The Development and Implementation of an Online Applied Biochemistry Bridge Course for a Dental Hygiene Curriculum


Abstract: This article describes a curricular change project designed to improve instruction in biochemistry. After years of unsatisfactory outcomes from a dental hygiene biochemistry course, a decision was made to change the traditional lecture-based course to an online format. Using online technology and principles of educational pedagogy, a course was developed that fosters application of biomaterials principles to dental hygiene practice and provides a bridge between prerequisite chemistry coursework and biochemistry in a health professions program. Members of the dental hygiene graduating Classes of 2007 and 2008 participated in the revised course. The outcome measures used to assess the effectiveness of the revised course were student end-of-semester course evaluations, graduating senior survey results, student course performance, and National Board examination performance. While the results are based on only two classes, the positive outcomes suggest that the revision was a worthwhile endeavor. The use of technology in teaching holds the potential for solving many of the curriculum and instruction issues currently under discussion: overcrowding of the curriculum, lack of active learning methods, and basic sciences taught in isolation from the rest of the curriculum. It is hoped that the results of this change will be helpful to other faculty members seeking curricular change and innovation.

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Key words: computer-assisted instruction, curriculum, dental hygiene

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It is widely accepted that graduates of health professions programs must be critical thinkers and lifelong learners to keep pace with the ever-expanding biomedical body of knowledge. The graduates of our health professions educational systems should have a strong foundation in basic and biological science to enable them to comprehend patients’ health abnormalities, the etiology and mechanisms of these problems, and clinical problem-solving. Ideally, graduates should have the ability to collaborate with diverse teams to provide competent, high-quality, evidence-based care. Many have argued that the health professions curricula offered to today’s students do not foster the development of these characteristics. Rather, health professions curricula have been criticized for being overcrowded, dominated by inactive learning methods, and having a curriculum structure that is so highly discipline-based that students struggle to develop an integrated knowledge base. Failure to help students make the connections among biomedical, clinical, and behavioral content areas inhibits development of competence. Leaders in dental and allied dental education have joined together in recent years in advocating curricular change. This article describes a curricular change project designed to improve instruction in biochemistry in the Bachelor of Science dental hygiene program at the University of Missouri–Kansas City School of Dentistry (UMKCSOD).

Faculty members at the UMKCSOD provide the majority of instruction in the dental hygiene curriculum; however, basic science instruction is provided by another academic unit. This creates many challenges to integration between basic and clinical sciences education. The previously taught biochemistry course had been problematic in many ways. During the previous eight years, this course received the lowest rating of all courses in the dental hygiene curriculum in student end-of-semester evaluations and senior survey results. Students complained about being inundated with facts that were unrelated to the domain of dental hygiene and reported that they spent an inordinate amount of time studying for the course. After repeated meetings with the basic
science faculty and attempts to address integration of basic and clinical sciences issues along with poor student evaluations, the dental hygiene program director decided change was warranted. While many dental hygiene programs do not have a stand-alone biochemistry course as part of their curricula, departmental faculty members consider biochemistry a critical part of the curriculum as it serves as a bridge between prerequisite chemistry coursework and concurrent and subsequent courses in nutrition, oral pathology, and physiology, as well as other courses. Furthermore, an understanding of basic principles of biochemistry is seen as foundational to subsequent evidence-based practice.

One of the primary complaints of students who participated in previous biochemistry courses taught by the science faculty is that the material lacked relevance. Students felt they were not being taught to appreciate and understand specifically how biochemistry applies to the practice of dentistry and dental hygiene. Armed with nearly a decade of poor outcomes for this course, the decision was made to revise biochemistry to incorporate active learning and foster clinical integration—which are also part of the American Dental Education Association’s Commission on Change and Innovation reform agenda for dental and dental hygiene education. The use of web-based or online instructional technology was agreed upon as the means to deepen students’ learning and reform the course. The faculty endorsed the concept of modifying the course and converting to an online approach. The director, who had experience in online instruction, enlisted the help of an interdisciplinary Ph.D. student, a dentist with prior dental school teaching experience, to a student’s perspective in an online learning environment.

