Case Study

Enabling Interactive Engagement Pedagogy Through Digital Technology

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ABSTRACT

For most college and university faculty, there seems to be no shortage of digital tools available for use in teaching. Think for a moment about such technology as presentation and communication tools, the internet, the laptop computer, and personal response systems (i.e. clickers) and what such tools have done to change the classroom learning environment. Such change, however, begs an important question for faculty to consider: In what ways have digital technologies enhanced student learning? Such a question is addressed in this paper as the authors explore the overall impact of digital technology on student learning in undergraduate biology courses in the U. S. More specifically, this paper weaves a historical, theoretical and philosophical perspective about life science education reform efforts aimed at providing undergraduates with interactive learning experiences, and in doing so offers readers a framework for a more focused understanding about how digital technology can lend itself to good teaching that is interactive and dependent upon well thought out learning outcomes. Further, the authors provide readers with descriptive examples of practical applications for digital technology use in the interactive biology classroom, and conclude by positing some key questions that serve to guide faculty who wish to use their research skills to understand how their own use of digital technology affects student learning.

Key Words: assessment, digital literacy, digital technology, educative assessment, forward-looking assessment, foundational knowledge, just-in-time-teaching, interactive learning environment, learning activities, learning outcomes, life science education reforms, self tutorials, scientific teaching, significant learning, student-centered learning environment, visual/spatial imagery

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> *Wide-eyed first semester freshman filed past the metal desk at the front of the room and dispersed among the 30 seats facing black slate-topped immovable benches. Preserved animal specimens, skeletons, lab solutions and a variety of unused artifacts, sat idle behind the glass doors of cabinets that lined the wall. The architecture of such a classroom, and larger classrooms such as the lecture hall, is part of a historical legacy in biology that has been influenced by a pedagogy that is lecture based and content driven. But looking beyond the remnants from the past, even a casual observer of this classroom could see that the learning experience for these students would be far removed from your typical lecture course. Five movable white boards were placed strategically about the room to accommodate clusters of five or six students. A portable cart housing twenty-five laptop computers linked to a wireless network stood ready for use. The last of the students trickled in and the professor introduced a biology problem-solving activity. Teams of two selected laptops to begin an activity, and the room erupted into a flurry of activity and interaction.*

Introduction

In the opening narrative, we describe a vision of how our biology classrooms and courses of old are in the process of being transformed through both pedagogical and technological innovation. The reasons for such changes have many influences, some key ones of which we will address in this paper. It is difficult to find a professional in higher education today who hasn't used digital technology for classroom use or hasn't at least heard claims that digital technology can offer a cure for all that ails the pedagogically-challenged classroom. It is a fact that digital technology and the expanded use of the word "digital literacy," used to describe one's "embededededness of the digital in the culture and practices of society…," (Gilster, 1997, pg. 1) has become part of a common language for educators around the world. At the same time, however, there is a growing concern among educators that a technology/teaching disconnect exists in higher education that must be addressed, yet is often ignored. More specifically, there has been a disconnect between the digital technology used in teaching and it's impact on student learning (Madigan, 2006). For example, although there have been many claims of late that digital classroom technology produces gains in student learning, most research in this area is sparse and too often anecdotal (Cuban, 2001). New and more research that measures the impact of digital technology on both affective and cognitive gains in student learning needs to be done--and can be done en masse if we look within our own teaching environments.

Foremost, we as faculty need to be better researchers in our own courses—to ask better questions regarding how any technology might impact student learning. Before we look at digital technologies for use in teaching, we need to ask ourselves these key questions: how does the technology support the learning outcomes? And more specifically, we need to ask ourselves how will the technology support what Fink (2003) refers to as the key components of an integrated course design? This means the integration and interconnection of course learning outcomes, the assessment of those outcomes, and the activities that support achievement of those learning outcomes. For us, this translates into paying particular attention to a student-centered learning environment where interactive learning is the standard pedagogy of choice. Interactive learning, nor the pedagogy that frames it, is not new. For example, Dewey (1933), founder of the early 20th century progressive movement, called for a student learning environment in which the students learned by doing, not by sitting passively listening to lectures. More recently, researchers (Lorenzo et al., 2006; Felder & Brent, 1999; Hake, 1998; Bonwell & Eison, 1991; Kolb, 1984) have shared with educators the value of active and experiential learning as a pedagogy that embraces a student centered curriculum and course design.

