CONTENT VS. LEARNING: AN OLD DICHOTOMY IN SCIENCE COURSES

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ABSTRACT

The principles of course redesign that were applied to a gateway Cell Biology course at the University of Wisconsin-Milwaukee are applicable to courses large and small, and to institutions of any size. The challenge was to design a content-rich science course that kept pace with present and future content and at the same time use principles of active learning to model how science is done, from deduction and inference to the articulation and testing of hypotheses and the interpretation of experimental data. Redesign began with recognition that active learners achieve deeper understanding than passive learners. Key features of the resulting blended course include (a) online delivery of all basic content; (b) greater responsibility of students for their own learning; (c) student-centered activities with specific learning objectives; (d) a new balance of summative and low- stakes progressive assessment of student achievement of learning objectives. In the final version of the blended course, there are no F2F lectures. Freed from the anxieties of content coverage, the instructor facilitates student engagement with content and with each other in assessed activities that support broadly defined *essential learning outcomes*. Samples of integrated online and F2F interactive, collaborative learning activities are included with preliminary data indicating a positive impact of blended learning in Cell Biology.

KEYWORDS

Course design, instructional design, active learning, science, student-centered, progressive assessment, engagement, essential learning outcomes, integrated online and face to face

I. INTRODUCTION: AN OLD DICHOTOMY IN SCIENCE COURSES

Introductory and gateway science courses are a feast of rich content. Jargon, details and concepts of biology (or chemistry or geology…) must be learned before students can meaningfully explore, manipulate and describe their experience of the discipline. Most often basic content is covered by assigned text readings, these days often supplemented by web content including readings, animations and other video presentations. Then, whether in a large lecture hall or in a smaller classroom, F2F time is spent re-covering the content, chapter and verse. This kind of learning is mainly focused on repetition and memorization while pedagogic practices leading to deeper learning are relegated to upper level and graduate courses. The result is the perpetuation of a long-discredited system of passive 'lecture hall' instruction [1, 2].

Our continued reliance on lecturing as a primary mode of instruction [3-6] is all the more puzzling given the timeline since Dewey's original *constructivist* theory of learning beginning in the early 20th century [7], later refined by Ausubel [8]. The theory posits that students learn best when they create knowledge by organizing new information within a framework of existing knowledge and experience. Instructors facilitate the process of organization while students learn by actively by making connections and thinking more critically about course content than passive learners. As early as 1983, the National Commission on Excellence in Education called for *more* student-centered courses to meet defined "student outcomes" [9]. Writing recently on the *Dysfunctional Illusions of Rigor*, Nelson reviews studies that time and again refute the efficacy of the traditional lecture mode of instruction, suggesting in no uncertain terms that effort *spent on improving lectures* (as a way of improving learning) *was a waste of time in comparison with that spent on transforming the pedagogy* [10].

Despite more than 20 years of evidence that active learning supports knowledge construction and deep learning in the sciences [10-16], colleges and universities have been discouragingly slow to implement change. Whether from misguided pride or a pedagogical misfire, required introductory courses continue to be treated as *weed-out* courses in which students who memorize and test well are more likely to succeed. This intentionally exclusionary approach consigns otherwise bright and capable learners to non-science careers in an era when we need more scientists and a more scientifically literate citizenry. *Weed-out* practices persist (with evident adverse consequences) even in the face of data suggesting that while more student engagement helps all students, the inherent inclusivity of engagement may benefit "underserved" students even more than "more advantaged students" [17].

Consonant with the demonstrated merits of engagement pedagogies, the American Association of Colleges and Universities (AACU) recently inaugurated a *Liberal Education and America's Promise* (LEAP) initiative defining *essential learning outcomes* including among others critical thinking, inquiry and analysis, and quantitative literacy [18]. These outcomes are essential to a science education. It is against this background that a traditional Cell Biology course was redesigned to the blended format. The challenge in low- or high-enrollment classes in any size institution is to introduce more active, collaborative learning and student engagement into science courses [19] without compromising basic content delivery. To meet the challenge, students must take greater responsibility for acquiring new content while instructors must monitor and assess the integration of new information within students' cognitive framework, i.e., the 'construction' of knowledge. Specific course learning objectives should be articulated and directed at broader disciplinary and institutional *essential learning outcomes*. The blended learning model seemed ideally suited to achieve these goals and to satisfy the needs of students for more flexible course scheduling options. The choice to design the blended course was thus opportune, fueled by growing numbers of children of baby boomers and returning students [20-22]. The transition to the blended cell biology course described here invoked Wiggins and McTighe's principles of 'backward design' [23,24], informed by a constructivist model of assessed learning objectives. The blended Cell Biology course that finally emerged integrates fully online delivery of basic content with 100% interactive classroom activities. The prime motivation then, in writing this article is to promote blended learning in the sciences as perhaps the best way to achieve the dissemination of all relevant course content while at the same time allowing unprecedented opportunities for student engagement, collaborative learning and construction of knowledge to model the practice scientific (critical) thinking.

