Lecture-Free High School Biology Using an AUDIENCE RESPONSE SYSTEM

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ARTICLE

Thomas Lord's constructivist college teaching methods (Lord, 1998; Lord, 2001; Lord, 2005; and Lord & Orkwiszewski, 2006) have changed my teaching of compulsory high school biology. My students have enjoyed some successes by moving away from a teacher-centered classroom toward a more constructivist learning environment, defined by Dufresne et al. (1996) as "a set of beliefs about knowing and learning that emphasizes the active role of learners in constructing their own knowledge." For example, cooperative learning groups have replaced straight rows and the daily "bell-ringer" activity is no longer a question about a factoid the students had allegedly learned the day before. Now, at the beginning of each class, teams of three sophomores strive to solve a biological problem about which they have very little background. Blank stares and recalcitrance remain a persistent challenge, but participation usually increases as the course progresses and most students have responded favorably to these changes. However, we had not realized the dramatic improvements often reported at the college level (Burrowes, 2003; Wood, 2005).

In accordance with constructivist philosophy, I have attempted to eliminate traditional lectures, as Wood (2005) successfully accomplished with her college students, but have found it to be a particularly vexing challenge at the high school level. For instance, several years ago my students tried a peer-teaching approach within each cooperative learning group in lieu of traditional lectures. Students became "experts" on small parts of the unit and then taught their topic to their team members. A few students created wonderful short lessons, but most morosely read the text aloud to their group, evidently encountering the strange words for the first time. We abandoned the experiment and returned to comfortable lectures, but broke them up with frequent small challenges embedded within the notes. For example, students might brainstorm five forms of evidence supporting evolution before copying notes on the topic. The notes also evolved to include a printed version (omitting illustrations and key terminology) issued to each student. This facilitated students being able to listen to stories and examples while remaining engaged enough to fill in some important terminology. Regretfully, however, the method remained a long way from the Thomas Lord student-centered constructivist approach that had so inspired me at several National Association of Biology Teachers conferences.

Audience Response Systems (ARS) represent a powerful new tool for increasing student engagement and I report here on my use of the technology to eliminate traditional lectures in high school biology. ARS technology (known variously as electronic voting systems, personal response systems, interactive student response systems, and classroom performance systems) includes one hand-held remote per student, a receiver (infrared or radio frequency, depending on the system), a computer for recording student responses, and a means for projecting information to the class (Lowery, 2005). Positive ARS use outcomes are widely reported at the college level (e.g., Draper & Brown, 2004; Judson & Sawada, 2002; Lowery, 2005; Kennedy & Cutts, 2005), but are less studied at the high school level (e.g., Conoley, 2005). ARS are used in a variety of ways including imbedding questions into traditional Powerpoint lectures, recording responses to tests and quizzes, increasing student collaboration, and conducting anonymous surveys. Claims made by ARS manufacturers that the technology increases interactivity and student involvement are largely corroborated by the literature.

Student views of ARS are generally positive. For example, at the college level, Uhari et al. (2003) reported that "More than 80% of the students felt that voting improved their learning, and most of them felt that it enhanced questioning during lectures, although some students disagreed on this latter point." Draper and Brown (2004) found that "... learners almost always saw ARS as providing a net benefit to them." In a statistics course, 87% of the students "... saw more benefits than disadvantages in the use of the handsets" (Wit, 2003). Other studies show a positive empirical relationship of learning outcomes when college students use ARS (Kennedy & Cutts, 2005), and a dissertation conducted on the use of ARS in a high school agri-science course showed "... a significant increase in student achievement" in addition to positive student and teacher impressions of the technology (Conoley, 2005).

I used an ARS called Qwizdom as a tool in my compulsory high school sophomore biology classes to eliminate formal lecture and note-taking, and report on the learning gains made by my experimental group compared to gains made by students in my traditional lecture-based classes. All students experienced both lecture-free and lecture-based approaches, so I also include student assessments of the different approaches.

Methods

Forty-three students at an Idaho public high school enrolled in compulsory "Biology B" between November 27, 2006 and March 2, 2007 learned the content of three units through both lecture-based and Qwizdom-mediated lecture-free methods. Students took a 30- to 42-question ungraded multiple-choice pre- and post-test on the first and last day for each of three units. During each unit (approximately 11

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school days long with 70-minute class periods), two class sections used Qwizdom to learn the unit content by lecture-free methods. The other two sections learned the same material through traditional Powerpoint lecture methods. The classes rotated through lecture-free and lecture-based methods in each unit so that all students experienced both approaches during the course. All other classroom procedures, labs, videos, and practices were identical.