With this background, coauthor Crain adopted a systematic approach to the development of course content and objectives utilizing national and school competencies, National Board review materials, prior course evaluations, and collaborative meetings with course directors teaching coursework especially relevant to biochemistry (nutrition, oral pathology, etc.). A chemistry textbook was chosen that includes specific application to health care, an accompanying pamphlet on the Human Genome Project, and an interactive CD-ROM to address visual learning styles, along with an accompanying website maintained for the text. Chapters and sections of chapters of the textbook and of the pamphlet on the Human Genome Project were selected for the course in order to guide student learning through basic chemistry and organic chemistry, general biochemistry principles, and introductory molecular genetics as foundation knowledge for the cellular and subcellular levels of understanding of health and disease. An attempt was made to weave in practical application and relevance to the practice of dental hygiene to supplement the content found in the chemistry textbook. Six modules were developed: 1) Chemistry Foundation (this module provides a refresher of prerequisite chemistry coursework concepts and a foundation for the following modules); 2) Organic Chemistry Foundation; 3) Organic Compounds: Carbohydrates, Carboxylic Acids and Esters, Lipids, Amines, and Amides; 4) Macromolecules: Proteins,

Methods

Members of the graduating Classes of 2007 and 2008 participated in the revised course during their junior year in the program. These two classes of dental hygiene students form the sample for this study (n=60). The outcome measures used to assess the effectiveness of the revised course were student end-of-semester course evaluations, graduating senior survey results, students’ performance in the course, and National Board examination results. In addition, samples of student discussion board postings taken from the revised course illustrate the interaction among the students, active learning, and the applied component of the course showing the integration of basic science and clinical science.

The UMKCSOD Department of Oral Biology, in concert with the School of Graduate Studies, offers an interdisciplinary doctoral program (I.Ph.D.) that must include the in-depth study of at least two disciplines. In fulfillment of course requirements for the I.Ph.D. program, one of the coauthors (Crain) participated in coursework in education (educational methods and special issues in higher education, and curriculum and instruction in science) and in oral biology (oral pathology, molecular genetics, and biochemistry) that provided foundational knowledge and educational resources for the subsequent development of an online course in applied biochemistry. The educational methodologies and the special issues in higher education courses completed by the coauthor provided vital information related to teaching in a higher education environment. Additionally, they were delivered online, providing an opportunity to participate from a student’s perspective in an online learning environment.
Enzymes, Nucleic Acids, and Protein Synthesis; 5) Metabolism and Energy Production; and 6) Integration/Application of Biochemistry Principles. The learning modules were housed on the Blackboard course management system. Students were given weekly assignments that included readings and problem sets from the text and use of the interactive CD-ROM and accompanying website, along with online discussion groups. The thirty students in the course were organized into discussion groups of five students each. The course director (coauthor Crain) posed an application question based on the module content, and students were required to discuss the question within their assigned groups using the online discussion format. Figure 1 is an excerpt of the recommended timeline, topics, and assignments found in Module 1.

The six modules followed the sequential order presented in the textbook but represent a portion of the book (not the entire book as in the previous traditional course) in that several chapters and sections of chapters were omitted by the course director due to a lack of direct relevance to the course objectives. The course director monitored the discussions on a weekly basis. In many instances, questions posed in the discussion group were answered by student peers (see Figure 2). In those instances in which questions needed to be addressed by the faculty or the discussion went off track, the course director posted a response to bring the topic back into focus or posed additional questions to probe the students’ critical thinking about the topic. Figure 2 displays an example of a discussion thread among the students that evolved from an applied question posed by the instructor. While student identifiers have been removed, all content was copied exactly as it appeared in the discussion forum in Blackboard, and therefore misspellings and other errors exist.

Another example of a discussion thread that evolved from the applied questions is shown in Figure 3. This discussion thread (much like the one in Figure 2) illustrates how students are applying information from other coursework into their discussion and integrating basic science with clinical science. In this particular discussion thread, one can see how the students had to search for additional information to assist in critical thinking and problem-solving since the students had not taken their local anesthesia course at this point in the curriculum.

Five online examinations and a comprehensive on-site final examination were used as assessments of students’ learning. A discussion thread was created in Blackboard in which students were required to develop and post exam questions based on information from other coursework and integrate it into content learned in the current biochemistry course. The students’ questions were used as a basis in the development of some of the test questions that appeared in the final exam. Again, a main objective when developing the online biochemistry course was to ensure that it had application to dentistry. The goal for the strategy of asking students to develop questions was to stimulate students to think critically about how biochemistry factored into the practice of dentistry and dental hygiene and raise students’ awareness of how content across the curriculum is related.

Students in the graduating Class of 2007, the first class to take the online applied course, completed a formative midterm evaluation in an attempt to address concerns prior to the end of the semester and make revisions as warranted. Both Classes of 2007 and 2008 completed end-of-the-semester evaluations of the course.

Results

Demographic characteristics are displayed in Table 2. Individual students did not always fill in all the data, thus explaining those instances in Table 1 when the “n” is less than 60.

The first outcome measure, results from the students’ assessment of the course and instruction at the end of the semester, can be found in Table 2. Overall student ratings were very positive as compared to the previous eight years, when student end-of-semester course evaluation results yielded the lowest rating of all courses in the dental hygiene curriculum.