II. STEPS IN COURSE REDESIGN

To permit some experimental freedom without overloading the instructor or students, the first versions of the blended course enrolled 35-40 students. In the future, the course will be open to 80-100 students, enrollments typical of our F2F Cell Biology sections. The redesign is described below, followed by specific examples of learning modules that address specific learning goals directed at overarching essential learning outcomes.

The original F2F Cell Biology course met twice a week for 150 minutes. A map of this course is shown in Fig. 1A. Seat time in the blended course was cut in half, meeting once a week. The blended Cell Biology course matured in two iterations. The first version of the blended course introduced a *muddiest points* activity and placed a portion of the course lectures online, chunked out as 10-20 minute voice-over PowerPoint[tm] recordings (VOPs; Fig. 1B). Homework/online activities also included asynchronous *Discussion forums* and several formal *writing assignments*. Fewer lectures in the classroom allowed time for interactive and collaborative activities including the clickers (student response systems) and open-ended *Index Card* activities. In the second offering of the blended course all lectures were recorded, eliminating classroom lecturing (Fig. 1C).

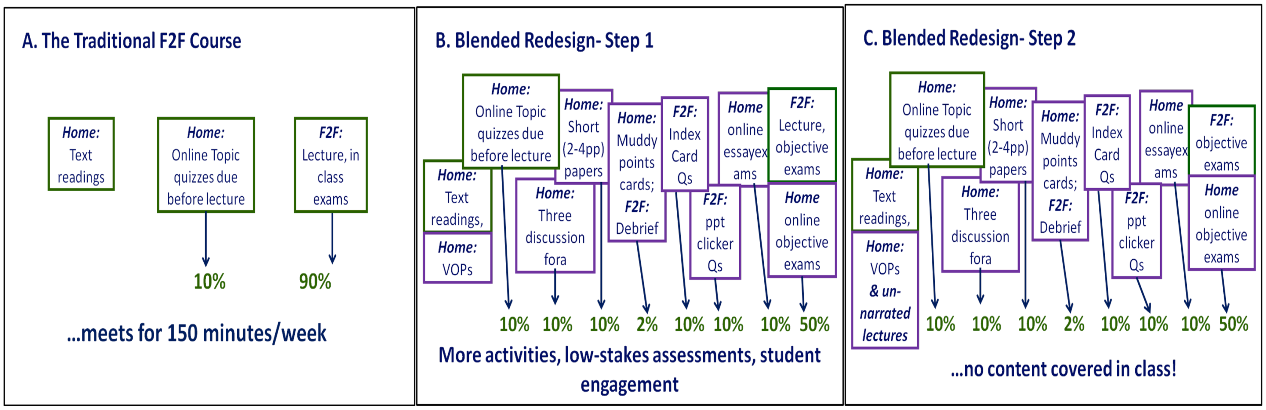

Fig. 1: Transition from a Face-to-Face Cell Biology course (panel A) to the blended Cell Biology Course in two steps (panels B and C). Redesign elements are boxed in purple. Note the increase in, and greater emphasis on low stakes assessments in the blended courses, and the elimination of in-class lecturing in the final version of the course (panel C).

A key feature of the redesign process was an increase in the number and value of formative assessments. The latter was accompanied by the devaluation of summative assessments (objective exams) from 90% to 50% of the final course grade (cf. Fig. 1A and either 1B or 1C). Note also that the total value of assessments in both offerings of the blended course sum to 112% (100% was a perfect score). This was intentional, to give students alternate ways to demonstrate understanding of cell biology by the achievement of different learning objectives. Though Figures 1B and C look similar, the big difference between the two blended courses is that there is no longer any lecture-based content delivery in class

Creating the VOP lectures represented a significant initial time investment. The goal was to create re-usable recordings focused on stable, unchanging course content that could be easily re-used. Scripts were written to ensure as smooth a lecture delivery as possible. Another advantage of these scripts is that they can (and will!) be incorporated into the VOPs in the next offering of the course to meet accessibility mandates for hearing impaired students. With all of content (readings, VOPs) moved online, and with no in-class lectures, F2F activities were entirely focused on student engagement with content and each other. There was ample time for students to tackle challenging (clicker and essay) questions in class that modeled scientific thought and collaboration.

One danger in redesigning a F2F course to the blended mode is that online exercises are simply added to the existing F2F activities without regard to how online and F2F learning will work together. This often leads to a work overload for students… and for instructors that must grade assignments. In the blended Cell Biology course, classroom learning did not repeat, but was based on students reading assigned pages in the text and viewing VOPs. The asynchronous interactive discussions were based on content explored in depth in the classroom. Thus, online activities, readings and classroom activities were mutually reinforcing. This two-way integration was an intentional feature in the design of the blended Cell Biology Course, ensuring a manageable workload and that the course was not in effect split into two concurrent but parallel 'courses.'

III. EXAMPLES

The description of each of each of the following activities is accompanied by its *learning objective(s)* and the *essential learning outcomes* supported by the activity. The relative values of each are included in the description, with implicit or explicit commentary on how the activities are integrated in the course.

