 12 post-test questions.

Fidelity. The students in each group were exposed to the specific set of videos applicable to their group, so that the intervention was only administered to the treatment group. To accomplish separate viewing, intervention videos were only posted to the Google Classroom stream for the class period selected as the treatment group; and control videos were only posted to the Google Classroom stream for the class period selected as the control group. The researcher's Google Classroom account streams were reviewed by another biology teacher to verify that the groups received the respective video lessons exclusively for all four sets of video lessons to achieve 100% fidelity of assigning treatment and control videos to the corresponding groups only (see Appendix B). The other biology teacher also verified that lessons were executed within the specified time frame to ensure fidelity to the procedures. The videos were reviewed by the researcher and another biology teacher to ensure each of the applicable components (e.g., lecture and applicable summarizing components) were present in each video to achieve 100% fidelity to the stated components of each treatment and control video-lecture.

Both sets of videos contained the same content (e.g., lecture), only the summary portion of the videos differed.

Ethical Considerations

Individual student scores referenced in this study were identified using an assigned number, and not the students' names. An ethical consideration in this case involved denying half the students in the sample of the more effective learning strategy. It was a reasonable risk as the knowledge gained from this study can be applied to subsequent units to improve learning for all the students in the sample.

Validity threats. The selection of the two groups of students was not random, but a convenience sample of two classes. There may have been differences in ability levels or demographics that did not make the two groups directly comparable. Administering a pre-test and post-test allowed improvements to be measured to determine overall improvements for each group and to compare scores between groups. While the pre-test and post-test questions were identical, influence on the post-test due to memorization of the questions on the pre-test was not likely to be a large threat as the pre-test and post-test were separated by four weeks, so students were unlikely to remember the questions from the pre-test. The tests used to assess content comprehension were multiple-choice with a single correct answer that was provided in the answer key of *Computer Test Bank for Prentice Hall Biology* (2003), so there was no researcher bias in scoring the pre-test and post-test.

Students that did not watch the video and complete the summarizing activity could have posed a threat to validity. Students were encouraged to follow the procedures of their assigned activities. Students had an incentive of receiving a grade for completion of the assignment, as well as a grade on the in-class quiz based on the assignment.

A possible threat was diffusion of intervention to the control group. The treatment and control groups were in separate class periods and were not informed that they were receiving different treatments, however, it was possible that students from the control group could have interacted with students from the treatment group outside of these class periods and revealed picture summaries to the control group. Because the two groups were given identical video lectures and content comprehension was assessed on a multiple-choice test with answer choices that were exclusively correct or incorrect, researcher bias was limited to execution of in-class activities. A lesson plan was constructed for each class and the researcher made an effort to adhere to the same lesson plan for classes throughout the four-week unit, however, variations in execution were probable.

Data Analyses

All data were entered into the Statistical Package for the Social Sciences ® (SPSS®) for Windows, version 24.0.0 (SPSS, 2016). No names or identifying information were included in the data analysis. Before analyses were conducted all data were cleaned to ensure no outliers were present (Dimitrov, 2012). After cleaning the data, the final sample size was 29 participants for the treatment group and 26 participants for the control group. Independent (control and treatment groups) and paired (pre-test and post-test) samples t-tests were conducted to determine the significant difference in content comprehension scores generated from *Computer Test Bank for Prentice Hall Biology* (2003). Further, before interpreting the analytical output, Levene's Homogeneity of Variance was examined to see if the assumption of equivalence had been violated (Levene, 1960). As Levene's Homogeneity of Variance was not violated (i.e., the variances were equal across groups), data were interpreted for the assumption of equivalence.

Results

Two independent samples t-tests were conducted on the whole sample (n = 54) for both the pre-test and post-test scores. Results for the pre-test were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed and the t-test showed non-significant differences between the mean scores on the pre-tests between the two groups $t(53) = 1.52$, $p > .05$. The pre-test scores for the treatment and control groups were not significantly different and could be considered comparable (see Table 1).

Results for the post-test were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed and the t-test showed non-significant differences between the mean scores on the post-tests between the two groups $t(53) = .39$, $p > .05$. The post assessment scores (with a total of 12 questions) for the treatment and control groups were not significantly different, so the intervention does not show a positive or negative effect compared to the control group (see Table 1).

Table 1

Results of Independent Samples T-Tests

	Mean	SD
Pre Test		
Treatment	7.07	2.28
Control	7.88	1.61
Post Test		
Treatment	9.97	1.32
Control	10.12	1.56

Note. SD = Standard Deviation.