In addition to the items listed in Table 2, students were able to provide narrative comments on the evaluation form. Comments from the Class of 2007 (the first time the course was offered online) were utilized for revisions and modifications of the course prior to the Class of 2008 taking the course. Participants who provided qualitative comments during the first offering of the course were evenly split with regard to the online format. Five of the participants provided positive feedback regarding the online format while five of the written comments indicated the desire for a traditional classroom environment (Table 3). Constructive criticism indicated a desire for more live classroom sessions with the instructor and feedback on how to improve the discussion group activities.
**Recommended Timeline**

Module 1  
(Weeks 1–2)  
Jan. 9–20

**Recommended Topic**

“Chemistry Foundation”

**Assignment/Discussion**

Chapters 2, 4, 5, 6, 10

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<thead>
<tr>
<th>Chapter 2</th>
<th>Atoms and Elements</th>
<th>Textbook CD:</th>
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<td>- Tutorial: Atoms and Isotopes</td>
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<td>- Tutorial: Bohr’s Shell Model</td>
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<td></td>
<td></td>
<td>- Review Questions 2.1 and 2.3</td>
</tr>
</tbody>
</table>

Timberlake Textbook:

- Read: 2.1 Elements & Symbols
- Questions and Problems: (odd) p. 47
- Read: 2.3 The Atom
- Questions and Problems: (odd) p. 55
- Read: 2.6 Electron Energy Levels

**Chapter 4**  
Compounds and Bonds

Textbook CD:

- PowerPoint: none assigned
- Tutorial: Covalent Bonds
- Tutorial: Bonds and Bond Polarity
- Review Questions: none assigned

Timberlake Textbook:

- Read: 4.1 Valence Electrons
- Read: 4.2 Octet Rule and Ions (omit p. 117)
- Read: Health Note: Some Important Ions in the Body, p. 118
- Read: 4.3 Ionic Compounds
- Read: 4.5 Covalent Bonds
- Read: 4.7 Bond Polarity
- Read: Health Note: Polyatomic Ions in Bone and Teeth, p. 143
- Read: Health Note: The Chemical Sense of Taste and Smell, p. 151
- Questions and Problems: none assigned

**Week 1: Blackboard Discussion**

**Hydroxyapatite and dental calculus**

Blackboard Discussion 1: Each group of five students has been assigned a discussion topic for the Week 1 Blackboard Discussion Thread (see below). Post and discuss your answers with your group members on Blackboard. Be sure to review all six group discussion threads to thoroughly understand how this past week’s study of chemistry applies to dentistry.

In your own words:

- Group 1: Distinguish between atoms and elements.
- Group 2: Distinguish between elements and compounds.
- Group 3: Briefly explain what bonds are and what types exist.
- Group 4: What is the molecular formula for hydroxyapatite?
- Group 5: Where is hydroxyapatite found?
- Group 6: What compound(s) make up dental calculus?

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*Figure 1. Module 1 excerpt: Chemistry Foundation*
Discussion Question: Discuss saliva as a biological buffer. Include in your discussion thoughts about mutans streptococci and acid-base reactions.

Student 1:
From our readings we now understand that buffers are substances that by its presence in solution increases the amount of acid or alkali necessary to produce a change in pH. So relating saliva, we can understand that saliva acts as a biological buffer in our oral cavity, controlling the pH level in our mouth as it fulfills its duty to lubricate and cleanse the hard and soft tissues of the oral cavity. One way saliva works as a biological buffer is that it works hard to ensure that calcium and phosphate levels are saturated enough to aid in either obstructing the demineralization process or boosting the remineralization to the tooth structure. Saliva has an antibacterial function that includes 4 important antimicrobial proteins. Remember these guys—lysozyme, lactoferrin, salivary peroxidase and secretory immunoglobulin. In our Primary Preventive book, it states that lactoferrin for example strongly inhibits the adherence of S. mutans to saliva coated hydroxyapatite blocks, in vitro. So, this is one way saliva has components to beat out the S. mutans bacteria.

From my readings I gathered that acid-base reactions depends on the pH and how the substances react when they dissolve in water. If substances produce hydrogen ions when they are dissolved in water then they are considered acids. Substances are bases if they are ionic compounds that dissociate into a metal ion and hydroxide ions when they dissolve in water.

Student 2:
From the Chemistry text (Student 1; name omitted for confidentiality) did an awesome job explaining what constitutes an acid or a base depending on what the reactant does in water, either releasing OH− (base) or H+ (acid).