As a faculty developer and biology professor, we have come to embrace digital technology as an effective way to enhance student learning in the biology classroom. We have found that digital technology has been used to enhance the visual presentation of biological functions and processes; to provide opportunities where communication, collaboration and the sharing of resources and ideas are encouraged; to serve as a means to learn how to learn; and to provide meaningful ways to assess and track student learning. We have also come to realize that the technology cannot be effective, nor should it be considered, unless it is thought of within the context of an integrated course design. In this paper, we will first discuss how our pedagogy and use of technology has been shaped in view of the integrated course design. Next, we will explore some examples of technologies that are shaping or have the potential for shaping the way we teach today in the biological sciences. Finally, we will address some key questions about digital technology and course development that will assist all educators in understanding how to create a student-centered learning environment that is both dynamic and responsive to well thought out learning outcomes.

Background

…and the point is to live everything. Live the questions now. (Rilke, 1984)

It is indeed the questions that we live and that we generate that has driven the current transformation occurring in our science curriculum. Our university, like other universities and educational systems in our country, has become the beneficiary of the technology push for the last 10 years. Digital technology is everywhere and has established a firm foothold in the learning environments that we teach in. Yet as a faculty developer and a biology teacher we have observed that the technology used in the face-to-face classroom has not always been chosen with care or for the right reasons. Sure, presentation software, with its organizational and visual capabilities, takes the worry out of the delivery of course content. Yet, we all know of student and faculty complaints about the over use of presentation software at the expense of an interactive learning environment. And even when faculty can identify a seemingly rational response for using digital technology in the classroom, that rationale may more often be related to convenience and flash than improvement of student learning for the long haul. We have learned that the reason for the use of digital technology in the classroom or any student-learning environment must be associated with the enhancement of student learning. The stakes are too high to just accept digital technology because it is available.

We came together as colleagues several years ago as we both pursued a common interest and questions regarding student learning. Two major questions drove our inquiry: What should undergraduate biology students be learning? How do we know our students are learning? To expand and support our inquiry we put together a life science learning community of eight faculty to, as Rilke (1984) would say, live the interesting and complex questions about the teaching of biology to undergraduates (Sirum et al., 2006). These questions set the tone for serious inquiry about student learning. For example, during one learning community meeting, an intense discussion developed regarding digital technology use in an active learning classroom. Some thought the technology had merit—others eschewed digital technology altogether. In the end, we were challenged to think about why or even if digital technology was necessary for an actively engaged classroom. But even then technology questions and issues were not foremost on our minds during these early meetings. For us in those early meetings, the technology issues regarding what, how, where and when to use digital technology in the face-to-face classroom took second billing to the larger questions regarding student learning in general. To eventually get to the technology questions we had to address our own pedagogies.

The Impact of Educational Reforms

Current biological science education reform efforts are transforming our ideas about life science education learning goals from the memorization of facts and details towards a broader conceptual understanding of biological processes and the development of scientific thinking skills. The goal is to help the students begin to think as a scientist and use scientific reasoning skills in their every day lives. Researchers in a variety of fields agree that a pedagogy based on the lecture format class is less effective at producing student learning gains on conceptual understanding and critical thinking skills than an interactive classroom (Johnstone & Percival, 1976; Burns, 1985; Fensham, 1992; Staley, 2003). Addressing the scientific audience, Klionsky (2001/2, 2004) has argued that the dominant lecture-based pedagogy currently used in the biological sciences needs to be replaced by an active learning approach that engages students in problem solving strategies to learn key biology concepts. Similarly, physics education research has shown the interactive pedagogies such as cooperative learning, peer instruction and group problem solving increase student learning of physics concepts (Lorenzo et. al, 2006; Hake, 1998). Handelsman and her colleagues in science educational reform (2004) have introduced the term “scientific teaching” to represent a teaching/learning model in the classroom that encourages science faculty to think as scientists not only in their research lab, but also in their classrooms, paying attention to the literature on what strategies promote learning and experimenting with these methods in their own classroom. And, Sirum et al. (2006) have described how faculty learning communities (Cox, 2004) provide science faculty with an opportunity to share knowledge and experiences about teaching while at the same time help prevent the isolation that many science faculty feel regarding their teaching. Finally, borrowing from researchers on the science of learning

