ENGAGING SCIENCE STUDENTS WITH HANDHELD TECHNOLOGY AND APPLICATIONS BY RE-VISITING THE THAYER METHOD OF TEACHING AND LEARNING

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ABSTRACT

Organic chemistry instructors integrate handheld technology and applications into course lecture and lab to engage students with tools and techniques students use in the modern world. This technology and applications enable instructors to re-visit the Thayer Method of teaching and learning to create an updated method that works with 21st century students. The Thayer Method is based on the premise that students are willing and capable of making substantial preparation before coming to class and lab in order to maximize efficiency of student-instructor contact time. During this student preparation phase, we engage students with handheld technology and content applications including smart phone viewable course administrative materials; "flashcards" containing basic organic chemistry nomenclature, molecular structures, and chemical reactions; mini-lectures prepared using the Smart Board Airliner Interactive Tablet for upcoming class periods and laboratory technique videos demonstrating tasks they will perform as part of laboratory experimentation. Coupled with a student friendly course text, these handheld applications enable substantial student preparation before class and lab. The method, in conjunction with handheld technology and applications, has been used with positive results in our organic chemistry courses.

Keywords: Undergraduate, science education, chemistry education, multimedia-based learning; computer-based learning, wireless application, Thayer Method.

INTRODUCTION

Organic chemists at Georgia Gwinnett College (GGC) have been working since 2007 to create an organic chemistry program that embodies the GGC vision "where learning will take place continuously in and beyond the confines of the traditional classroom [1]." While innovative use of educational technology is part of the vision, President Daniel Kaufman has often stated that "it's not about the gizmo (holding a smart phone up for a group of newly hired faculty to see), it's about using the gizmo to enhance student learning [2]."

Organic chemistry is the gateway course for students pursuing training in the health professions as well as upper level biology, biochemistry, and chemistry programs. Most students find organic chemistry exceptionally challenging because of the breadth and depth of content and the rapid pace of the course, referring to it as "the infamous, dreaded 'orgo', a marathon of memorization." Such sentiment is common at most schools, where between 25-50% of students do not continue to the second semester [3]. At GGC we seek to avoid the infamous, dreaded orgo by engaging students with handheld technology and course content applications to extend learning beyond the confines of the classroom and laboratory.

Pedagogical approaches to teaching demanding, rigorous courses such as organic chemistry have been thoroughly investigated. Alternatives to lecture include active and cooperative learning, student directed and team learning, grade-study contacts, problem-solving and collaborative learning, as well as distance-education. Studies indicate enhanced learning and greater student satisfaction when lecture is supplemented with other instructional techniques. As long as class size is relatively small (<30), an approach that enhances student engagement is the Thayer Method, named for Sylvanus Thayer, Superintendent of West Point from 1817-1833. The Method's hallmark is that *students prepare in detail prior to class*, so each lesson assignment is published in advance with lesson objectives, study assignment, terms, concepts, and homework problems. The tenets of the Method are:

- *Students responsible for their learning, which is incremental and sequential*
- *Small class size (<30 students)*
- *Students prepare in advance of class/lab attendance via detailed syllabus*
- *Instructor facilitates student learning before, during, and after class/lab*
- *Minimize lecture; maximize active, student-directed, collaborative learning*
- *In class board work:*
  - *student ownership and responsibility for their actions in the classroom*
  - *students demonstrate mastery in a formal process*
  - *students "publish" and defend*
- *Frequent assessment and feedback*

There is essentially a contract whereby students commit to preparing before class and instructors commit to flexibility in facilitating student learning during class by allowing sufficient time for discussion, exploration of more challenging topics in depth, and student problem solving under the guiding and mentoring eye of the instructor (via whiteboard sessions) [4].

Students new to organic chemistry typically memorize functional groups, structures, reactions and mechanisms, at least initially. Instructors intend that as students progress through the curriculum, the notion of memorization is replaced with understanding. To assuage students' dread of organic and help them advance to the point of understanding, we searched for ways to supplement traditional pedagogical approaches with instruction adapted to the life and learning style of today's generation of students [5]. Our search led us to update the Thayer Method for the 21st Century by engaging students with handheld technology and applications tailored for organic chemistry.

Students already demonstrate facility with handheld devices, so our intent is to further develop handheld organic chemistry content with flashcards, mini-lectures, and experimental techniques demonstrations that enable student engagement, enhance effectiveness and efficiency of student preparation outside of class, and maximize effectiveness and efficiency of faculty-student contact time during class and lab periods. A recent study by the American Enterprise Institute reported a decline in college student study time from 1961 to 2003 [6]. The most likely explanation for the decline is that academic achievement standards have fallen. Students report, however, they are using learning technologies more than ever as noted in the 2009 National Survey of Student Engagement (NSSE) [7]. Therein, students express positive impacts on learning via course management systems and interactive technologies (such as course blogs, student response systems, etc.). These results further motivated us to use educational technology to support student preparation before class, enabling a modernized Thayer Method.