Saliva is a great example of a biological buffer because from what I understood in the readings it is a place where the H2CO3/HCO3 buffer system is incorporated into our bodily fluids. A buffer solution is defined in Timberlake as being a solution that resists a change in pH when small amounts of acid or base are added. In our mouth we are taking in all different kinds of food. Acidic foods such as soda, oranges, even bread is consumed and sometimes basic foods are incorporated into our diets as well, (TUMS anyone?) without saliva as a buffer organisms such as S. Mutans thrive in acidic environments. S. Mutans as we all know are one of the biggest culprits in caries so without saliva available to buffer our daily soda some of the “good” bacteria in our mouths could not survive which could leave space for S. Mutans to thrive. On top of just thriving in an acidic environment S. Mutans also add to the acidity by acid production. All I have to say is way to go saliva! Wash away my food and buffer out my diet coke!

Student 3:
Nice job (Students 1 & 2), I’ll add what little more I know...you guys covered it all nicely!!!!

All I can think about is the picture that Professor X showed us in morph of the guy that sucked on lemons and had terrible erosion. We know that the normal ph of saliva is 6.0-7.5 and if the pH falls below 5.0 it can be harmful to oral tissues (enamel and dentin, mainly). Like (Student 2) said a buffer resists change when SMALL amounts of acid are added. It’s a fine line to balance on because yeah a candy can increase salivary flow—which is great to help fight off S. Mutans, but an acidic candy like lemon drops adds to the acidic environment where S. Mutans can thrive! So I guess that cocaine is also extremely acidic (because of the picture shown of the cocaine user). So the moral of this story is don’t suck on lemons, lemon drops or use cocaine!

Student 4:
(Students 3),
I don’t really know if cocaine is acidic or not, but I think that picture you are thinking of was caused by the drug user actually rubbing the cocaine onto his teeth and gums, so the damage was from more of an abrasion standpoint. I could be wrong, but that is what I gathered from that lecture. Anyway, you could be right and cocaine is acidic and in that case, I also strongly suggest everyone to discontinue their use of cocaine!!!(:)

Student 3:
Hey Girls, I looked up cocaine before I made my post because I was also unsure if it were acidic… Cocaine in its pure form is a alkaloid of course because we all know it comes from a plant. Cocaine is cut many times to add to the “numbing” effects of it. It is most often “cut” with hydrochloride...as the next sentence states that I found on a website. Cocaine appearing in powder form is a salt, typically cocaine hydrochloride. Hydrochlorides are salts resulting, or regarded as resulting, from the reaction of hydrochloric acid with an organic base. So now we all know that HCl is acidic. I agree with (Student 4), when brushing our teeth it seems like that would be much more abrasive than putting cocaine up there, because I assume cocaine dissolves pretty fast once it comes in contact with your saliva I think that the pics were from it being so acidic just like the lemons. Good thoughts girls!!!
Discussion Question: Discuss the local anesthesia used in the practice of dental hygiene. Center your discussion around the chemical makeup of some of the common agents used.

Student 1:
Local anesthetics are weak bases that contain an aromatic group (benzene ring), an intermediate chain (ester or amide), and an amine group. Different kinds of anesthetic vary in the structure and relationship of each of these components. The aromatic ring structure is soluble in lipids, making it possible for the anesthetic to penetrate the nerve membrane. The amine structure is water soluble, allowing it to be delivered in a "liquid" form, and giving it the ability to remain in solution on either side of the nerve membrane. Since we haven’t studied local anesthetic much in any of our other classes, I was looking around on the internet for information and found a really interesting article that is very relevant to us as hygienists. It discusses the different types of LA used and some characteristics of each. The article comes from the "Dimensions of Dental Hygiene" journal, and summarizes the 4 major local anesthetics we have to choose from. Here is the link if anyone's interested:
http://www.dimensionsofdentalhygiene.com/ddhright.asp?id=719

Student 2:
That was a great article, (Student 1) - Thanks for sharing!

Student 3:
So I can’t compete much with the information from (Student 1)’s article but I’ll go ahead and put in my two cents. I did my physiology report on allergies and I had included some information on local anesthetics. Luckily it can apply here as well. According to our dental management book, there are only really two main groups of local anesthetics: Paraamino-benzoic acid (PABA) esters and amides.
Procaine (Novocain) and tetracaine (Pontocaine) are both benzoic acid esters. Benzoic acid is the simplest aromatic carboxylic acid; it has a benzene ring with a carboxylic acid functional group. When the acid is catalyzed with alcohol it will form a benzoic acid ester.
Lidocaine (Xylocaine), mepivacaine (Carbocaine), and prilocaine (Citanest) are all amides. Thus they all contain nitrogen. The dental management book also states that the benzoic acid ester anesthetics may cross-react with each other, whereas the amide anesthetics do not usually cross react. However, cross reaction does not occur between ester and amide local anesthetics.
Great article though!!!