Figure 1. Qwizdom Q5 audience response system hand-held remote.

Lecture-Free Methodology

Lecture-free classes used Qwizdom Q5 radio frequency remotes (Figure 1) to enter responses to approximately 50 to 60 questions per unit while working in collaborative groups of three or four (Figure 2). These questions were broken into three separate assignments that collectively addressed all of the unit objectives. Student teams worked on the task for three or four of the 11 days in each unit (each session lasted roughly 40 to 60 minutes). Most questions were multiple answer, with some multiple choice, numeric, and sequence-type questions (Figure 3). For example, teams of students worked at their own rate, typically using the textbook and discussing responses to each question amongst themselves. Higher order thinking skill questions were achieved by using multiple answer questions (e.g., which of the following are true?) and sequence type questions (e.g., place the following in the correct order from earliest to most recent). Correct and incorrect student responses instantly appeared on the computer monitor at the front of the class (Figure 4), revealing each student's comprehension. Because students could not tell if their responses were correct, they had to reconsider questions and possibly change their answers until they were confident that they were correct. As a last resort I "lectured" on those concepts that remained problematic for most students. After all student scores reached between 70 and 100%, I recorded the students' Qwizdom scores and revealed answers to those questions that at least one student had missed.

Figure 2. Students worked in groups of three and responded to multiple-answer, multiple-choice, numeric, or sequence-type questions using radio-frequency Qwizdom remotes.

Lecture-Based Methodology

I presented Powerpoint notes to the lecture-based classes on the same days the lecture-free students worked with Qwizdom, striving to keep the total amount of time equivalent between both groups. Students received an outline of the notes (three or four pages) lacking the Powerpoint images and 10 to 20% of the text. As I proceeded through the presentation, students filled in the blanks with central ideas and terminology from the Powerpoint lecture. Students sometimes collaborated with their team to see if they could fill in certain sections of the notes before the presentation, but remained largely passive during the note-taking process.

Pre- & Post-Test Analysis Methods

On the first day of each of the three units, all students used Qwizdom to take an ungraded 30- to 42-question multiple-choice pre-test created from our textbook's testing software. Students retook the same test on about Day 10 of each unit, making it possible to compare the average percent gains for both lecture-free and lecture-based classes. Significance ($p = 0.05$) was determined using a two-tailed *t*-test.

Students took the same three ungraded tests a third time during the final three days of the trimester to determine if lecture-free teaching using Qwizdom remotes positively affected long-term retention compared to lecture-based teaching. By the end of the course, however, students generally knew their likely final course grade and were also fatigued from final exams in other classes. I therefore motivated the students to do their best by rewarding them with extra credit tied to their overall improvement between their first pre-test and their last post-test scores. Otherwise, methods and analyses replicated those conducted in the first trial.

Figure 3. Sample Qwizdom questions from the evolution unit.

1) What did Darwin know about inheritance? Choose all that apply.
a) Offspring inherited traits from their parents.
b) Units of heredity called genes passed between generations.
c) The genetic material was DNA.
d) Very little.

2) How might a gene pool change over time?
a) Gene pools become larger over time.
b) The gene pool becomes deeper as Earth ages.
c) The frequency of a particular gene or set of genes may become more or less common in a population over time.
d) Gene frequencies become more common as the environment changes.

3) How does the relative frequency of genes affecting skin color change as one moves north from Africa to Finland?
a) Alleles causing dark skin become less frequent.
b) Relative frequencies change at unpredictable rates.
c) Gene pool populations become more common.
d) Alleles causing light skin become less frequent.

4) How would a geneticist define evolution?
a) An appearance of a new gene.
b) An individual passes on a mutation to its offspring.
c) Increasing gene frequencies in a population.
d) A change in gene frequencies in a population.

5) What is true of genetic mutations. Choose all that apply?
a) They may increase an organism's fitness.
b) They may decrease an organism's fitness.
c) They may have no effect on an organism's fitness.
d) They occur when a DNA sequence changes.

6) Why is there so much variation with a species? Choose all that apply.
a) Mutations.
b) Meiosis, which generates genetically different gametes (sex cells).
c) Crossing-over during meiosis.
d) Crossing-over during mitosis.