(Donovan and Bransford, 2005; Zull, 2002), cooperative learning (Millis and Cotell, 1997) and our own early research and knowledge about how undergraduate students were learning, or not learning biology at our university, we envisioned a philosophy and a practical roadmap that would move us forward in transforming not only the way we teach, but how we design our classrooms to accommodate our net generation of students (Carlson, 2005).

Integrated Course Design

In looking back at our digital technology debate within our learning community meeting two years ago, we see more clearly why group was divided. First and foremost it seemed that the two sides that formed, for and against digital technology in the classroom, argued emotionally mainly because they were invested in their preferred way of teaching. Also, technology issues of cost, learning curve, access, and availability competed for center stage that day. All of this was at the expense of asking some very important questions such as, what should our students be learning? How should they go about learning? And, how do we know our students are learning? In all fairness, moving away from a discussion about digital technology in the classroom at that time was the right thing to do as we had not yet addressed fully how to attain the student learning we imagined with biology undergraduates. The question of whether digital technology could enable student learning in our new biology courses became secondary to other key issues. So, we took a step back from the digital technology issue and addressed some more pressing pedagogical issues about the merits of active learning and the problems with passive learning. Eventually, we began to focus on topics and issues related to the development of an interactive undergraduate biology course, particularly at the introductory level.

As we moved on from the learning community, we eventually broke down the design of a course to look closer at its elements. We began to see a pattern emerge. If we value the development of our students as critical thinkers and we want them to leave with an understanding of biological concepts that they retain beyond 6 weeks or 6 months after the final exam, then we must design our course in such a way that key components of learning outcomes/goals, assessment and learning activities, are fully integrated. For example, if we want our students to develop their critical thinking skills then we should assess development of those skills and not only give multiple choice exams based on memorization of content. Students will work to develop the skills they need for the exams and therefore what we assess is what we get (McClymer & Knoles, 1992). Fink (2003) articulated this well in his model that showed the interconnectedness and two-way relationship among those three elements. For example, although creating learning outcomes may be the first task of an instructor designing an undergraduate biology course, one should not develop those outcomes without understanding how learning activities and assessment directly impacts the learning outcomes. Foremost, however, Fink suggests that for an integrated course to be truly effective we need to rethink how we define our learning outcomes for a course.

Past experiences had taught us that introductory biology courses relied heavy on learning outcomes that emphasized foundational knowledge. Yet, while foundational knowledge is indeed an important learning outcome, it is only one of six categories in Fink's "taxonomy of significant learning" that should be considered when developing learning outcomes. The six are foundational knowledge (understand and remember key concepts); application (know how to use the course content); integration (be able to relate the subject to other subjects); human dimension (understand the social and personal implications of knowing); Caring (care about the subject); learning how to learn (know how to keep on learning about a subject).

In considering this taxonomy, our learning outcomes for our future introductory biology courses began to take shape. One such course focused on foundational knowledge goals such as gaining an understanding of: the molecules and cell structures that compose all living organisms; how organisms get their energy, the information mechanisms they use to guide their activities; and how these instructions for cellular activities are carried out in the cell. However, the following learning outcomes were also included to reflect a broader view of what students should learn:

- Be aware that values arise in the process of scientific investigation as well as how science is communicated, and be able to identify how values influence the scientific process at the individual as well as institutional level. (*caring, integration, human dimension*)

- Develop skills in scientific reasoning by learning how to use scientific ideas to think critically about choices made in everyday life. (*learning to learn, application, integration*)

- Learn how to learn, how to ask questions, design strategies to investigate possible answers, and do the interpretation that leads to the answers. (*learning to learn, application*)

- Develop an ability to collaborate and work in groups. (*human*)

Impact of Digital Technology on an Integrated Biology Course

With such focused outcomes in place for the course, forward-looking assessment strategies, modeled after Wiggins' (1998) educative assessment model (providing frequent and formative assessment to show where students need a better understanding of concepts), and learning activities were more fully developed in support of an integrated course. It was at this point that we were able to assess more carefully our technology needs, which eventually included laptops, a wireless system and whiteboards, in support of our new interactive biology course. The following illustration (Figure 1) reflects this important process as we see the reciprocal relationships among the key three components, and the relationship between digital technology tools and each of those components.