Student 1:
Random thought after reading (Student 3)’s post...
I have heard many patients say that they are allergic to Novocaine, and cannot use it for dental anesthesia. Since other anesthetics (such as Lidocaine) have a different chemical structure, are those safe to use on patients with a Novocaine allergy? Or are they similar enough that a completely different type of anesthetic has to be used? Just curious...anyone have any thoughts?

Student 3:
The dental management book actually addresses this. There is no better way to say it than the book so I’m just going to type it for you.
“Procaine (Novocain) is the local anesthetic with the highest incidence of allergic reactions. Its antigenic component appears to be PABA, one of the metabolic breakdown products of procaine. Cross-reactivity has been reported between lidocaine and procaine; however, this could be traced to the presence of a germicide, methylparaben, which has been used in small amounts as a preservative and is chemically similar to PABA. Thus a patient who is allergic to procaine may react to lidocaine solution if it contains methylparaben. Lidocaine that does not contain methylparaben can now be readily obtained and should be used when dealing with a patient who has an allergic history to procaine.” (Dental Management of the Medically Compromised Patient, James W. Little, pg323)
That addressed both Novocain and Lidocaine, but I’m not sure if it answered your question completely. Hope it helped.

(continued)
Student 1:
Wow (Student 3), thanks for looking that up and answering that question for me. When you mentioned that PABA was probably the cause, it made me curious and I looked up some additional information on it. One thing that I noticed when I was reading is that PABA should be avoided on children, pregnant women, and nursing mothers. So...do you guys think this means that when we treat children or pregnant women we should be using a different type of anesthetic? I’d never heard that before, so I was just curious!

Student 3:
Here are some more things I thought might be helpful when it comes to allergies and local anesthetics. These too came from our Dental Management book.

When administering an alternative anesthetic to a patient with a history of a local anesthetic allergy, the dental professional should follow these steps:

1. Inject slowly, aspirating first to make sure that a vessel is not being injected
2. Place one drop of the solution into the tissues
3. Withdraw the needle and wait 5 minutes to see what reaction, if any, occurs. If no reaction occurs, as much anesthetic as needed for the procedure should be deposited. Be sure to aspirate before making the second injection.

Signs and symptoms of a toxic reaction to local anesthetic:
Talkativeness, Slurred speech, Dizziness, Nausea, Depression, Euphoria, Excitement, Convulsions

Dental Management: pages 322 & 323

Student 2:
Have any of you guys heard of this new product called Oraqix? It is a topical anesthesia comprised of lidocaine and prilocaine. Here is some information directly from their website:

"Oraqix is applied on the gingival margin around the selected tooth using the blunt-tipped applicator. Then after waiting 30 seconds, the periodontal pocket is filled with Oraqix until it becomes visible at the gingival margin"

"The scaling and root planing procedure may begin 30 seconds after the application of Oraqix to the periodontal pocket. Anesthetic effect, as assessed by probing of pocket depths, has a duration of approximately 20 minutes (individual patient overall range 14-31 minutes)."

I don’t know about you guys but this sounds like an awesome option since I personally don’t love needles and am not exactly looking forward to learning how to give injections!

Student 4:
So, is this is what (Student 3) was discussing earlier today...thats exciting I would much rather have a topical anesthesia than a needle though the stuff they used for my surgery was in a needle I didn't feel a thing...or at least I don’t remember...lol...I had like three different things so I wasn’t feeling anything and can I say that waking up is the weirdest thing ever.

Student 1:
The office that I worked at in Manhattan used this product a lot! The hygienist usually used it when a patient had isolated periodontal pockets that were 4-5 mm deep. Not too extreme, but enough to cause some sensitivity when root planing. It also works well when you have just one area that you need to do selective S/RP and don’t want to anesthetize the whole area. It helped with time management for the hygienist because she didn’t have to wait as long for the anesthesia to “work”...but I know that all the patients appreciated this method of anesthesia as well!

Student 5:
Some info that I came across in one of our textbooks that made me say HMMMM...

"Cocaine was the first local anesthetic used, but because of its toxicity and potential for abuse, alternatives have been developed. The first synthetic byproduct of cocaine used for local anesthesia was procaine, which was produced in the 1950’s. Other local anesthetics of this type include lidocaine and tetracaine."
Fewer students from the Class of 2008 provided narrative comments on the end-of-semester course evaluation form as compared to the Class of 2007. This could be a result of changes that responded to student feedback the prior year. Based upon student recommendations from the Class of 2007, the course was revised for the second year to include two optional live question and answer sessions (one at mid-semester and one prior to the final examination). Additionally, a revision to the online discussion format included more open-ended questions posed by the instructor for each module discussion on Blackboard. (The discussion board format is explained more fully in the discussion section below.)