A. Muddiest Points Allow Students to Inquire

As they enter the classroom, students must hand in an index card articulating something that they did not understand from the weekly readings or viewings. Some questions just ask for simple clarification, e.g., *What is the difference between a myofiber and a myofibril?* A more reflective question was: *After a strenuous workout, lactic acid builds up (in skeletal muscle) and causes the 'burn' sensation. This is* *because lactic acid is one of the end-products of fermentation (anaerobic respiration). Why does your body choose the anaerobic respiration pathway when your heart rate and respiration rate are increased? If you are breathing faster and deeper and taking in more oxygen, why is anaerobic respiration used?*

At each class meeting, the first activity was to read aloud some of the more substantive questions (without attribution of course) for other students to try to discuss and answer. This debriefing of muddiest points could take 10 to 20 minutes, after which all selected questions were answered, either by classmates or the instructor. Students whose muddiest points were not answered in class were encouraged to submit their questions by e-mail. By the end of the semester, submission of muddiest point cards was worth up to 2% of the final course grade.

B. Index Card Questions Engage Students in F2F Collaboration, Analysis and Critical Thinking

Index Card Exercises present scenarios or experimental data not encountered elsewhere in the course. They are embedded in a set of interactive classroom Power-Point slides. In a typical example students collaborate to think critically about the evidence presented and articulate a reasonable explanation for the phenomena observed. Students then record their responses on an index card individually in their own words, or by consensus as a group. Consider the example below:

A ship's captain visiting a far-away paradise island saw much livestock and produce. Years of breeding had recently yielded a variety of fast-growing maize with more and larger kernels on the cob. So island farmers stopped growing the other varieties of maize. Needless to say, the captain was well pleased to re-store her ship from the available abundance. Some years later, the captain returned with her ship to find the island desolate, strewn with animal and human remains. Why?

For this exercise, students seated near each other were instructed to work in impromptu groups of 3-5 (no more, no less). They spent ~10-15 minutes discussing this scenario and then recording a consensus response on a 4 x 6" index card (some exercises allow even more time). Group members sign the card. At the end of this exercise students should understand that evolution leads to species diversity and be able to explain the true value of diversity (even human diversity!).

Index Card Exercise questions build on material students have studied at home or anticipate online learning in the immediate future. Slides preceding the question slide often come from PowerPoint^{tm} slides viewed online as a reminder of essential principles or facts that should help them deal with the question. An index card question might even be followed by a relevant or reinforcing C*licker Slide Question* (see below). Responses are scored based on the quality of thought, logic, and correctness of the answer; for group responses, all group members get the same score. Whether scored as individual or group responses, students achieve deeper learning through discussion, analysis of observations and experimental results, and interpretation of data (i.e., formulation of hypotheses). In aggregate, a semester's worth of Index card exercises is worth 10% of the final grade. Multiple Index Card Exercises were prepared for each class meeting, though they are usually not all completed. After class, all of the questions are posted on the course management site for students to try out and review. A key is made available a few days before exams.

C. Clickers Engage Students in F2F Collaboration, Analysis and Critical Thinking

In any class, clickers (student response systems) are a painless way to increase student participation and attendance [25-27]. The technology involves students using a hand-held keypad (the *clicker*) to answer multiple choice and true/false questions projected on a screen. I use clickers because in large or small enrollment classes, they engage not just a few, but *all* students with each other and with the class material. Of course, they can be especially effective in the F2F portion of a blended course. I post and/or record PowerPoint^{tm} lectures without clicker questions, but with open-ended questions on which clicker question in class can be based. Because they reinforce learning, the combination of in-class clicker slides and the relevant slides from posted lectures are mutually reinforcing learning objects [28]. While clicker questions necessarily present choices from which students must select an answer, they can be used to promote classroom discussions that more deeply probe conceptual understanding and develop analytical skills. The example in Fig. 2 is actually a follow-up to the sample Index Card Exercise above.

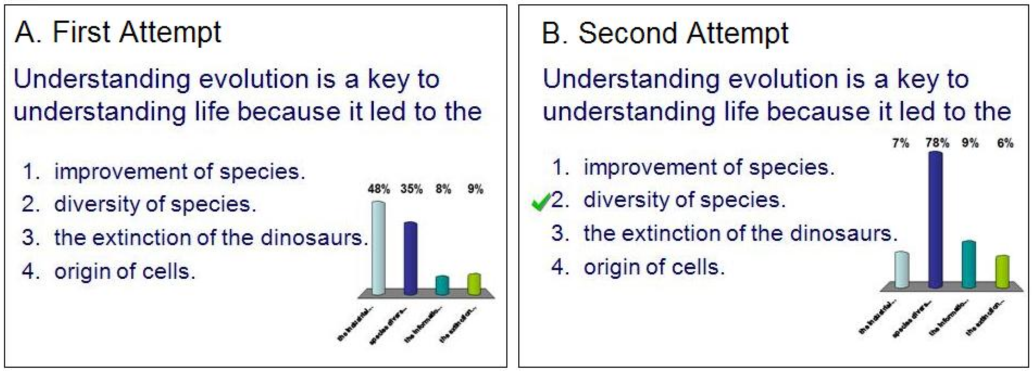

Figure 2: In the first response to this question probing student understanding of the connection between evolution and species diversity, only 35% of the students answered correctly. After allowing students to discuss the question among them and to respond to the question a second time, 78% of the student's answered correctly.