After determining the differences between pre-test and post-test scores between groups, two paired t-tests were run for both groups (i.e., treatment and control) to determine if participants mean scores from pre to post were significantly different within each group (see Table 2). Results for each group were as follows: treatment group, $t(28) = -7.01$, $p < .001$; control group, $t(25) = -5.98$, $p < .001$. Both the treatment and control groups showed statistically significant differences between the pre-test and the post-test. Additionally, the negative t-value for each group indicates an increase in scores from pre-test to post-test. Meaning that both groups improved between the pre-test and post-test, however neither group statistically out-performed the other group. Therefore, these findings do not support the hypothesis that content comprehension would be higher in students presented with picture-based summaries in a flipped classroom.

Table 2

Results of Paired T-Tests

	Mean	SD
Treatment Group		
Pre	7.07	2.28
Post	9.97	1.32
Control Group		
Pre	7.88	1.61
Post	10.12	1.56

Note. SD = Standard Deviation.

Discussion

The purpose of this study was to determine if presentation of picture-based summaries of Cornell notes for a video-recorded lecture improved comprehension in evolutionary biology concepts for grade nine biology students. The study included 29 students that generated Cornell notes of pre-recorded lectures with the exception of receiving a teacher-generated picture-based summary in-lieu of creating a written summary of notes, and 26 students that created Cornell notes of the pre-recorded lecture in the traditional format.

Based on the results, the hypothesis that picture-based summaries would show improvement in content comprehension should be rejected. Both groups showed significant improvement in comprehension from the pre-test and post-test. Therefore, while the intervention did not show significant improvement in scores compared to the traditional Cornell note-taking strategy, it could be considered as effective. Each lecture's content was represented in the pre-test and post-test with three questions per lecture. Students in both groups improved in the number correct for each objective, on average, between the pre-test and post-test with the exception of one objective that can be attributed to one question where students tended to choose one incorrect distractor. In sum, the traditional and picture-based summaries resulted in consistent improvement for both groups.

Both of the groups in the study were exposed to the flipped classroom model. Following the assigned video-recorded lecture completed as homework, students experienced an in-class student-centered activity that elaborated on the content reviewed in the lecture. According to Bergmann and Sams (2012) flipping the classroom increases interactions between students and between teacher and students compared to traditional lecture, thereby allowing the teacher to monitor learning and provide tutoring when needed. Additionally, the assigned video-lectures accounted for much less time compared with the class time focused on the same learning objective. It was possible that the in-class learning had a much stronger effect on learning of the objective compared with the assigned video-lecture and summarization method. Several studies (e.g., Fujinuma & Wendling, 2015; Mazur ,1997; Missildine et al., 2013) support this notion that student-centered learning is more effective than teacher-centered lecture. The efficacy of one summarization method over the other may not be clear, however, students did successfully demonstrate learning using the flipped classroom model.

Another reason the groups showed no difference could be that each objective was presented to both groups using multiple modalities. Students in one classroom may have a range of preferred learning styles, so the presentation of content in multiple ways could benefit more students than using one method alone (Denig, 2004). All students listened to the video lecture accompanied by the lecture slides, created lecture notes, processed their notes through creation of questions and prompts, and either generated a summary of notes or was provided with a picture-based summary in addition to the supporting activities in class. Because this novel strategy performed similarly to the traditional written summary method, this picture-based summary could be recommended in order to differentiate instruction between students with different learning styles (i.e., assigning different summary types to different students), or assigning a summarization method according to the visual compatibility of the content (i.e., how well the content translates into pictures). The flipped classroom model allows flexibility for presenting content in multiple ways. However, caution should be taken to observe the limitations to this short-term study involving a specific sample.

Limitations

One limitation in this study was the use of a convenience sample, therefore generalizations to wider populations are limited. The sample used in this study could have been the reason the intervention was not successful. Therefore, future studies should use more random sampling methods to ensure all groups are represented. Moreover, larger samples should be used in future studies to examine if with larger and more diverse samples the intervention is more successful. Additionally, a unit of study was selected that was easily translated into a series of pictures, however, not all lessons may lend themselves to picture representations. Another recommendation for future studies would be to use the intervention in various content areas.

This study was modeled most closely after Leopold and colleagues (2013) study that was able to utilize multiple assessments in order to measure multiple aspects of student comprehension. In that study they used multiple-choice pre and post assessments of knowledge, open-ended assessments to measure deep understanding and problem-solving transfer of knowledge, and a visualization test to measure students' spatial representation ability of the content (Leopold et al., 2013). This study was limited to a measure of content knowledge assessed by multiple-choice items. Multiple-choice items are not designed to assess deep understanding and problem-solving transfer of knowledge or spatial representation ability. A recommendation for future studies would be to construct multiple assessments to be able to get a deeper understanding of how students have learned the content. It is clear that learning is taking place using this novel summarization strategy, however, additional tests may reveal advantages that a multiple-choice assessment could not measure.