7) What is the frequency in your classroom of widow's peak to no widow's peak (number of people with a widow's peak divided by the number of people without a widow's peak)?

8) What is true of polygenic traits? Choose all that apply.
a) More than one gene determines the trait.
b) One gene determines the trait.
c) A polygenic trait may have several different phenotypes and genotypes.
d) Polygenic traits have one or two phenotypes.

9) How might speciation occur? Choose all that apply.
a) A population becomes geographically isolated.
b) A population breeds at different times.
c) The behavior of two very similar species makes them unlikely to mate with each other.

10) How did the Abert and Kaibab squirrels become different species?
a) They began breeding at different times.
b) Their behaviors kept them from mating with each other.
c) They could no longer create viable offspring.
d) There populations became separated by a habitat that both populations could not cross.

11) If two populations can and do mate and produce viable offspring, what are they?
a) A single species.
b) Two species.
c) It depends on how often they reproduce with each other.

12) After portion of a population becomes reproductively isolated, what may happen? Choose all that apply.
a) Genes stop flowing between both populations.
b) A mutation may become common in one population, but not the other.
c) Both populations will evolve and change in the same way at the same rate.
d) Two species may form.

13) What did the Grants discover about the medium ground finches of Daphne Major?
a) They annually migrated off the island and returned to Ecuador.
b) The birds were nearly clones of each other.
c) Variation existed in the ground finch population.
d) When they were starving they picked at the tails of large seabirds and drank their blood.

14) Which birds survived more frequently during a drought?
a) Short-beaked birds.
b) Medium-beaked birds..
c) Large-beaked bird.

Student Perceptions of Lecture-Free & Lecture-Based Teaching

After all students had experienced both learning methods, Qwizdom was used to anonymously survey the classes about their views of lecture-free and lecture-based teaching and of the use of Qwizdom. Students "strongly agreed," "agreed," were "neutral," "disagreed," or "strongly disagreed" with seven statements (consolidated into "agree," "neutral," and "disagree" categories in Table 1). Finally, students voluntarily and anonymously provided written responses to three questions about their views on Qwizdom and lecture-free vs. lecture-based teaching.

Pre-Test & Post-Test Results

Although combined pre- and post-test comparisons for all three units showed that lecture-free classes scored on average 2.6% higher than students in the lecture-based classes, the difference was not significant (P = 0.13) (Table 2). Comparing the first pre-test to the second post-test at the end of the course yielded

a smaller gain of 1.7%, which also was not significant (P = 0.64). The Unit 2 test did yield a significant (P = 0.04) gain of 8.1%.

Student Attitudes Toward Lecture-Free vs. Lecture-Based Teaching & Qwizdom

Students had largely favorable impressions of lecture-free teaching methods compared to lecture-based methods (Table 2). A majority of students said they preferred lecture-free methods, that they learned more, and had to use their brains more, when compared to lecture-based methods. A smaller majority felt that lecture-free methodology was the more frustrating of the two approaches. Students clearly agreed with the statement, "Working in small groups to answer questions on Qwizdom is a better way to learn than working individually." Students also agreed, although not as strongly, that small group work on Qwizdom helped them learn more than Powerpoint presentations. The largest proportion (93%) believed that Qwizdom should be used two or more days per week (Figure 3).

Figure 4. Qwizdom software showing correct and incorrect responses for each student and each question.

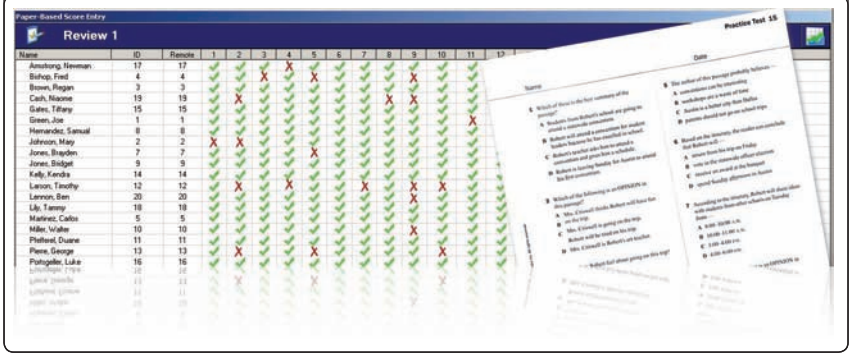


Table 1. Anonymous survey results from 41 sophomores about lecture-free vs. lecture-based teaching and the use of Qwizdom remotes.

