

TEACHERS' TOPICS

Creation of Medicinal Chemistry Learning Communities Through Enhanced Technology and Interdisciplinary Collaboration

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Objectives. To build an integrated medicinal chemistry learning community of campus and distance pharmacy students through the use of innovative technology and interdisciplinary teaching.

Design. Mechanisms were implemented to bring distance students into campus-based medicinal chemistry classrooms in real time, stimulate interaction between instructors and various student cohorts, and promote group work during class. Also, pharmacy clinician colleagues were recruited to contribute to the teaching of the 3 medicinal chemistry courses.

Assessment. Student perceptions on the value of technology to build community and advance learning were gleaned from course evaluations, in class feedback, and conversations with class officers and student groups. Responses on a survey of second-year students confirmed the benefits of interdisciplinary content integration on engagement and awareness of the connection between drug chemistry and pharmacy practice. A survey of clinician colleagues who contributed to teaching the 3 medicinal chemistry courses found their views were similar to those of students.

Conclusions. The purposeful use of technology united learners, fostered communication, and advanced content comprehension in 3 medicinal chemistry courses taught to campus and distance students. Teaching collaboration with pharmacy clinicians enhanced learner interest in course content and provided insight into the integrated nature of the profession of pharmacy.

Keywords: interdisciplinary, technology, medicinal chemistry, learning communities

INTRODUCTION

Knowledge of drug chemistry is foundational to the practice of pharmacy. At Creighton University, students are exposed to medicinal chemistry content in 2 required courses offered in the second year. These courses, entitled the Chemical Basis of Drug Action I and II, along with selected lessons incorporated within them, have been described in detail.¹⁻³

In 2010, lessons on acid-base chemistry and receptor chemistry were removed from the Chemical Basis of Drug Action I course during an extensive revision of the professional curriculum. While students are exposed repeatedly to these topics during their pre-professional coursework and in professional biochemistry and pharmaceuticals courses, the faculty members recognized that their knowledge confidence and optimal understanding could be improved through additional instruction and practice. These lessons, along with lessons on physicochemical principles and properties and stereochemistry,

were bundled into an elective course entitled Scientific Foundations of Drug Action. This elective was offered to interested first-year pharmacy (P1) students in the spring semester, prior to the first required medicinal chemistry course they would take in the fall. This placement was intended to promote retention of knowledge needed for the analysis of structure-activity relationships to predict pharmacological actions and therapeutic utility of drug molecules.

Creighton University offers a campus-based and a distance pathway to earning the PharmD degree. Unlike many distance pharmacy programs, the distance cohort is widely distributed across the country so students do not gather at a single site to hear course lectures. Rather, students interact with course content via robust course Web sites, and with instructors, mentors, and one another via conferencing software associated with the Angel Learning Management System (LMS) (Blackboard Collaborate, Washington, DC, www.blackboard.com). Instructors and mentors are also available to distance students via telephone and, in some cases, in-person meetings. All pharmacy students are required to complete Chemical Basis of Drug Action I and II in order to earn

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the PharmD degree. Scientific Foundations of Drug Action is an elective and, in the 2 years of its offering, 63% and 75% of the campus P1 students and 38% and 41% of the distance P1 students have enrolled.

Course evaluation data over the years have confirmed student appreciation for the interactive lesson handouts that include periodic quizzing. Likewise, students have found the use of tablet computers beneficial in medicinal chemistry courses where drawing and reaction annotation are routine. The LMS used to deliver course content is robust and easy for students to navigate, and it allows for the timed distribution of content, including active-learning exercises and keys to completed examinations and quizzes.

Interprofessional education is a goal of all pharmacy programs, in part because it is expected by accreditation standards.⁴ With the implementation of the revised curriculum, which emphasizes vertical and horizontal content integration, the medicinal chemistry faculty members recognized the need to be more proactive in linking chemistry content to the practice of the profession. Clinical relevance has always been stressed in the Chemical Basis of Drug Action courses, but it was made more explicit by the inclusion of clinical practitioners in the presentation of selected lessons.⁵ When designing Scientific Foundations of Drug Action the authors proactively engaged clinicians in lectures and active-learning sessions. The faculty also recognized the value of bringing the 2 learning cohorts (campus and distance) together to engage in classroom activities in real-time. Techniques which allowed for the broadening of the in-class learning community will be described, and the robust use of technology to both unite learners and advance deep learning will be addressed. Our course objective was the creation of a learning community that integrated campus students, distance students, course faculty and clinical faculty through the purposeful use of technology.