Out of a total of seven comments from the Class of 2008, four addressed the online format, with three of the four comments supporting the current format of online instruction. Five of the seven comments were positive. Two comments provided constructive criticism related to the difficulty of taking an online course and the comment that the course could be a prerequisite.

The second outcome measure was the senior survey, which is administered to graduating seniors. Students rate the perceived quality of instruction of all of the courses in the curriculum. Historically, biochemistry has been the lowest rated course on the senior survey. This was not the case with the Classes of 2007 and 2008. For the Class of 2007 it was rated second from the last, and for the Class of 2008 it moved up to fourth from the last. One could hypothesize that the instructor’s modifications of the online course as a result of feedback from the inaugural offering resulted in these more positive ratings the second year the course was offered.

The third outcome measure included student performance in the course (grades). Students were required to pass five online examinations with a minimal score of 70 percent. The online examinations could be retaken one time with no penalty. Subsequent attempts were permitted but were not awarded a score higher than 70 percent. Failure to pass one or more examinations by the end of the semester resulted in a failing grade for the course. The final examination was taken on-site at UMKCSOD at a specified time and location (Figure 4). All students from both the Classes of 2007 and 2008 earned a final grade of A or B.

A fourth outcome measure was performance on the National Board Dental Hygiene Examination (NBDHE). Each year the Joint Commission on National Dental Examinations (JCNDE) sends out an analysis of outcomes following the administration of the NBDHE. This analysis provides comparative feedback as it applies to subject areas. While physiology, biochemistry, and nutrition are a combined subject area on the final NBDHE analysis, these results still provide a variable of comparison from previous years. For the Class of 2007, the NBDHE included ten questions that were analyzed for this

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**Table 1. Demographic characteristics of participants (n=60)**

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<th>Characteristic</th>
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<th>Percentage</th>
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<td>Gender</td>
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<tr>
<td>Female</td>
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<td>Male</td>
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<td>Age</td>
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<td>GPA (entering program)</td>
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<td>Hispanic</td>
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**Table 2. Dental hygiene students’ end-of-semester evaluation of the course and the instruction**

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<thead>
<tr>
<th>Item</th>
<th>n*</th>
<th>Mean (SD)</th>
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<tr>
<td>Organization of the course was . . .</td>
<td>50</td>
<td>4.07 (±.81)</td>
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<tr>
<td>Instructor’s effectiveness in teaching the subject matter</td>
<td>42</td>
<td>4.00 (±.80)</td>
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<tr>
<td>Clarity and fairness of evaluation and grading techniques were . . .</td>
<td>49</td>
<td>4.30 (±.77)</td>
</tr>
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<td>Instructor’s ability to communicate effectively</td>
<td>50</td>
<td>4.28 (±.74)</td>
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<td>Ability to motivate students to learn</td>
<td>43</td>
<td>4.02 (±.93)</td>
</tr>
<tr>
<td>Prompt and constructive feedback on student’s progress over the term was . . .</td>
<td>48</td>
<td>4.19 (±.85)</td>
</tr>
<tr>
<td>Overall, this instructor was . . .</td>
<td>43</td>
<td>4.28 (±.73)</td>
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</table>

*Do not total 60 due to missing values and response rate less than 100%.
5=Excellent, 3=Average, 1=Poor, X=Don’t Know/Not Applicable
Table 3. Qualitative review of written comments from the 2006 evaluation of the course

<table>
<thead>
<tr>
<th>Spring Semester 2006</th>
<th>Positive Feedback</th>
<th>Constructive Criticism</th>
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<tr>
<td>Online versus classroom</td>
<td>• I really enjoyed the class; it fit into our busy schedule &amp; I was able to learn a lot from the course. • The course was very organized &amp; structured. There was more than enough material provided to be successful.</td>
<td>• Biochemistry would not have been a course that I would’ve chosen to take via Internet. This material is complex. • This course should be taught in the classroom. It’s hard to learn concepts in this environment.</td>
</tr>
<tr>
<td>Desire for live classroom sessions with the instructor</td>
<td>•</td>
<td>• I do wish we had some personal interaction. I felt we could learn a lot from her. • I think it would be helpful to meet a couple times to touch base &amp; address any of our concerns. • The discussion board was ok because it created a way to apply biochem to dentistry. The only fallback was if you were not the first or second person to respond to the subject, then the information to submit was usually a repeat of what was already started. A true discussion was hard to achieve. • The only thing that I really didn’t like was the discussion due to the fact that after one person answered the rest really was repetitive.</td>
</tr>
<tr>
<td>Discussion board</td>
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Module 6: Integration and Application of Biochemistry Principles

Essay Questions

1. The Biochemistry of Diabetes

A 32-year-old female patient arrived for her appointment with you. In reviewing her health history you noted that she has diabetes. When you asked her if she had taken her insulin this morning, she replied that she was running late, grabbed a quick breakfast and coffee, but forgot the insulin. Knowing that insulin is a hormone that is required for the movement of glucose into the cells for normal metabolism, answer the following questions.