Educational technology has moved far beyond course management systems to include "mobile learning" via content and applications on handheld devices [8]. Device mobility determines the method and frequency of student use. In a recent Educause survey, 51% of student respondents report owning an Internet-capable handheld device and access the Internet in bursts of short duration in contrast to longer duration work via laptop or desktop computer. As a result, course materials designed for access on handheld devices should capitalize on student's short duration study efforts rather than duplicate what can already be done on a computer. Investigators at the City University of Hong Kong assessed the impact on learning of mobile devices and associated applications with 2400 students who were provided wireless PDAs [9]. Results indicate learning enhancement for a small cadre of the students and demonstrate the need for integrated, pedagogically driven instructor and institutional efforts to make the devices more widely useful. Indeed, a recent investigation by Conole, *et al* found that students are aware of the strengths and weaknesses of various technologies and do not use technologies that do not provide direct personal benefit [10].

There are many computer-based applications for organic chemistry, but as many GGC students do not own a computer or are not inclined to use a desktop or laptop computer, these applications are not particularly user-friendly for them. In addition, computers do not offer the 24/7 convenience of handheld devices. For example, while electronic, web-based based reaction flash cards have been shown effective in enhancing student ability to learn reactions [11], they require a desktop or laptop computer and students miss the learning opportunity of creating their own flash cards – distinct disadvantages. As an indication of how the younger generation is using new media tools, the UCSD Organic Chemistry program was recently featured in a Physorg.com article titled "Organic Chemistry for the YouTube Generation" in which students perform organic techniques, pre-lab briefings, and demonstrations in short audio-video clips [12].

With the advent of the iPhone and other handheld devices, students can access this organic course content 24 hours a day. This degree of access is likewise available with "podcasts" that are appearing in instructional efforts in many disciplines [13]. As students migrate to the versatility, mobility, and convenience of cell phones - they can listen to music, watch videos, text or call friends, email, surf the web, play games - all on a pocket size device, the allure of the laptop computer is rapidly waning. A challenge for educators is to capitalize on the pervasive use of cell phones by younger students for educational purposes.

INSTRUCTIONAL METHOD

Organic chemistry courses at GGC are taught in small sections with no more than 24 students, and as a result, this offers many opportunities for instructional flexibility. Instructors use a version of the Thayer Method to enable 21st Century student preparation, providing students the following course materials, viewable on a handheld device. These materials are published on the course Blackboard site and are also available on the public GGC web page via the University of System of Georgia (USG) podcast server (14).

- *Detailed syllabus*
  - *Admin info*
  - *College Integrated Educational Experience (IEE) Goals*
  - *Academic Program Goals*
  - *Course Goals*
  - *Lesson Objectives*
  - *Daily lesson outline w/study assignment, terms, HW problems*
  - *Faculty contact information: phone text/voice messaging faculty⇄ student (faculty phones and data plans are provided by the college administration)*
- *Student-friendly text and solutions manual*
- *Flash cards (computer or handheld device operable)*
- *Airliner podcasts (computer or handheld device operable)*
- *Lab techniques videos (computer or handheld device operable)*

Students prepare before class using these materials so that class time is not spent with the instructor lecturing, but rather by focusing on students' specific questions and issues from the homework. The 75-minute class period becomes a student-led discussion and problem solving session with a faculty facilitator. As the instructor has no fixed agenda during the class period, he or she is more responsive to students and guides the class based on student-driven discussion, questions, and issues. The typical class session sequence is described below.

- *Students prepare before class using detailed syllabus*
- *Targeted query gauging student understanding at beginning of class*
- *Student driven discussion, Q/A, focused on daily lesson*
- *Chemical demonstrations and discussion*
- *On-the-fly instructor mini-lectures as needed*
- *Student whiteboard work (individual and groups) and recitation demonstrate achievement of lesson objectives*
- *Frequent quizzes to provide rapid feedback to students on their progress and reward student preparation of the daily assignment*

This interactive and engaging class format allows for student recitation under the watchful eye of the instructor, offering students opportunities to develop their oral and written communication skills in a low stress environment. **Figure 1** illustrates typical class activities using the Thayer Method. The lab program is also directly integrated and synchronized with the class, using the same instructor for each lab and class section. This approach has the synergistic benefit of enabling instructors to incorporate chemical demonstrations which link classroom topic discussions to the laboratory experiment.

