RESEARCH

Students' Perception of Self-Efficacy Following Medicinal Chemistry Skills Laboratory Exercises

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Objective. To analyze student perceptions of self-efficacy in meeting medicinal chemistry course related educational outcomes and skills following a medicinal chemistry skills laboratory.

Methods. Four activities were implemented in a pharmacy skills laboratory (PSL) for second-year pharmacy students. Students (n=121) worked individually on exercises for three of the four activities. Pre/post-laboratory surveys on self-efficacy were administered. The McNemar test was performed to evaluate students' self-efficacy above 70% related to course outcomes before and after the exercises in each activity. An independent *t* test was conducted to compare the mean of students' responses on meeting course outcomes based on the 70% anchor for the perspective confidence on meeting course outcomes.

Results. The post-PSL scores on all self-efficacy questions improved. The majority of students reported skill development in all exercises. Students and clinical faculty qualitative responses indicated they felt exercises were effective.

Conclusion. A PSL can serve as a valuable opportunity to address course related educational outcomes and specific skill development and can help students assess their self-efficacy in meeting them.

Keywords: Medicinal chemistry, perception, self-efficacy, curriculum, skills lab, integration, pharmaceutical sciences, clinical relevance

INTRODUCTION

With the introduction of Standards 2007 by the Accreditation Council for Pharmacy Education (ACPE),¹ our program, and other pharmacy programs in general, had to modify curricula to require that skills laboratory courses meet accreditation-mandated expectations and program-specific competencies for students. Many faculty members took advantage of the introductions of skills laboratories to address key educational outcomes as part of their courses²⁻⁶ and to improve required skills.

At Creighton University, the pharmacy skills laboratory (PSL) course sequence was implemented in 2009. Among its goals was the opportunity for faculty members to offer exercises to reinforce, integrate, and apply the content covered in simultaneously offered didactic courses and help students develop essential skills as they progressed towards advanced pharmacy practice experiences (APPEs). For pharmaceutical sciences faculty members, the PSL offered a vehicle to demonstrate the

importance of their discipline to the comprehensive curriculum and to pharmacy practice.^{2,6}

We previously implemented several classroom-based strategies including treatment algorithms,⁷ electronic integration of prerequisite content,⁸ learning games,⁹ and the structurally-based therapeutic evaluation (SBTE) concept¹⁰ to help students appreciate the relevance of medicinal chemistry to pharmacy practice and to instill self-directed learning by students.^{11,12} The PSL was intended to provide a unique venue with sufficient time to reinforce what was being taught in the classroom, to challenge students to integrate and apply what they had learned, and to increase their confidence in their ability to meet course objectives and perform (self-efficacy). Several authors from a variety of health sciences disciplines have studied the positive correlation between self-efficacy and academic performance,¹³ performance in the clinical arena,¹⁴ and readiness for self-directed learning.¹⁵ In this manuscript, we document student perception of self-efficacy following the medicinal chemistry PSL and the lessons learned.

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METHODS

The Chemical Basis of Drug Action course sequence is a 2-semester sequence (2.5-credit hours each) taught in

the second year of the professional curriculum. The class meets two or three times per week. The study was incorporated into the fall semester offering of the course. Enrolled students have completed required courses in biochemistry, communication skills, physiology, microbiology and immunology, pathology and pharmaceuticals, and are concurrently enrolled in pharmacology, patient assessment, and basic pharmacokinetics courses. Meetings were held with pharmacology faculty members over three years at the beginning of each year to synchronize the content taught by the two courses.

The laboratory has a main area of approximately 5400 square feet with six examinations rooms (80 square feet each) equipped with patient assessment and mobile recording equipment. There are 72 student work stations, each with a flat screen computer with access to the Internet, Health Sciences Library resources, and two pharmacy management programs (QS1and Etreby). In addition, there are 34 phones (one per two stations) for telecommunication simulations. There are four horizontal flow hoods, one vertical flow hood, two compounding aseptic isolators and six simulated hoods. The PSL is a self-care simulated pharmacy front area with nonprescription products and a variety of durable medical supplies (eg, canes, crutches, walkers, wheelchairs).

The process of developing the PSL exercises started by asking what the primary goal was and what outcomes we were trying to achieve. The answer to the first question underpins our educational philosophy related to medicinal chemistry, which is the appreciation of the applicability to patient care of the knowledge gained in class. To answer the second question, we referred to the course syllabus, which identified three key educational outcomes and their respective competencies (Table 1). Four activities with several exercises were employed in the PSL. Instructions for completing each exercise were provided (Table 2). Students had previously completed study

of adrenergic agonist, beta adrenergic antagonist, and anticoagulant drug classes addressed in the PSL. For this offering of the PSL, we decided not to assign a grade for student work since activities and related exercises were intended to help students assess their abilities to apply knowledge gained two days before the third examination. Electing not to assign a grade for student work was also intended to foster self-awareness and professional growth and to advance the concept of self-directed learning, as part of meeting the professionalism, citizenship, and leadership outcome (Table 1).

The medicinal chemistry PSL was not offered before the first or second examination. Students were informed about the laboratory and its format three weeks in advance of examination 3 to give them time to prepare, reflect on the content, apply what they learned, and gauge their preparation for the examination. Students were also encouraged to schedule meetings or e-mail any questions to the respective faculty member following the PSL.