26. Describe briefly the metabolism that would have happened if your patient had taken her insulin (restoring “normal conditions”).

27. Since your patient did not take her insulin, and the cells are therefore “starved” of the glucose that is circulating in her blood, describe the metabolism that is now occurring in her cells (metabolism in the absence of glucose).

28. You noted that your patient asked you for a cup of water before she was seated and again while you were talking. She asked if she could use the restroom, blaming it on the coffee she had with breakfast. When she returned, you noticed your patient was experiencing some difficulty breathing. Describe the metabolic process that is most likely responsible for what your patient is experiencing.

Figure 4. Sample examination questions from Module 6
subject area (physiology, biochemistry, and nutrition), and school averages outpaced national averages with a school average score of 7.7 questions answered correctly and a national average of 6.8. For the Class of 2008, there were eleven questions, and the school and national average was the same with 6.2 questions answered correctly.

Finally, although direct outcomes of student performance in subsequent courses in the curriculum were not formally measured, the director of the nutrition course—the course that most closely builds on knowledge gained in the biochemistry course—did feel that the students in the newly formatted course had a better understanding of basic biochemistry concepts than had been the case in previous years.

Discussion

Based on a long history of less than ideal outcomes with a biochemistry course, the decision was made to develop an online, applied biochemistry course for a baccalaureate dental hygiene program. The course was first offered in spring 2006 (members of the graduating Class of 2007 were course participants as junior students) and again in spring 2007 (members of the graduating Class of 2008 were course participants as junior students). Multiple methods were used to evaluate the new course, and changes were made throughout the implementation process in response to student formative feedback.

As a result of the Class of 2007 participants’ desire for additional scheduled live classroom times (only one live classroom session was scheduled for the first cohort), the instructor scheduled two on-site classroom sessions for the Class of 2008 cohort (midway through the semester and before the final on-site examination). It is interesting to note that a small percentage (10 percent) of the Class of 2008 students attended the optional on-site question and answer midterm classroom session, and no students attended the optional live question and answer session prior to the final examination. It also is worth noting that course evaluations prior to the development of the online course indicated that students felt the previous traditional format course took up too much time, especially during an already busy semester in which students first took clinical courses; they also had felt that the depth and breadth of the previous course content was “too broad,” “too detailed,” and “not applied.” Narrative comments from the Classes of 2007 and 2008 supported the idea that providing the course in an online format addressed some of the time constraints felt by previous students, and the more applied nature of the online course resulted in zero comments related to the course being too broad, too detailed, or not applied. When compared to previous course evaluations prior to the development of the online format, student evaluations have been more positive for the Classes of 2007 and 2008 despite the fact that there were some students who desired a traditional classroom format. Ongoing analysis of student satisfaction will be necessary.

In terms of the discussion board format, the first cohort (Class of 2007) provided feedback to guide revision for the second offering of the course. While the objective for the discussion board was to post application questions to encourage students to integrate material from several of their courses in an effort to increase critical thinking and problem-solving, narrative comments from the first cohort stated that, by the time the first or second student responded to the discussion question, answers from subsequent students became repetitive. To address this issue for the Class of 2008, the instructor emphasized the use of open-ended style questions for each discussion group for each module based on a common theme designed to encourage further discussion. For example, the theme for Module 1, Chemistry Foundation, had questions related to compounds and bonds. The group discussion questions were as follows:

Group 1: Give the chemical formula for calculus and describe what types of bonds are likely to be present;

Group 2: Give the chemical formula for enamel and describe what types of bonds are likely to be present;

Group 3: Give the chemical formula for dentin and describe what types of bonds are likely to be present;

Group 4: Give the chemical formula for cementum and describe what types of bonds are likely to be present; and

Group 5: Give the chemical formula for bone and describe what types of bonds are likely to be present.

The instructor also indicated that exam questions would come from each of the questions posted in the five different discussion threads. The intent was
to encourage students to not only participate in their assigned discussion group but also take time to review the discussion threads of the other four groups.