DESIGN

Overview of Course Management and Instruction

Both authors were highly involved in the instruction of the 3 medicinal chemistry courses over the 2-year period described here and brought a similar pedagogy to each. Lesson content was delivered via conversational handouts constructed in Word or SoftChalk, which students were responsible for reading before class. Pre-class reading comprehension quizzes, sometimes referred to as team readiness assurance tests, or tRATs, could be completed collaboratively but had to be submitted individually.⁶ Completion of the open-book quizzes prepared students for in-depth discussion, problem solving, and active-learning exercises during the lecture periods.

In-class problem solving was facilitated by ResponseWare (TurningPoint Technologies, Youngstown, OH) personal response system technology that permits polling of class responses to content application questions. Examinations in all 3 courses were administered online, and focused significantly on clinical application and problem-solving, as opposed to information recall.

Active learning was purposefully incorporated into the 3 medicinal chemistry courses, albeit in different ways. Lecture-embedded active-learning strategies such as think-pair-share exercises and structure challenges were used in Chemical Basis of Drug Action I and II, and voluntary recitation periods were used for more in-depth active-learning activities such as computerized medicinal chemistry case studies⁵ and Patched-Up Drug Exercises (described below). Defined active-learning sessions were an integral component of Scientific Foundations of Drug Action, and always comprised the second hour of the 2-hour weekly class session. Examples of active-learning exercises used in Scientific Foundations of Drug Action include a double-entry journal activity on a published article on acid-base chemistry, case studies related to acid-base chemistry, an acid-base strength Jigsaw Challenge, an Induction-Deduction Challenge (acid-base strength) and a functional group treasure hunt. Copies of all active-learning exercises are available from the authors.^{7,8}

Interdisciplinary Collaboration

To advance content integration of the 3 courses, interdisciplinary collaboration was pursued. Clinical colleagues from within the university were invited to participate in selected sessions of The Chemical Basis of Drug Action and the Scientific Foundations of Drug Action courses. For example, the medicinal chemistry of antihyperlipidemic statins is addressed in Chemical Basis of Drug Action I, and the pharmacy practice faculty member who practices at a regional VAMC contributed to the class session where the SAR of statin products was applied to therapeutic decision-making. The entire class session was comprised of a series of therapeutic application problems/questions posed to the class. After the students applied their knowledge of drug chemistry to make appropriate therapeutic recommendations for specific patients described in the problems, the pharmacy practice faculty member reinforced the validity of their analyses by sharing related patient care experiences and emphasizing the importance of chemical understanding to comprehensive patient care.

In Scientific Foundations of Drug Action, clinical faculty colleagues shared class sessions on acid base chemistry and physicochemical properties. With regard

to the former topic, the pharmacy practice colleague shared experiences that reinforced why pharmacists require an in-depth understanding of acid base chemistry to keep patients safe in a hospital setting. With regard to the latter topic, the pharmacy practice faculty member who works with bariatric patients shared the podium with the medicinal chemist in a fully integrated class session addressing the clinical relevance of molecular lipophilicity (Log P) and its significant impact on therapeutic decision-making.

Technology

By using specific, cross-platform technologies, student and faculty cohorts were able to actively dialog about course content in the Chemical Basis of Drug Action I and II course and the elective course. Through the Learning Management System (LMS), distance students entered the classroom online, permitting them to hear and view what the campus-based students were experiencing. The instructor's desktop was shared and distance students could make comments or ask questions by texting if they were online or by voice if they were in the classroom. Through a voice over Internet protocol, distance students also could be given audio ability so that everyone, including campus-based learners, could hear them, or their rights could be restricted to typing out their question in a textbox. When questions were typed, the faculty member monitoring the chat repeated the question aloud for everyone to hear before it was addressed. Lecture capture recorded the entire class session for students to review if desired.