In sum, the study found that presenting picture-based summaries to students was not more effective in increasing content knowledge compared to traditional written summaries of Cornell notes. However, the picture-based summarization method seemed to be as effective as the traditional method. Therefore, a picture-based summarization could be an effective differentiation strategy for students favoring visual learning strategies. Future research utilizing tests that measure how students process the content using each of these summarization strategies could prove useful. These tests could help reveal if one strategy is more helpful in allowing students to visualize concepts and transfer concepts to new situations—arguably more useful in assessing deep understanding than the multiple-choice test used in this study.

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Appendix A

Pre-test and Post-test Questions

Objective 15.3.3

When lions prey on a herd of antelopes, some antelopes are killed and some escape. Which part of Darwin's concept of natural selection might be used to describe this situation?
a. acquired characteristics
b. reproductive isolation
c. survival of the fittest
d. descent with modification

According to Darwin's theory of natural selection, the individuals that tend to survive are those that have
a. characteristics their parents acquired by use and disuse.
b. characteristics that plant and animal breeders value.
c. the greatest number of offspring.
d. variations best suited to the environment.

Which of the following phrases best describes the results of natural selection?
a. the natural variation found in all populations
b. unrelated but similar species living in different locations
c. changes in the inherited characteristics of a population
d. the struggle for existence undergone by all living things

Objective 15.3.4

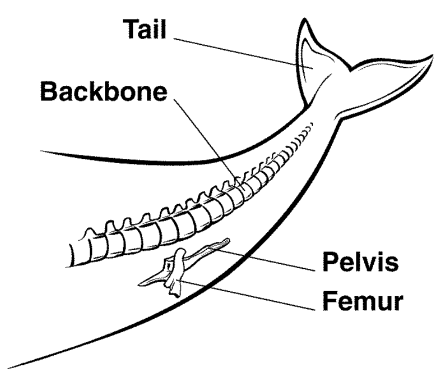

Figure 15–1

In humans, the pelvis and femur, or thigh bone, are involved in walking. In whales, the pelvis and femur shown in Figure 15–1 are
a. examples of fossils.
b. vestigial structures.
c. acquired traits.
d. examples of natural variation.

Modern sea star larvae resemble some primitive vertebrate larvae. This similarity may suggest that primitive vertebrates
a. share a common ancestor with sea stars.
b. evolved from sea stars.
c. evolved before sea stars.
d. belong to the same species as sea stars.

The number and location of bones of many fossil vertebrates are similar to those in living vertebrates. Most biologists would probably explain this fact on the basis of
a. the needs of the organisms.
b. a common ancestor.
c. the struggle for existence.
d. the inheritance of acquired traits.

Objective 16.1.1

All the genes of all members of a particular population make up the population's
a. relative frequency.
b. phenotype.
c. genotype.
d. gene pool.

If an allele makes up one fourth of a population's alleles for a given trait, its relative frequency is
a. 100 percent.
b. 75 percent.
c. 25 percent.
d. 4 percent.

In a population, the sum of the relative frequencies of all alleles for a particular trait is
a. equal to 100 percent.
b. equal to the number of alleles for the trait.
c. constantly changing.
d. dependent on the number of alleles.

Objective 16.3.1

The separation of populations by barriers such as rivers, mountains, or bodies of water is called
a. temporal isolation.
b. geographic isolation.
c. behavioral isolation.
d. genetic equilibrium.

A factor that is necessary for the formation of a new species is
a. reproduction at different times.
b. geographic barriers.
c. different mating behaviors.
d. reproductive isolation.

What situation might develop in a population having some plants whose flowers open at midday and other plants whose flowers open late in the day?
a. behavioral isolation
b. geographic isolation
c. temporal isolation
d. genetic drift

Appendix B

Fidelity Checklist

1. Control period 1 videos posted on Google Classroom that have slide prompts containing phrase "Your summary sentence of this slide." Topics of videos:
    a. evolution of populations
    b. speciation
    c. evolution by natural selection
    d. evidence for evolution
2. Treatment period 2 videos posted on Google Classroom that have slides with picture summaries. Topics of videos:
    a. evolution of populations
    b. speciation
    c. evolution by natural selection
    d. evidence for evolution
3. Lecture and content for each topic is the same for both classes—only summarizing slides are different for each period's videos.
4. Treatment videos are not posted on the Google Classroom of period 1.
5. Control videos are not posted on the Google Classroom of period 2.
6. Time period between Video 1 and Video 4 does not exceed 4 weeks.