	Agree	Neutral	Disagree
I liked the "lecture-free" approach more than the "lecture-based" approach.	51%	22%	27%
The "lecture-free" approach was more frustrating than the "lecture-based" approach.	44%	29%	27%
I feel that I learned more from the "lecture-free" approach than I did from the "lecture-based" approach.	51%	20%	29%
I had to use my brain more in the "lecture-free" approach than I did in the "lecture-based" approach.	68%	22%	10%
Working in small groups to answer questions on Qwizdom is a better way to learn than working individually.	68%	25%	7%
Rather than all "lecture-free" or all "lecture-based" approaches, I think a mixture of the two would be best.	64%	29%	7%
Working in small groups to answer questions on Qwizdom helps me learn more than taking notes from Powerpoint presentations.	49%	32%	19%

Discussion

The testing gains made by students who learned in a lecture-free class were encouraging but were not significantly (P = 0.13) larger and therefore do not definitively support my desired outcome – that is, the less the teacher speaks, the more students learn. Student survey responses, however, were more clearly positive. Averaging student responses to six questions about lecture-free methods and Qwizdom showed that 55% preferred the approach and technology, while only 20% did not (25% were neutral). Based on survey results and verbal feedback, students have a largely positive view of Qwizdom.

As lecture-free students worked on their Qwizdom questions, they often debated their responses, saying something like, "OK, are we in agreement on this one?" after having discussed the various choices and studying the text. Most questions were "Choose all that apply," which greatly increased the difficulty of the question because students had to accept or reject each choice. The exchanges I overheard were consistent with Judson and Sawada's (2002) conclusion that "The only positive effects upon student academic achievement, related to incorporation of electronic response systems into instruction, occurred when students communicated actively to help one another understand." Apparently, these college students needed to talk to each other while using the ARS in order to benefit from it. While my empirical data did not show that a Qwizdom-mediated lecture-free class resulted in significantly greater learning, 68% of my students believed that "Working in small groups to answer questions on Qwizdom is a better way to learn than working individually."

Here are some student comments about lecture-free and lecture-based teaching methods:

- *I like doing the search and learning myself or with others because I can't concentrate when I have to listen for a long period of time.*
- *I think the lecture-free based approach is helpful but is also more of a challenge for me because I am never sure of exactly what questions are right and wrong.*
- *Lecture-free I think is more interesting or active compared to lecture-based where you just take notes and is kind of boring.*
- *Although I can deal with either, I prefer the lectures over the Qwizdoms because the information is more straightforward.*
- *I liked the lecture-free approach because I taught myself and did it how I could learn better instead of being taught in a way I couldn't always understand.*
- *The lecture free approach was difficult because we had to teach ourselves the answers and with the lecture based approach you gave us the answers.*
- *I like the lecture free because it makes me use my brain more and is more challenging. The lecture based is kind of confusing to me.*
- *Lecture free method does not clearly outline what information is needed to score high on tests and even if it does, there is virtually no organization. A problem easily solved by pre-*

senting lectures in a logically organized fashion, i.e., notes.

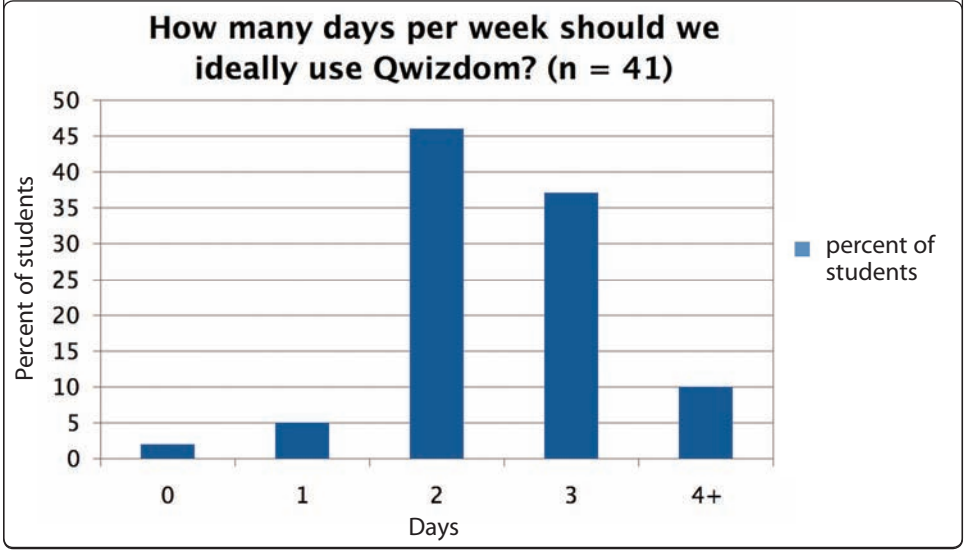
- *I feel like the lecture-based is better for me because when we are done with the notes we can go over them for the test.*
- *I like the lecture-free approach much better because when you use the Qwizdoms you actually have to understand and comprehend it and with lecture I tend to zone out and copy the words.*
- *The lecture-free approach helps me learn the material better. Even though I learn better this way I don't exactly like it. I scored better on the lecture free test than the lecture based.*