The Angel LMS system permitted the establishment of several breakout online "rooms" in which distance Scientific Foundations of Drug Action students could "gather" to work on in-class active-learning exercises. The course mentor (a senior medicinal chemistry faculty member at another institution), who was present during each Scientific Foundations of Drug Action class session, moved from virtual room to room to address questions while the campus-based instructors were working with campus-based students. The course instructors also checked in with the distance students during active-learning sessions to ensure that all questions were being addressed.

A suite of question types were made available in Softchalk through an electronic Quiz Me feature. Through Quiz Me pop-up windows, answers to embedded questions were invisible to the students until the question was attempted. True-false, multiple-choice, and multiple-answer questions were available, as were more complex challenges such as crossword puzzles and structure drawings with "hot spots" that corresponded to the questions asked. In addition

to Quiz Me questions, SoftChalk pop-up windows could be embedded with images, chemical structures, or additional text. The pop-ups could display full motion videos or movies embedded in the document or hyperlinked to an outside source. Embedded videos with proper citation were preferred in case unanticipated changes were made to the original Web site URL.

The tablet computer is a highly useful tool for interactive problem solving. When used in class, instructors could spontaneously draw on slides or graphics to illustrate concepts in response to student questions. Likewise, students could "ink" (write) on their lesson notes or on the PowerPoint slides used to deliver a lesson in class, and forward captured images of those modified pages or slides to faculty members when asking questions or requesting clarification of a concept. The capabilities of the tablet computer allowed faculty members to understand and correct areas of confusion, ask students to demonstrate their understanding of topics under discussion, and reinforce accurate thinking. Tablet PCs are uniformly configured and issued to all Creighton pharmacy students and faculty members.

The VOIP has built-in presentation functions that allowed faculty members to hold virtual office hours when students and faculty members could speak to one another. Students in both cohorts could join an online help session during which questions could be asked verbally or in writing. The presenter's desktop or files could be shared and confusing concepts could be addressed explicitly.

PRSs such as TurningPoint Technologies' ResponseWare allowed students to respond immediately and anonymously to questions posed in class. Responses were displayed as a percentage of respondents selecting each possible answer, allowing faculty member to recognize when students' understanding was suboptimal and giving them the option to reinforce principles before proceeding with the lesson/presentation. PRSs were also used as an indicator of individual students' grasp of content so that focused remediation could be offered. Unlike the use of traditional "clickers," which demand the user be physically present in the classroom to participate, ResponseWare allowed both campus and distance students to engage in in-class polling.

The Patched Up Drug Exercise (Creighton University) allowed students to practice constructing and modifying pharmacophores to build drug molecules (real or envisioned) that accomplish specific therapeutic goals. The program facilitated understanding of how key drug functional groups honor known structure activity relationships and permit a compound to elicit desired therapeutic actions. When using the Patched Up Drug Exercise, the faculty member uploaded functional group images appropriate

for a given class of therapeutic agents as transparent *.png files or smiles strings.⁹ The students logged into the application and selected a chemically-based therapeutic case designed by the faculty member. As preloaded questions appeared at the top of the screen, students dragged, dropped, and rotated selected functional groups on a pharmacophoric skeleton to create a compound that acceptably addressed the case question. Students had the option to view a structure uploaded by the faculty member as an ideal solution to the case question, and/or they could use embedded e-mail to send their molecule to the faculty member for feedback. When responding, the instructor was able to annotate the student's image to highlight functional groups of importance, as well as provide narrative comments and corrections.

Several new cases were added to the Computerized Medicinal Chemistry case studies (reported on previously^{10,11}), the most complex of which was based on Star Wars characters and addresses adrenoceptor agonist and corticosteroid drugs used in the treatment of asthma.¹²

Synchronous use of this computer-assisted learning tool by distance students in the Scientific Foundations of Drug Action course was required and these students had to rearrange their work and or study schedules to accommodate the 2-hour weekly class session and at least a third of the distance class did so over the 2 years of the course described here. The VOIP technology permitted seamless integration of the distance cohort into the class setting. Students could be heard easily by the campus students and they were proactive participants in class discussions.

The option to participate in the Chemical Basis of Drug Action I and II class sessions routinely drew up to 15 distance students (20.5% of the class) each period. The cohort participating in real time was consistent over the course of the semester. Approximately half of the participants gained familiarity and comfort with the VOIP technology through previous enrollment in the Scientific Foundations of Drug Action course, indicating that the technology is sufficiently intuitive to use without extensive past experience.