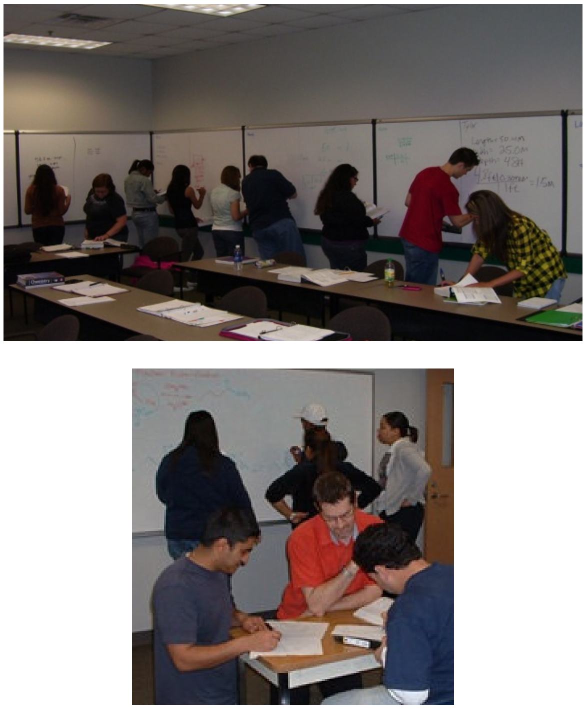

Figure 1. Thayer Method class activities.

Students have access to digital flash cards for such topics as functional groups and reactions (**Figures 2a and 2b**), to name but a few. As GGC is an open access institution and many of our students cannot afford their own handheld device, iPod Touch devices have been purchased for two sections of students through the GGC Vice President for Academics and Student Affairs (VPASA) seed grant program. There are also numerous computer labs throughout campus, as well as free campus-wide WiFi, that students may use to access material.

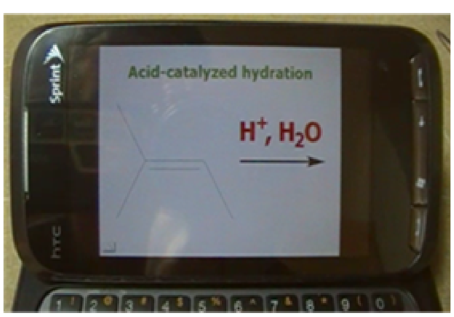

Figure 2a. Front of organic reaction digital flash card

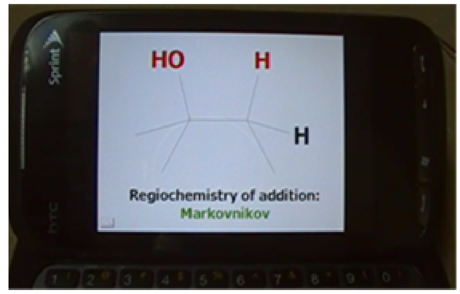

Figure 2b. Back of organic reaction digital flash card

In addition to flash cards, students also use podcast mini-lectures, created by faculty using the SmartBoard Airliner wireless tablet, as they prepare their homework assignments. These mini-lectures, accessible via handheld device or computer through the USG podcast server, supplement the textbook study assignment and feature faculty audio "voice-over" of a white board "chalk-talk". A particularly effective aspect of these mini-lectures is that students control the pace—they may pause, rewind, or replay the mini-lecture until they understand the concept and are able to continue their homework preparation. As a result, students don't get discouraged and quit preparing homework. Rather, they may use the mini-lectures to help them overcome the barrier to self-teaching during homework preparation so that they are able to come to class with specific questions rather than what faculty dread, that is, students saying "I don't understand anything and couldn't even get started with the homework." Faculty members have created an assortment of mini-lectures for topics students traditionally struggle with. The listing may be viewed on the GGC iTouch Chemistry Project web site and examples are shown in **Figure 3**, that illustrate the level of detail viewable on a hand held device.