An examination of the discussion thread on saliva in Figure 2 illustrates how this form of learning can provide opportunities for critical thinking and problem-solving beyond the original question. In discussing the effect of acidic products on the teeth, a question is posed by one group member about whether cocaine is acidic as she saw a picture of a cocaine user in her morphology course who had severe erosion. The next post in the discussion thread shows another group member seeking out the answer and finding that hydrochloride acid is often added to cocaine, resulting in cocaine being an acid product. In the discussion thread on local anesthesia (Figure 3), many examples can be seen in which the students pulled information from other courses and other resources in order to answer the application question for biochemistry. At this point in the curriculum, students had not taken a course on local anesthesia. One student referred her peers to an article in Dimensions of Dental Hygiene related to local anesthesia for background information in which to learn about the different types of local anesthesia used and some characteristics of each in order to address the application question.15 Another student referred classmates to a section of their dental management textbook to answer a question regarding allergic reactions to local anesthesia.16 Both of these examples illustrate again how discussion threads can be effectively used to stimulate critical thinking, problem-solving, and integration of curriculum content.

The third outcome that was examined was student performance (grades). While the Classes of 2007 and 2008 received As and Bs, by comparison, the Class of 2006 who took the traditional lecture-based course delivered by the basic science faculty received a few As and Bs, a majority of Cs, and a few Ds. Recall that previous classes complained that the course took an inordinate amount of study time and in the end they left the course with little or no understanding of the relevance that biochemistry has to the practice of dentistry and dental hygiene. In the revision of this course, it was the philosophy from the beginning that, based on prior outcomes, the course needed to be applied in order to provide the bridge between biological science and clinical science. Another philosophical difference that was captured in the design of the course was the concept of mastery learning. Students had the opportunity to retake the online examinations, so that in those instances in which they failed on a first attempt, they could take time to remediate and prepare before attempting the exam again. The literature indicates positive effects of mastery learning on students, especially in the areas of achievement, attitudes toward learning, and the retention of content.17

Another outcome variable that is often considered when examining learning outcomes is National Board Dental Hygiene Examination (NBDHE) results. NBDHE reports are provided to individual dental hygiene programs and present information about overall student performance in a variety of subject areas compared to national data. Physiology, biochemistry, and nutrition are a combined subject area on the final NBDHE analysis and report. Examination of this combined subject area results found that students from the Classes of 2007 and 2008 were at least comparable to students nationwide in correct answers on the relevant section. These results mirror results from previous years when school and national averages on this section of the NBDHE were similar. Therefore, it would appear that the revision of the biochemistry course has not had an adverse effect on National Board performance.

The use of technology in teaching holds the potential for solving many of the curricular and instructional reform issues being discussed today, like the overcrowding of the curriculum, lack of active learning methods, and basic sciences taught in isolation from the rest of the curriculum. In a recent article in the Journal of Dental Education, the authors proposed assigning basic science courses (biochemistry, microbiology, and physiology) to prerequisite coursework.18 The assumption is that this could free up a significant block of curricular time to then devote to emerging science and clinical procedures. In contrast, we believe that the approach described in our project illustrates the centrality of the basic sciences, specifically biochemistry, to the dental sciences. Rather than demote basic sciences to prerequisite status, we propose that bridge courses like the one described in this article be developed utilizing technology as a way of delivering course content. Students would take prerequisite basic science courses prior to matriculation, but then bridge courses during the initial phase of the curriculum would assist dental and dental hygiene students to make the connection between basic science and the science of dentistry. Although the instructor did not log hours during the development and administration of the course, it was felt that less time was needed to prepare for and manage the course than in tradi-
tional lecture courses previously taught by co-author Crain. The Blackboard format was easy to learn and use, and technology support was readily available through the university as needed. The majority of time the instructor dedicated to the course was during the course content development phase: determining which chapters and sections would be included, designing the discussion questions, and constructing the tests. It should be noted that, once the tests were created in Blackboard, the grading of examinations and the management of student progress took only a few minutes per student during the course. Similarly, the monitoring of student discussion took little time as compared with the time needed to prepare for lectures during previously taught traditional format courses in the course director’s experience. Also, since the course was created in Blackboard, the course site was easily reproduced and edited for the subsequent year’s course offerings. Despite the lack of face-to-face interaction with the students, it was the experience of the instructor that more directed and personal communication occurred via email with individual students and through the group discussions on the course site than occurs in a traditional lecture-based setting.

Obvious limitations to this study are the small number of participants and the fact that this study is based on only two classes who have taken the online biochemistry bridge course to date. Ongoing examination of student learning and acceptance of the online course format will be necessary.

**Conclusion**

While online teaching and learning are still relatively new to dental and allied dental education, there can be no doubt that the use of instructional technology to deliver education online will continue to evolve. Accordingly, the purposes of this article were to describe the conceptualization, development, implementation, and evaluation of an online applied biochemistry course, and discuss the rationale and pedagogical approach for this course design. While challenges remain, we hope our experience can benefit others who are looking to establish online applied instruction in the basic sciences in the dental and dental hygiene curricula.

**REFERENCES**