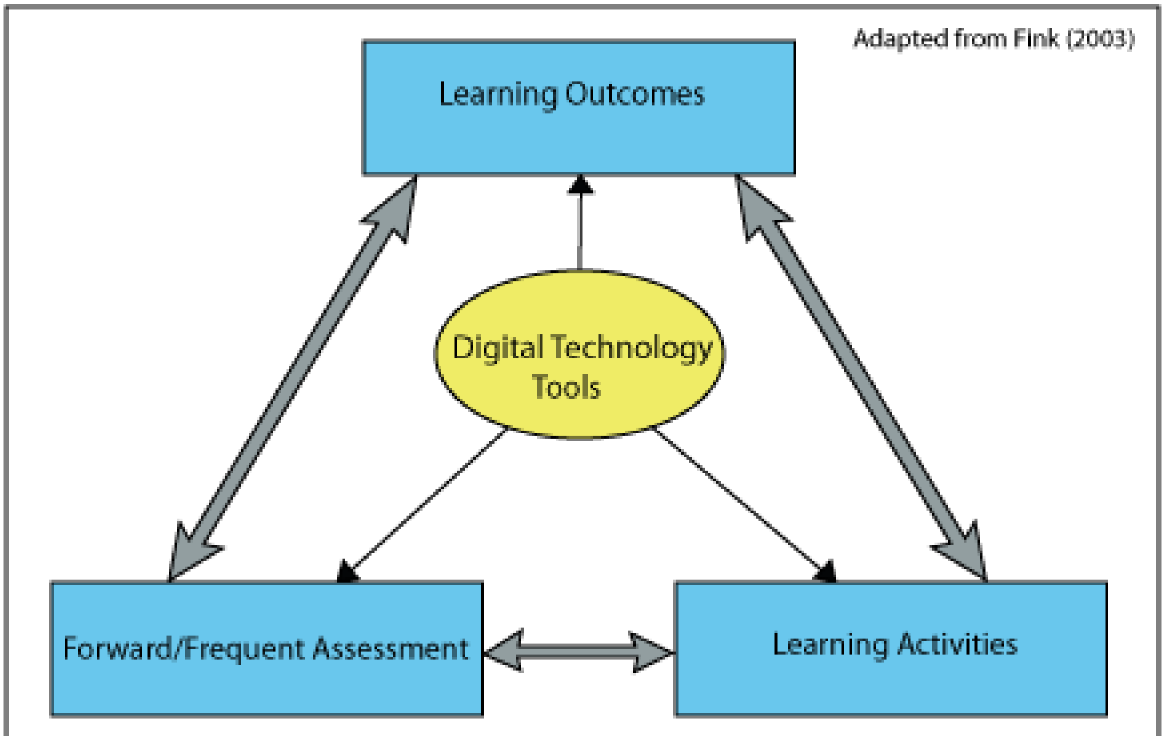

Figure 1

As we reflect on transformation in our introductory biology courses, and the role that digital technology can play in those courses, we begin to see more clearly some important and practical ways that digital technology tools can serve to enable an interactive pedagogy and practice. Our next section describes some of those ways.

We understand that there are many digital tools available today that could enhance learning for students in the sciences, but to describe them all in this paper is not possible. Instead, what follows are some key and readily accessible technologies that capture the essence of new technologies to enhance student learning, and that have a wide range of uses for any integrated biology/science course and any learning environment that promotes students conceptual understanding of course content and critical thinking skills.