From panel A, it is clear that most of the students did not understand that evolution in fact accounts for species diversity. After the slide was re-set, students had a few moments to discuss their responses with classmates in their immediate vicinity. They then responded again, with a much better result. The learning objectives here were to have students engage on peer instruction and to recognize that evolution drives species diversity. As with the index card challenge questions, the technique of allowing students to talk about clicker questions in class, either before *or* after an initial response, fosters critical, scientific thinking. Used as described, clicker questions support several essential learning outcomes such as, interpretative, inquiry and analytical and quantitative literacy skills.

Clicker questions can also be used to get students to think about experiments and interpret quantitative data, as in the example in Fig. 3. This question usually elicits at best a plurality of correct responses, after which I again reset and allow students to discuss and respond a second time to the question. Classroom PowerPoint^{tm} slide sets usually include 25 or more clicker questions as well as the Index Card exercises. If all of the clicker questions can't be completed in class, students can access the entire set after it is posted to the course management course site. All classroom slide sets and answer keys are posted for review and study before exams. In the blended Cell Biology course, students earn 'clicker' points whether they answer the questions correctly or not. Clicker use is now worth more than 10% of the final grade.

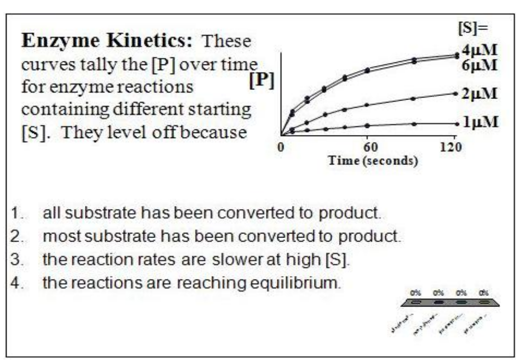

Figure3: Interactive clicker question requiring analysis and interpretation of quantitative data.

D. Crossword Puzzles Provided Online Help Students Study for the Cumulative Final Exam

Looking more like a Scrabble[tm] board, these crossword puzzles are low-stakes exercises designed to get students to work the puzzles with classmates as a way of studying for exams (e.g., Fig. 4). One goal was that students practice and become familiar with the terminology and the jargon of cell biology. Another

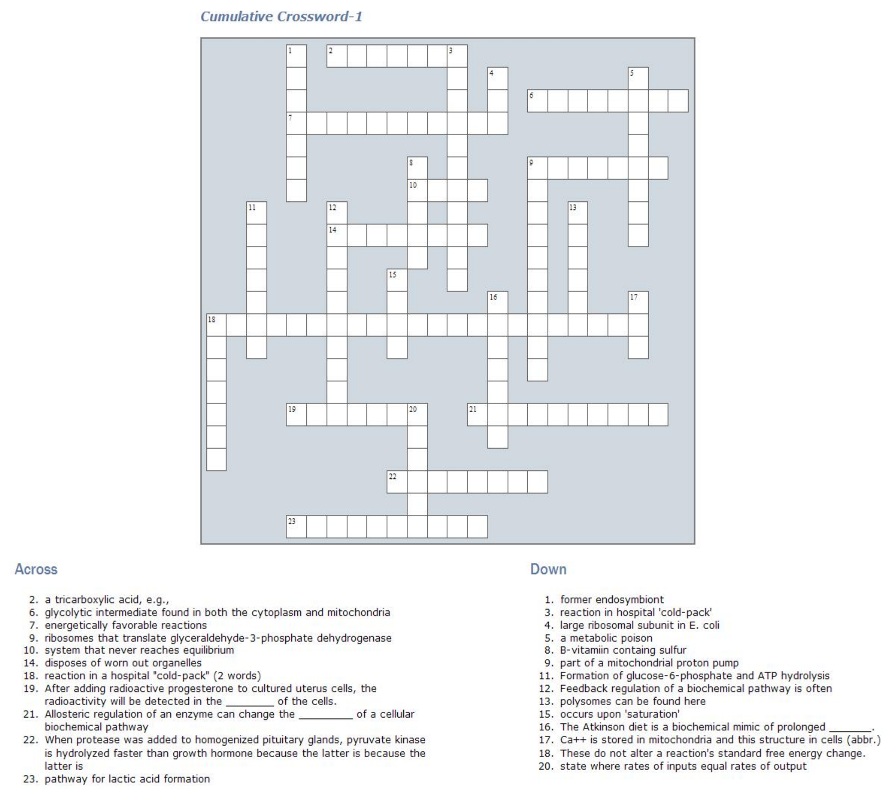

Figure 4: Sample Crossword Puzzle used to facilitate study prior to summative exams

was to encourage correct spelling (these were crossword puzzles after all)! Note that some of the clues go well beyond definitions, requiring more critical understanding of concepts. Multiple crossword puzzles are provided in the week prior to each summative exam. All of the puzzles earn extra credit, in aggregate worth 1.5% of the final grade. Students are instructed to print the puzzles out and encouraged to work on them together. To get credit for the puzzles, students must enter the terms and expressions in their puzzle into a corresponding online fill-in-the-blank quiz. While only about half of the class tried their hands at the crossword puzzles, anecdotally two or three students were often discussing their answers as they walked in to class the week of the exams. Evidently for some, solving the puzzles was a group effort.