ASSESSMENT

An assessment of the impact of clinician involvement in the chemistry classroom the previous fall in the Chemical Basis of Drug Action I course was conducted by surveying students enrolled in the Chemical Basis of Drug Action II in January 2012 using a self-reported, aggregate, de-identified survey instrument with Likert scale responses. Of the 180 students enrolled in the course, 56 (30.9% of the class) completed the voluntary survey instrument. The survey was sent to students at the end of the semester and was voluntary, and both factors

may have contributed to the low overall response rate. Responses were clustered at the 80%-82% agree/strongly agree end of the scale and confirmed the positive impact of the integrated class session on content interest and awareness of the importance of chemistry to the practice of pharmacy. Between 3.5% and 7% of respondents disagreed/strongly disagreed with the statements on interest in the content and relevance of the course. Slightly over 27% of the respondents either agreed or disagreed that the integrated session stimulated additional student questions during class, while 45.5% were not sure of the session's impact on their in-class questioning.

Approximately 55% (31 students) of the respondents had also taken the Scientific Foundations of Drug Action elective course the previous spring. Between 75%-80% of PHA 391 participants found value in the involvement of clinicians in those class sessions. Specifically, they felt clinician involvement reinforced the clinical relevance of medicinal chemistry and increased their interest in the class session. Only 1 respondent disagreed with these statements.

The 3 clinical colleagues who participated in the Scientific Foundations of Drug Action and/or Chemical Basis of Drug Action I classes were given a post-lesson survey. Responses indicated that they felt prepared to contribute to the session and that their session effectively promoted interdisciplinary content integration. One respondent was not sure if their session appropriately reinforced the clinical relevance of medicinal chemistry, while the other 2 strongly agreed with the statement. All indicated they were willing to participate in future classes.

DISCUSSION

The strategies used in the medicinal chemistry-related courses at Creighton (all of which are facilitated by technology) were intended to advance higher-level learning, engage learners across pathways, and/or promote interdisciplinary content integration.

The interactive nature of SoftChalk questions complements the collaborative and open-book nature of the pre-class reading comprehension quizzes, or tRATs. Students can treat the Quiz Me questions like a game, which encourages intellectual debate between students about right answers and focused discussion on course content. Quiz Me questions can be inserted in sections of the lesson handout that cover material found in the tRAT to prompt/guide student thinking and promote success on the quiz and in the course. As the instructors improve the courses in their quest for purposeful integration of clinical expertise in the classroom, more structurally based therapeutic application questions can be embedded to stimulate student-clinician dialog.

Likewise, properly executed-videos that illustrate abstract concepts are a boon to students who self-identify as visual learners. For example, envisioning the 3-dimensional orientation in space of a drug with 1 or more chiral centers docked in a receptor active site can be overwhelming for a student whose primary resource for understanding is the written lesson handout. However, the Softchalk lesson with embedded 3D video allow students to play the animation of the drug-docking process and stop it at key points to discuss what is happening, and to take screen captures to send to faculty members with questions.

The use of tablet computers greatly enhanced the efficiency of faculty-student interaction around confusing concepts. Instead of trying to articulate a chemical confusion only in words, students can also illustrate their thoughts by drawing on a faculty-generated document or slide, which usually highlights the pivotal issue much more quickly. The ability for both students and faculty members to spontaneously draw on computer-based documents without the need for a drawing program has been particularly invaluable in online office sessions or examination review sessions.

Faculty members often embrace personal response system (PRS) tools as a way to titrate the learning ongoing in a given class session, but the capabilities for learning advancement are significantly more robust. Using the ResponseWare software, each class session's PRS data can be collated into 1 report, and students performing at a selected level (eg, < 70% correct responses) can be highlighted. Faculty members can then reach out to students who do not appear to understand content at an acceptable level or who may be at risk for examination or course failure. Focused content remediation can be constructed in areas where PRS responses indicate a lack of understanding, although the responsibility for following through remains with the learner. Targeted in-person and online review sessions can be offered to address problem areas, and the tutors supported by pharmacy organizations and the school administration can be prompted to work on these identified issues with their protégés.