World Wide Web

In our introductory biology courses we have begun to explore how the web can provide many important resources for our students and ourselves. Using laptop computers, a wireless network, search engines, readily available data bases, and web resources, we have imagined multiple purposes for the web both in and out of the classroom. For example, web resources have made the common biology textbook unnecessary. Instead, students can be directed to carefully selected websites such as:

- NIH books <http://www.ncbi.nlm.nih.gov/entrez/query/Books.live/Help/bookhelp.html>,

- Online interactive biology learning resource <http://www.biology.arizona.edu/DEFAULT.html>
- DNA Learning Center, Cold Spring Harbor Labs <http://www.dnaftb.org/dnaftb/15/concept/>

From these sites, students can locate current, relevant resources and challenging activities to support their understanding of key biological concepts. Such availability of web resources along with a wireless network in the classroom and an active-learning pedagogy, can turn almost any classroom into a sea of activity for student learners. Additionally, as more science researchers and educators share their knowledge and resources on the web, and as data bases and library resources are made available, teachers of biology have begun tap that gold mine on a regular basis. In turn, we understand that the information literacy skills that we are learning and have learned are absolutely necessary skills for our students to learn as well. Without such critical skills, students would not achieve one of our key learning outcomes for our introductory courses, that is, knowing how to find information, assess its value, and use the knowledge gained to understand the living world.

Assessment Tools

In developing an integrated biology course, we have paid careful attention to designing assessment strategies that are both frequent and forward looking, and that provide the type of formative feedback to students that we understand contributes significantly to their learning (Angelo & Cross, 1993). One such tool used for instant and frequent feedback is the Personal Response System (PRS), or more commonly referred to as clickers. Some teachers of large and small classes attempt to become more efficient in giving, grading, and distributing quiz results through the use of clickers. We follow other science faculty who have looked beyond that purpose and imagine a classroom where students are frequently asked to choose an answer to a question that reveals their understanding of a biological concept and to discuss their answers with their classmates. By submitting their answers through the PRS system, not only can the teacher immediately can get a read on whether or not the majority of the students have gotten the concept, but the students can too. If they haven't, the instructor can take measures to correct the lack of understanding by further explanation or activities. Online surveys can also be effective in assessing important factors such as motivation and attitude that have a profound impact on student learning. These can be given periodically or even as pre and post surveys that measure change and provide us with important information about issues related to learning. In addition, biology faculty are borrowing from the work of physics educational researchers to create Just in Time Teaching modules (Novak et al., 1999). As such, students are doing readings and activities online that are being assessed by teachers to see if their students have learned key concepts. Accordingly, the face-to-face in-class session that follow can be adjusted depending on whether the students have or have not learned the concepts given within the online resources.

Self-Tutorials

Digital technology, and especially web technology, has allowed biology faculty to extend the classroom in ways that make more efficient use of study time for the students. Students can use time outside of the classroom to learn key biological concepts that they have not yet grasped in the classroom setting, or that they may want to explore before engaging in classroom activities by using interactive tutorials instead of simply reading a text. Klymkowsky (http://www.colorado.edu/MCDB/MCDB1111/) demonstrates a model web environment with self-tutorials that provide practical and responsible ways for students to achieve key learning outcomes in introductory level biology courses. His tutorials cover a range of introductory biology concepts and subjects such as "Science and It's Methods," "Life's Origins," and "Lipids and Membranes." The advantage of such tutorials is instant feedback for the student through the online, un-graded quiz, with the students able to access them whenever they need them and for as many times as they see fit. Such tutorials are representative of digital tutorials that are very utilitarian and versatile. Others include simple video tutorials captured in QuickTime movies that might show a process or procedure that students need to learn as a preface to or as a result of classroom activities. Imagine a lab procedure or short experiment that you demonstrate in class--one that the students need to know in order to learn a key concept. The one-time demonstration could be enhanced greatly if the activity could be captured on video and compressed for video suitable for the web. As such, students could access this video resource as many times as they would like or need to in order to understand the concept.