E. Fostering Scientific Literacy with Short Writing Assignments

Blended Cell Biology was a chance to introduce short writing assignments. A 4-6 page paper was based on an article that appeared recently in the lay press (*Time Magazine*, *Newsweek*, *U.S. News*, etc.). This paper was worth 3% of the final course grade. Instructions (edited for brevity) are shown below:

Scientists speculate that Abraham Lincoln suffered from one of several possible congenital illnesses. With the advent of modern biotechnology and the preservation of artifacts of his assassination, it is possible to ask just what the disease was. Write a 4-6 page (1000-1500 word, double spaced) paper on the topic of *Lincoln's Genes.* You must submit your paper to the Lincoln's Genes folder in the D2L Dropbox no later than May 4th at 11:59am. For full credit on this paper, address/include all of the following:

Introductory paragraph: describe the causes and symptoms of several of the genetic diseases that scientists speculate our 16th president may have suffered from, and introduce one of these illnesses that you will discuss in greater detail in this paper.

The body of your paper: Divide this section into as many paragraphs as you think appropriate. Start by describing in greater detail the genetic disease that you chose, and why some scientists think that Lincoln had it. Relate how and when the gene associated with this disease was discovered, what the normal version of the gene does (and when), and how the mutation in the gene causes the disease or symptoms of the disease. Describe (in overview) how scientists cloned and characterized the gene. Describe (in overview) the methods one might use to see if Lincoln had this mutant gene.

Concluding paragraph: Summarize the key points you made in your essay, and to offer opinions of your own about any aspect of what you learned in writing this easy.

Citing Sources: You can use any source to learn about your subject. Begin your search using any available resources (e.g., Google, library databases); see a librarian at the reference desk for assistance. Here are some basic guidelines on how to evaluate sources you discover on your topic. The best sources are peer-reviewed, with named authors. At least two of the sources you cite must be original, peer-reviewed research articles describing experimental methods, results and discussion by the actual researchers. If you are in doubt about whether your articles meet these criteria, send me the full citation, or check with the reference desk at the library. Original research articles and 'review' articles cite other sources that you may find useful; even Scientific American articles typically include a few additional readings at the end. Other permissible articles can include blogs, websites/links and the like. However these make few attributions. If you use them, make sure that you do not quote as fact what are either opinions or statements that advocate a point of view.

How to cite permissible sources: Cite permissible sources in the text of your paper, where you are referencing the information they contain. Citations of sources should appear in a *References* section in a consistent style (which you can model from any good research article). Do the best that you can when referencing articles on-line, keeping in mind that a reader must be able to readily access your sources from your citations.

These instructions indicate the breadth, depth and citation source requirements expected in the essay. They even suggest how students can organize their findings and ideas (most students opted to follow this ‘outline’). The learning goals of this assignment are to foster students’ ability to critically assess research articles and make science understood to others (in other words to develop and practice scientific literacy). These are key learning goals for any student of science that support the essential learning outcomes of improved reading, analytical, critical thinking and writing skills. A shorter (1-2 page) reading and writing assignment with similar objectives and expectations was worth 2% of the final grade. The grading rubric for each writing assignment was based on the requirements in the instructions. Spelling counted, but in lieu of grading grammar, a more subjective requirement was that “your Mom should be able to read and understand what you wrote!”

F. Discussion Forums as Study Aids

Like the crossword puzzles described above, discussions were designed with the goal of helping students study for exams. Students were divided into groups of 6-8 and required to write multiple choice questions of their own based on topics covered in an upcoming exam. Each student was then required to answer several of the questions submitted by a classmate and to explain their choices. Questions and explanations were graded; both the questions and responses/explanations had to meet specified criteria. Instructions applicable to these discussions are shown below:

> **Create multiple choice questions** of the sort you might expect on exams. The topics in this Discussion Forum precede, and should help you study for course exams. Read the instructions for each topic carefully before composing and posting your responses. Then, post your questions.

At the appropriate time, post answers to classmates' questions with an explanation of your answer choices. Your questions should ask about concepts or experiments requiring factual knowledge, and must not be simple recall questions or questions asking for the definitions of terms.

Here's a sample 'bad' question:

The organelle that oxidizes pyruvate is the

a) nucleus. b) lysosome. c) mitochondrion. d) chloroplast.

Here's a sample 'good' question:

In mitochondria, electrons flow from

a) pyruvate to acetyl-CoA. b) acetyl CoA to pyruvate. c) Pyruvate to NAD+. d) NADH to Acetyl-CoA.