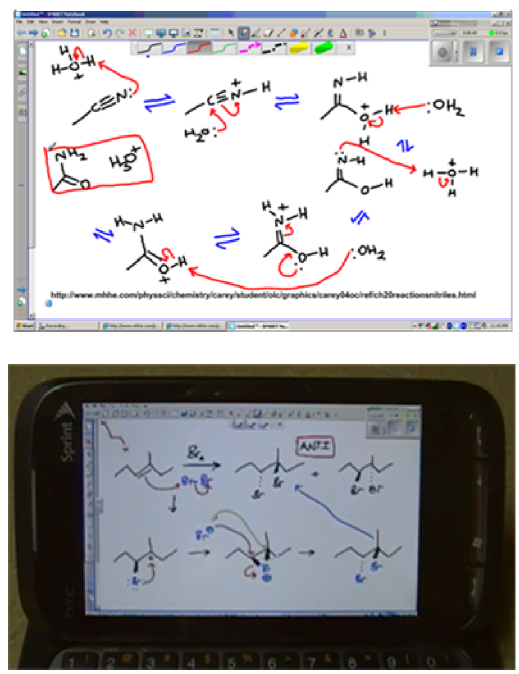

Figure 3. Smartboard Airliner mini-lecture podcasts

The organic faculty created microscale organic laboratory techniques videos that demonstrate common techniques students perform during the laboratory portion of the course, such as "microscale recrystallization." As with the flashcards and mini-lectures, the lab techniques videos are housed on the GGC iTouch® Chemistry Project web page. Our intent with lab, as with class, is to enable thorough student preparation. With such preparation, students are able to more efficiently and effectively perform the experiment while leaving more time for reflection and analysis of what they have accomplished.

INITIAL RESULTS AND DISCUSSION

Our ultimate goal with creating these materials is to enhance student learning of organic chemistry. Toward that end, we collected preliminary student attitudinal data concerning our approach to the course by supplementing traditional course materials with course content viewable on a handheld device. The faculty began the project three years ago with cell phone reaction flashcards and have gradually built a suite of supplemental materials viewable on handheld devices. A VPASA seed grant awarded in 2010 enabled us to outfit two sections of students with iTouch® devices, so by the end of the year we may be able to collect sufficient data to make initial judgments about whether the course content via handheld device enhances student learning. In any case, initial student feedback concerning the importance of learning organic chemistry reactions using organic cell phone flash cards as a tool to help them learn has been very positive. Students appreciate the value of cell phones that are always with them as opposed to more traditional tools, so that they may study the material at any time or place. Student comments below illustrate the positive attitude concerning cell phone flash cards:

- *"…no giant deck of cards to keep track of…"*
- *"…more convenient and more fun to look at than paper cards…"*
- *"…who wants to carry pages of paper cards…"*
- *"…always have my cell phone with me when I am in the bathroom…"*

The mini-lecture podcasts have also been very positively received by the students, and while we do not have sufficient quantitative data to demonstrate impact on student learning, it is apparent from their comments that at least students believe the mini-lectures enhance their learning. Student comments below illustrate the positive attitude concerning mini-lecture podcasts:

- *"...the prep videos help me understand the material much more than the book..."*
- *"for visual learners, this is exactly what we need…..It makes it easier for students to prep for class and come prepared with questions…"*
- *"…the videos are an excellent aid in my preparation for class….they also allow me to focus on the course objectives…and…the videos are very convenient – I …can learn at my own pace…"*

Our implementation of the Thayer Method in organic chemistry over the past three years has proven very successful particularly with respect to increasing student engagement and activity in the classroom. Student opinion of the method appears to follow a pattern – initially, many students are intimidated by the sequence of class activities and are somewhat hesitant about the idea of working problems at the boards. However, over the course of the semester, most students completely "buy-in" to the Method, growing to appreciate the value of lesson preparation and the engaging sequence of class activities during which they are *active participants* rather than *passive observers*. The following statement from an organic chemistry student confirms the overall positive attitude toward the Thayer Method. **"**The whiteboards were the most important part of the learning experience for me in this class. Working along side peers and having to think critically was vital for me to comprehend and retain the material. It basically made chemistry, a difficult topic, easy."

Likert scale quantitative student attitudinal data concerning the Thayer Method have been positive. Survey results clearly indicate components of the Thayer Method shown below are helpful to student learning:

- *Group use of the whiteboards in class.*
- *Faculty – student Q & A sessions in class.*
- *Viewing the preparatory videos (particularly in organic chemistry).*
- *Working homework problems before class.*

CONCLUSION

With the positive initial reception of cell phone flash cards, Airliner preparatory videos and the use of the Thayer method in general, the plan will be to adopt their use across other chemistry courses when they are offered at GGC. While the Thayer Method is not a teaching and learning method that many students have been exposed to before they come to GGC, the overall student response has been very positive. Many students respond well to a highly structured class format and feel that it allows them to study much more effectively for each class, rather than coming to class (without any preparation) and having no idea as to what will be covered that day. The expanded I-touch® study, which includes new, interactive chemistry software applications for two sections of Organic Chemistry I is currently underway. Having already determined that students respond very favorably to handheld organic content, our goal is this year is to investigate if the handheld devices lead to enhanced learning.

ACKNOWLEDGEMENTS

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