Visual/Spatial Imagery

In Kolb's (1984) seminal piece on learning styles, he reminds us that students learn in different ways, including through their visual and spatial intelligence. Such knowledge about visual and spatial imagery is crucial for biology educators designing their integrated and student-centered classroom. It is in fact the unusual course that does not include some visual imagery to illustrate processes and concepts. But until recently, instructional methods for presenting life science concepts and processes through images have limited biology educators mainly to two and possibly three-dimensional visuals. For example, 2D images of illustrations and cartoons are the norm for the typical biology textbook, and 3D models, often made of plastic materials, represent biological concepts that are usually costly and limited to instructional demonstrations. However, digital technologies exist today that are freely available, and that allow us to present and explore these processes in three and even four dimensions, in time and space as they actually occur in the life process. Despite the availability of such imagery, a cautionary note is needed as we must keep in mind that even dynamic 4 D digital visuals may not lead to the kind of learning that we espouse for our students. Research on the physiology of learning (Zull, 2002) indicates that strategies in which the students are engaged and interactive, such as problem-based and cooperative learning, lead to lasting gains. Therefore, of critical importance is how the students interact with the visuals and how they are used in the class. It may not be enough to simply watch a movie just as we know it is not enough to simply listen to a lecture and follow a PowerPoint presentation to promote the lasting learning gains we desire. Virtual biological science laboratory activities, such as presented Klymkowsky's virtual lab <http://virtuallaboratory.net/Biofundamentals/labs/WaterDiffusionMembranes/InWater.html> appeal to the visual learner and support an active learning pedagogy.

Digitally Enhanced Classroom

Our examples of digital technology for an integrated biology course would not be complete without reference to how our physical classrooms have started to change as a result of available and pedagogically supportive technology. For instance, in our opening narrative we describe a small classroom that bears the legacy and influence of lecture-based classrooms. Given the physical restraints of such a classroom, digital technology choices were limited for us. For example, we could not find a suitable location in the narrow room to mount the digital projector so that the students sitting seven rows deep could see it easily. But the beauty of digital technology is that it can be versatile if you are willing to be innovative and have the funding resources. With laptop computers for small groups and a wireless network, students limited to even the most constrained physical space are able to take advantage of web resources to problem solve and communicate. Such laptops are also valuable for doing in-class lab activities and for filing results so they can be easily organized and sorted for assessment. Our future plans include the completion of a new classroom modeled after MIT's Technology Enhanced Active Learning classroom (see TEAL at http://web.mit.edu/edtech/casestudies/teal.html#video). Such a digitally equipped classroom will accommodate our typical large class of 90-100 introductory biology students. It will serve up to 1,000 introductory level students a year who will be involved in an interactive classroom that will boast a centrally located teacher's center from which to project experiments, illustrations, and other resources to screens located around the room, which will easily be seen by cluster groups of students. In addition, the room will be equipped with a PRS system, whiteboards for problem solving at each individual round table, a wireless network, and laptop computers. In such cases of classes with large numbers of students, the technology is instrumental in facilitating the creation of an interactive learning environment.

Conclusions

As we conclude this paper, we must offer a caveat to our readers. We are neither luddites nor blindly driven about the use of digital technology in our biology courses. If used for improving student learning, technology can be a boon for science teaching faculty. If it is used just because it is available and accessible, the consequences can lead to an undermining of the integrated course and curriculum. We also understand that the process for developing and thinking about elements of an integrated biology course, including the role that new technologies may play, is not linear. Nor should this be an issue. For many educators, the creative lines are blurred as to what comes first in the thinking and development process of course design. Where technology fits in that thinking process has never been an issue for us. What is an issue is if technology is the driving force for the development of a course in lieu of a focus on the primary learning outcomes. In the end, if digital technology is available and necessary to support our integrated course, then we find it useful. Also, like many university faculty worldwide, we have chosen to use a blended approach for integrating digital technology into our biology courses. And unlike some college courses that use the blended approach to describe a variation of the fully online course (Cardwell and Madigan, 2004; Heinze and Procter, 2004), we use a mix of face-to-face student teacher contact blended with some online learning and usage of digital technology both in the bricks and mortar classroom and in the virtual world.

Finally, we leave you with some questions to ponder and to live as you consider using new technologies for enabling and enhancing student learning: To what degree will the technology enhance and support assessment strategies and learning activities that in turn help students achieve each of the learning outcomes your have identified in your course? Is the technology necessary or could you achieve an integrated course more effectively with other pedagogical methods?

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