IV. IMPACTS

Any one active learning strategy typically addresses more than one of the AACU essential learning outcomes [18]. While many studies support the efficacy of active learning, higher level learning outcomes are hard to measure and the effects of active learning on retention based on standardized exam performance are equivocal [reviewed in 11, 29]. For example, compared to traditional teaching, problem-based active learning had significant positive effects on long-term retention measured by exam performance [30, 31], but other studies showed only weak positive effects [32]. Yet other studies showed that active-learning medical students show modestly higher levels of clinical performance while more often than not scoring lower than traditional learners on exams [33, 34]. Clearly the contribution of active learning to improved learning outcomes may be subject to opposing interpretations. While all of the exercises exemplified here are student-engaged and interactive, the Index Card, Clicker questions and Essay Exam questions were essentially collaborative problem-based activities. All except the clicker questions involved student writing, but even with explicit rubrics, scoring these exercises is inherently subjective; one instructor's scoring can differ from another's. Thus, determining the impact of active learning in the blended Cell Biology course is no less subject to uncertainty than doing so in other courses represented in the studies mentioned. In spite of these caveats, some data was collected and some preliminary comparisons were attempted.

Where student opinion was sought, students have very favorable perceptions of active learning. Though not used in the F2F courses, clicker participation was a high point of the blended Cell Biology course, with 73% of 52 end-of-course student survey respondents agreeing or strongly agreeing with the statement that *The interactive 'clicker' questions presented in class made the class more interesting.* Almost 79% agreed or strongly agreed with the statement that *The interactive 'clicker' questions helped me learn the material in the course.* This high level of appreciation mirrors student opinion in this instructor's F2F introductory biology classes where clicker questions were first used to engage student in collaborative learning in large classes of over 250 students. In survey data taken over 5 years in these classes, levels of agreement with the same statements were >85% and >65% respectively (unpublished data).

Summative exam scores may be comparable despite differences in the value and administration of summative (objective) exams in the F2F and blended courses. One difference is that these exams were the sole basis of the final grade in the traditional F2F course; they were only worth 50% of the final grade in the blended course. Also, F2F course exams were taken in the classroom. In the blended course only the cumulative final exam was taken in the classroom; two exams were taken online. Online exams allow for open books and collaboration, though conditions of online exam administration limited both. On the other hand, questions on all exams tested at different levels of cognition. Most required concept recognition and retention while 15-20% of the questions tested deeper levels of analysis and critical thinking. Furthermore, by agreement with the Biological Sciences Department and colleagues teaching the F2F courses, 4-5 of the questions in the blended section exams were identical to more challenging questions in the F2F exams. A preliminary comparison of exam scores between the F2F and blended courses indicate no differences exams are compared between the traditional F2F and blended courses the data suggests no differences (Table 1).

Year	Average Exam Scores (+/-SD)				
	Exam 1	Exam 2	Exam 3	3-exam average	n
F2F spring '08	69.5 (+/-12.2)	64.7 (+/-14.5)	64.6 +/-(13.7)	66.2 (+/-11.9)	88
F2F spring '09	66.5 (+/-13.0)	67.6 (+/-11.6)	66.3 +/-(12.4)	66.8 (+/-10.8)	83
F2F Averages	68	66.2	66.5	66.5	171
Blended spring '08	64.8 (+/-9.7)	63.0 (+/-10.6)	65.9 +/-(13.7)	64.6 (+/-11.1)	26
Blended spring '09	69.8 (+/-9.2)	62.5 (+/-11.0)	65.1 +/-(11.3)	65.8 (+/-8.5)	33
Blended Averages	67.3	62.8	66.5	65.2	59

Table 1: Comparison of the average of averages of 3 exam scores of students in F2F and blended Cell Biology courses

One may conclude from this data (especially for cumulative final exams taken in the classroom) that active learning in blended cell biology courses had no negative effect on recall and retention. There seems to be no learning tradeoff incurred by recording lectures, moving them online and fully engaging students in interactive and collaborative learning activities the F2F portion of a blended course. Adding the average overall student evaluation of the second blended course offering of 4.0 out of 5.0 on the end-of-course survey, these are solid reasons for continuing to offer the blended Cell Biology course.

V. FUTURE DIRECTIONS

Based on having recently taught this course fully online, several course components items will be added:

Discussion Forums will ask students to respond to questions arising out of experimental scenarios or counter-intuitive cell and molecular phenomena. These will require ~300 word postings and 200+ word replies. These discussions will replace some of the multiple choice question discussions described above and will foster asynchronous collaboration and enhance critical thinking and writing skills.

A group project involving creation of a PowerPoint^{tm} presentation will also be included in the course, in lieu of one of the short writing exercises. The project proceeded in a series of steps, each with its own deadline, where meeting deadlines and productive collaboration were scored. The final PowerPoint^{tm} slide set is also graded on the basis of a set of criteria provided to the class. Because this is a blended course, students will also organize a presentation, which will also be graded. The group project will foster true 'learning communities' in which student engage in peer instruction. It also takes students into a collaborative realm that more nearly mimics a modern workplace, with individual responsibilities meeting deadlines for project design and group responsibility for delivery of a competent final product.

Another addition to the blended course, also based on a very successful component in the fully online course, is a Muddiest Points Discussion forum with instructions similar to those below.