Table 2. Average percent increases between post-test and pre-test scores for lecture-free and lecture-based classes. Probability determined by two-tailed *t*-test.

Unit	Number of days between pre-test and post-test #1	Lecture-free		Lecture-based		
		average gain	N	average gain	N	P
1	14	18.8%	24	18.3%	18	0.42
2	26*	20.4%	17	12.3%	22	0.04
4	13	12.2%	19	13.9%	22	0.93
Units 1, 2, and 4 combined	N/A	17.2%	60	14.6%	62	0.13
	Number of days between pre-test and post-test #2					
1	93	20.2%	25	18.9%	18	0.31
2	77	22.1%	17	20.6%	22	0.30
4	34	14.7%	18	13.0%	22	0.57
Units, 1, 2, and 4 combined	N/A	19.1%	60	17.4%	62	0.64

* All units were approximately 10-11 class days. Christmas break occurred in the middle of Unit 2. Post-test #2 occurred during finals week.

Figure 5. Chart showing student preferences on the frequency of Qwizdom use.



The students' comments revealed conflicts about lecture-free vs. lecture-based learning. In particular, some students were frustrated by not immediately knowing if their initial response was correct and resented having to reconsider questions they had already answered. I eventually did explain concepts and ideas that remained problematic, clarifying the material for students who were able to listen for a few minutes. Qwizdom's software, however, plainly revealed those students whose daydreaming commenced when I began speaking. For example, if I **specifically** explained the idea behind a question that most students incorrectly answered, the response chart typically improved dramatically, often to 100% correct. Nevertheless, occasionally a student still did not correct an incorrect response despite rather blunt hints from me. In such cases I sometimes checked in with him or her about the question or simply moved on.

In addition to facilitating lecture-free teaching, Qwizdom is useful as a tool for test review, laboratories, video comprehension guides, and student presentations. I use a video projector to present illustrated review questions to the class before an exam. After all students answer, we view a response chart to immediately check class comprehension for each question. Reviewing the same questions via a competitive game with sound effects and graphics is often the last activity before a test, one that rates high in student involvement. Each of my labs now also has a Qwizdom component. Students take their handheld remotes into the next-door lab room and respond to questions as they conduct the lab. Their answers reveal which parts of the lab are confusing, enabling the teacher to target specific instruction. During videos, students use Qwizdom in lieu of a written comprehension guide. If a student misses a video, he or she views it in the library, answering the questions on paper and later entering the responses into the Qwizdom software. Lastly, students use Qwizdom to generate their own questions to submit to their peers as part of student presentations.

The audience response system Qwizdom has allowed me to make major advancements toward a more constructivist approach in my high school biology classes by allowing me to eliminate traditional lectures. In doing so, student understanding of biological principles has slightly improved or not changed, compared to a traditional lecture format, and student participation, engagement, and enjoyment has increased. Methods used at the university level to eliminate traditional lectures often rely on the college student's maturity and willingness to accept a larger share of the responsibility for his or her learning. High school students, however, are less mature and learn in an environment where attendance is

compulsory; they may find that accepting a larger responsibility for their learning is too daunting a challenge.

By working in cooperative groups with Qwizdom, my high school students have become more active in their learning, and student assessments of the lecture-free approach have been positive. I now talk less and students talk more to each other about biological content and principles. Students frequently re-evaluate ideas and content they had earlier studied, and do so in a framework with enough guidelines to keep them from being overwhelmed. Qwizdom-mediated lecture-free teaching in my high school biology classes has been a success and I do not anticipate a return to traditional lectures.

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