Use of PRSs challenge questions engaged students in the lesson.¹³⁻¹⁶ Three polling questions per 50-minute class session spaced every 15 minutes appeared optimal. Student interest in performing well was also enhanced if points were awarded for correct responses.¹⁷ A key advantage of ResponseWare is cross-platform access to polling questions. As long as students have an Internet-capable device (eg, laptop computer, smart phone, tablet computer, etc) and are appropriately logged in to the ResponseWare session, they can participate. This cross-platform access is attractive when there is not a uniform

technology infrastructure, such as a mandatory laptop program, or if a student's laptop is in for repairs.

A benefit of distance students' real-time participation in the campus-based classroom was enhanced student engagement. Despite faculty encouragement to ask questions and contribute comments during class, campus students often did not want to raise their hand for fear of disrupting the flow of the lecture. However, distance student questions, which were initially written in a chat log associated with the VOIP, were not viewed by the campus cohort as disruptive because the faculty members were able to address the question at a natural break in their delivery. Campus students could also interact with the distance students through the VOIP associated chat log if they chose to do so. The faculty member could stop the lecture at planned times to ask all students for questions.

One caution to the use of technology to bring distance learners into the campus classroom is the level of preparation and practice required by the faculty members. In addition, all classroom technologies must be fully compatible to avoid malfunctions that disrupt learning and frustrate all concerned. Faculty members should work proactively with their technology support staff members to troubleshoot potential compatibility issues. Students must be patient as new technologies are implemented because, despite everyone's best intentions, challenges will inevitably occur. The goal is to keep them at an absolute minimum and to address any issues related to learning in a manner equitable to all cohorts.

As a result of the steps taken to increase interdisciplinary collaboration, student engagement and proactive questioning in the Chemical Basis of Drug Action I session on antihyperlipidemic statins was higher than had been noted in past lessons. Because the clinical faculty member was able to share how her knowledge of drug chemistry helped her make important therapy decisions for at-risk patients, students could better relate what they were learning in the classroom to their future practice. Based on the positive results of clinician involvement in the antihyperlipidemic statins lesson, additional pharmacy practice faculty members have agreed to contribute to similar Chemical Basis of Drug Action I and II class sessions on drug metabolism, antineoplastic agents, and opioid analgetics.

Likewise, in the Scientific Foundations of Drug Action course, having a respected clinical faculty member reinforce how his knowledge of science allows him to solve acid base chemistry problems encountered at the bedside and keep patients safe was a powerful lesson on the clinical relevance of drug chemistry.¹⁸ It also allowed both faculty members (clinician and chemist) to demonstrate how their different approaches to solving Henderson-Hasselbalch-related

problems result in identical answers, reinforcing the universal truth of this pivotal mathematical/chemical concept.

In an active-learning session in which the Patched Up Drug Exercise beta software was used, the students stated that the drag-and-drop nature of the exercise was intuitive. Within moments of the students logging into the program they were able to begin working on assembling structures that met the SAR criteria for answering a case-based question. Highlighting the functional groups and rotating them to fit the desired orientation was also simple and intuitive for the students. Student buy-in on the utility of the software was strong, as they could clearly make associations between a drug's functional groups and the role of each functional group in meeting the criteria for eliciting a therapeutic outcome.

The fully integrated chemistry/clinical lesson on drug lipophilicity took the concept of interdisciplinary collaboration even further. The chemist first set the stage by presenting foundational material. The clinician then illustrated how she applies these realities when addressing the specific needs of extremely obese patients, some of whom may be facing or recovering from bariatric surgery (eg, bypass, banding).¹⁹

CONCLUSIONS

Medicinal chemistry learning communities that span 3 courses were successfully created through interdisciplinary collaboration in teaching and use of enhanced technology. The participation of clinical colleagues in science-focused courses may serve as the first step toward achieving a fully integrated and interprofessional curriculum, a goal of all pharmacy programs. An additional benefit of interprofessional teaching is the establishment of relationships that can lead to interprofessional scholarship and publication. 'Also, the technologies described in this manuscript united campus and distance learning communities, fostered communication with faculty members, provided opportunities for active learning and command of content, and advanced meaningful learning.

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