> **<u>Muddiest Points Discussion</u>**: This Discussion is open to the whole class. You should post your own questions about what you are learning in the course, and/or replies to the questions of your classmates. You will earn credit for your replies (not your questions). **To get full credit (5 points), you must answer at least 5 of your classmates' questions during the semester.** After completing the weekly reading, viewing and listening assignments, or quizzes, use these weekly

Discussion topics to post questions about whatever is still unclear to you (a 'muddy point'). In your posting your question, please be specific and clear; guide us to what you have read or seen/listened to that is confusing, and tell us specifically what part (concept and process, experiment, etc) you did not understand. Remember, to get a good answer you must ask a good question!

When you are posting a muddiest point question referring to material in text readings, PowerPoint^{tm} Practice Questions or D2L Quizzes or any other source, **it must be possible to respond to your question without hunting for your sources.** Please cite your source(s) but also

- Indicate whether you are asking a question about text material, VOPs, PowerPoint^{tm} Practice Questions, Quizzes, Exams, etc.
- If you are asking about material in the text, cite the page number and type in the text of what you did not understand.
- If the question is about a PowerPoint^{tm} Question Set, D2L Quiz or Exam question, cut and paste the actual text from the PowerPoint^{tm} Question Set, quiz or exam that puzzled you.

When posting a reply to a classmate's question, first read through all of the postings; your questions may already have been posted and gotten some response. You will benefit more by contributing to an ongoing discussion thread about your muddiest point. In your reply, cite a source(s) that supports your answer or explanation. Sources can include our text, VOP or other reliable source. When citing sources, provide enough information for a reader to get back to the source. Your reply must be thoughtful, reflecting that you have read and understood the material relevant to your answer. Answering a simple question requiring a one-word or single sentence answer that you could get by reviewing the assigned material is not acceptable. Also, while you can add substance to another classmate's reply, you may not simply reiterate that classmate's reply. To get credit for replying to these kinds of questions, you must still provide some context and substance (call it 'value-added') to your response. How many of the 5 points you get will depend on it. While instructors will occasionally comment or guide your Muddiest Point discussions, you should use this space to learn from, and explain aspects of cell biology to each other.

This discussion forum captured nearly 280 posts and replies from about 60 students during the semester, with little instructor input. The postings and especially the replies were of remarkably high quality. If online muddiest points are incorporated into the blended course, they will serve instead of the paper-based muddiest points to initiate discussions in the classroom. Finally, students will still be allowed to demonstrate learning and the achievement of learning goals in different ways, the total value of assessments will be reduced to about 105%, i.e., 5% of extra credit.

VI. PRACTICAL CONCLUSIONS

Designing a blended course typically means adding more formative assessments and reducing the value of summative assessments. Consistent with the former, blended instruction is also an opportunity to introduce asynchronous online discussions and essays or other formal writing assignments in science. For all new assessments, especially discussions and writing assignments, it is useful (read ‘necessary’!) to provide explicit instructions and expectations for the assignments. Model assignments work well to show those expectations. To maintain instructor sanity, discussions and writing assignments must have scoring *rubrics* based on expectations and instructions. When contemplating VOPs, record the stable fundamentals of your discipline small chunks (10-20 minute videos); when the spirit moves, record short updates. If for larger classes (more than ~50) you are able to get a teaching assistant or grader, get a young one, be prepared to spend some time training them and hope that they will be available for several years! This applies to any instructor, but especially to faculty with significant research responsibilities. To sum up, redesigning the F2F Cell Biology course to the blended format was an effort, but the payoffs were:

- the archiving of enduring, easily updatable course materials,
- an opportunity to cover (judiciously) more rather than less content,
- more student collaboration and engagement with content and concept,
- more and deeper learning, and not least,
- a more enjoyable, more effective way of teaching and learning science.

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VIII. ABOUT THE AUTHOR

Dr. Bergtrom has been a researching faculty member in the Biological Sciences Department at the University of Wisconsin-Milwaukee for more than 30 years, with interests in cell biology and molecular evolution and teaching responsibility for introductory and upper-level gateway courses in the biology major curriculum. For the last four years he has also been appointed to the UW-M Learning Technology Center. Having pioneered the use of student response systems ('clickers') and taught the first blended course in the sciences, he now enjoys training colleagues across disciplines in the best practices of both.

IX. REFERENCES

1. **Nelson, C.E.,** Skewered on the unicorn's horn: the illusion of a tragic tradeoff between content and critical thinking in the teaching of science. In: Crowe, L.W., (Ed.), *Enhancing Critical Thinking in the Sciences,* Washington, D.C.: NSTA Press, 17-27, 1989.
2. National Research Council, *From analysis to action; undergraduate education in science, mathematics, engineering and technology*, Washington, D.C.: National Academy Press, 1996.
3. **Ebert-May, D., & Brewer, C.A..** Innovation in large lectures -- teaching for active learning. *Bioscience* 47: 601-607 (1997).
4. **Zoller, U.** Teaching Tomorrow's College Science Courses--Are We Getting It Right? *Journal of College Science Teaching,* 29: 409-414 (2000).
5. **Lazerson, M, Wagener, U., & Shumanis, N.** What Makes a Revolution? Teaching and Learning in Higher Education, 1980-2000. *Change* 32: 12-19 (2000).
6. 6**. Bok, D.,** *Our Underachieving Colleges. A Candid Look at How Much Students Learn and Why They Should Be Learning More,* Princeton, NJ: Princeton University Press, 2007.
7. **Dewey, J.,** *Democracy and education*, New York: MacMillan, The Free Press, 1916.
8. **Ausubel, D.,** *The acquisition and retention of knowledge: A cognitive review*, Boston, MA: Kluwer Academic Publishers, 2000.
9. National Commission on Excellence in Education. A Nation at Risk: The Report of the National Commission on Excellence in Education. *Phi Delta Kappan* 65: 14-18 (1983). http://www2.ed.gov/pubs/NatAtRisk/index.html.
10. **Nelson, C.E.,** Dysfunctional Illusions of Rigor: Lessons from the Scholarship of Teaching and Learning. In: Nilson, L.B., and Miller, J.E. (Eds.), *To Improve the Academy: Resources for Faculty, Instructional, and Organizational Development*, *Vol. 28*, San Francisco, CA: Jossey-Bass, John Wiley & Sons, Inc., 2010.
11. **Bonwell, C.C., & Eison, J.A.,** *Active Learning: Creating excitement in the classroom* (ASHEERIC Higher Education Report No. 1), Washington, D.C.: George Washington University, 1991. http://www.ntlf.com/html/lib/bib/91-9dig.htm.
12. **Lord, T.R.,** Using constructivism to enhance student learning in college biology. *Journal of College Science Teaching* 23: 346-348 (1994).

13. **Weld, J.** Save Your Lecture For Someone Who Cares. *Journal of College Science Teaching* 31: 489-490 (2002).
14. **Handelsman, J., Miller, S., & Pfund, C.,** *Scientific Teaching,* New York: The Wisconsin Program for Scientific Teaching (W. H. Freeman), 1-45, 2007.
15. Farrell, J.B. Active Learning: Theories and Research. Jewish Educational leadership 7(3) (2009). http://www.lookstein.org/online_journal.php?id=260.
16. Bergtrom, G., On Offering a Blended Cell Biology Course. J. Res Center Ed. Tech. 5: 15-21 (2009). http://www.rcetj.org/index.php/rcetj/article/view/12
17. **Kuh, G.**, *High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter*, Washington, D.C.: AAC&U, 2008.
18. Liberal Education and America's Promise (LEAP), *Essential Learning Outcomes*, Washington, D.C.: American Association of Colleges and Universities (AAC&U), 2010. http://www.aacu.org/leap/vision.cfm
19. **Wyckoff, S.** Changing the Culture of Undergraduate Science Teaching. *Journal of College Science Teaching* 30: 306-312 (2001).
20. **Bonk, C.J., & Graham, C.R.** (Eds.), *Handbook of blended learning: Global perspectives, local designs*, San Fransisco, CA: Pfeiffer Publishing, 2005.
21. **Allen, I. E., & Seaman, J.,** *Entering the mainstream: the quality and extent of online education in the United States, 2003 and 2004*, Needham, MA: Sloan-C, 2004.
22. **Vignare, K.,** Review of literature blended learning: using ALN to change the classroom – will it work? In: *Blended Learning Research Perspectives*. Needham, MA: Sloan-C., 2007.
23. **Wiggins, G. & McTighe, J.,** *Understanding by Design*, Englewood Cliffs, NJ; Prentice Hall. 2000.
24. **Wiggins, G. & McTighe, J.,** *Understanding by Design*, *Expanded 2nd Edition*, Alexandria, VA: Association for Supervision and Curriculum Development (ASCD), 2005.
25. **Mazur, E.,** *Peer instruction: A user's manual*, Upper Saddle River, NJ: Prentice Hall, 1997.
26. **Beatty, I.** Transforming student learning with classroom communication systems. *Educause Research Bulletin* 2004: 2-13 (2004). http://www.educause.edu/ir/library/pdf/ERB0403.pdf.
27. **Kaleta, R., & Joosten, R.** Student response systems: A University of Wisconsin System Study of Clickers. *ECAR Research Bulletin* 10: 2-12 (2007).
28. **Bergtrom, G.** Clicker sets as learning objects. *Interdisciplinary Journal of Knowledge and Learning Objects* 2: 105-110 (2006).
29. **Prince, M.** Does Active Learning Work? A Review of the Research. *J. Engr. Education* 93: 223-231 (2004).
30. **Norman, G., & Schmidt, H.** The Psychological Basis of Problem-Based Learning: A Review of Evidence. *Academic Medicine* 67: 557-565 (1993).
31. **Gallagher, S.** Problem-Based Learning: Where did it Come from, what does it do, and where is it going? *J. Education of the Gifted* 20: 332-362 (1997).
32. **Lott, G.** The Effect of InquiryTeaching and Advance Organizers upon Student Outcomes in Science Education. *J. Research in Science Teaching* 20: 437 (1983).
33. **Vernon, D., & Blake, R.** Does Problem-Based Learning Work? A Meta-Analysis of Evaluative Research. *Academic Medicine* 68(7) (1993).
34. **Albanese, M., & Mitchell, S.** Problem-Based Learning: A Review of Literature on its Outcomes and Implementation Issues. *Academic Medicine* 68: 1 (1993).