Students (N=121) were divided randomly into 24 groups of five or six. Twelve groups attended a morning skills laboratory session with the remaining 12 groups participating in the afternoon session. The duration of each PSL session was two hours. For each session, each student within the six groups was required to stop at station I (Patched-Up Drug Exercise) (Table 2). Each student was also allowed to choose between station II (Package Insert Exercise) and III (SBTE) Exercise) (Table 2) because the exercises under each addressed similar competencies (Table 1, educational outcomes 3 and 6). Each student had 25 minutes at station I to complete three exercises, and 25 minutes at station II or III to complete three exercises. The use of resources was not allowed at any of the stations.

All student groups were required to stop at station IV [Pharmacy and Therapeutics (P&T) Exercise] (Table 2). Station IV had three substations, one focused on each class of drugs that would be covered on examination 3 (adrenergic

Table 1. Chemical Basis of Drug Action Courses Educational Outcomes

Educational Outcome	Competencies
2. Professionalism, Citizenship, and Leadership	2.1 Communicate the importance of reflection, ongoing professional growth, and life-long learning
3. Critical Thinking	3.4 Given a practice-related issue, clearly define the question or problem and communicate a claim or thesis about that question/problem
	3.5 Utilize prior knowledge, available information, and new data to identify, prevent, and resolve problems and make appropriate decisions
	3.6 Communicate findings and justify recommended solutions
6. Medication Therapy Management	6.2 Identify physiochemical properties of medications that affect their solubility, bioavailability, stability, pharmacokinetic and pharmacodynamic properties, and pharmacologic actions
	6.3 Identify specific uses and indications for medications including their pharmacologic, chemical, and therapeutic classes)

Table 2. Description of Pharmacy Skills Lab (PSL) Exercises

Exercise	Description
Patched-Up Structure	<p>Students are presented with sheet with several functional groups. Students are required to evaluate the functional groups and construct a compound/structure that would address a case-based questions (eg, Construct an arylethanolamine that is a good choice to treat a patient with hypertension and a history of hyperlipidemia). Students are required to complete three patched-up structures with a minimum of one from either the adrenergic agonists or beta adrenergic antagonists. The answer booklet prompts students to write their name on top, the name of the exercise, and the substation number. Students are asked to draw their patched-up structure in the provided booklet. Students are asked to address the following information for all the exercises:</p> <ul style="list-style-type: none"> Identify pharmacophore; Identify structure activity relationship (SAR); Identify/predict pharmacodynamics properties/pharmacological action; Identify/predict therapeutic use; Identify/predict physiochemical properties of the medication that affect its solubility, bioavailability, stability; Identify/predict pharmacokinetic properties; Identify any clinical implications based on patient current medical history, past medical history, cultural background, side effects, compliance issues, etc.
Package Insert	<p>Students are provided with the drug structure as it appears in the package insert of a marketed product and are then challenged with the following scenario: You are the pharmacist working at a community, clinic, or hospital pharmacy. You are asked by a nurse about a new drug that just came on the market. While the other pharmacists are scrambling to find information about the new drug, you take one good look at the structure in the package insert and you proceed to explain key information about the new drug. Each student is required to complete the package insert exercise for two drugs, one each from the adrenergic agonists and beta adrenergic antagonists. Each student is asked to complete an analysis in the provided booklet based on the structure provided and address as much of the information summarized under the Patched-up Exercise.</p>
Structurally Based Therapeutic Evaluation (SBTE) ⁶	<p>Students are provided with short SBTE case scenarios and three possible drug structure choices and are required to choose the best drug structure choice based on the patient presentation. The topics covered are beta adrenergic antagonists and anticoagulants. Five case scenarios are authored to apply the SBTE concept. Each student is required to complete the SBTE for one of each of the drug classes identified above and the answer in the provided booklet.</p>
Pharmacy and Therapeutics (P&T) Committee	<p>Students are assigned into groups of 5 or 6 to a medicinal chemistry faculty member and a clinical faculty member. They are given the following scenario: You are the pharmacist(s) on the P&T committee. You can pick from a large rural hospital, a small rural hospital, a large urban hospital, or a large medical center. You are being asked to evaluate a drug based on its structure for a report to be generated to the P&T committee. You have 25 minutes as a group to research the drug, identify key aspects from the structure based on your knowledge of SAR, and summarize key information to educate members of the P&T committee. You are asked to use the information given in each scenario to make your decision. Please tap into your pharmacology, health systems and patient safety, pharmaceuticals, pharmacotherapeutics, and other knowledge gained so far, and indicate any other issues that may impact your decision including the type of hospital you are working in. You will be matched with another group who is researching a drug structure within the same class. Your group and the other student group will have five minutes each to present your drug. Then you will be engaged in a dialogue for 15 minutes with your peers and your faculty member regarding your drug and why or why not it should be included on the formulary. Topics covered are beta adrenergic antagonists and/or anticoagulants. Emphasis is on students identifying key chemistry and pharmacology information to support their decision related to their drug (therapeutic indication/duplication, therapeutic advantage/effectiveness, safety issues, cost-effectiveness, adherence issues, drug stability issues, restrictions, no restrictions, dose or quantity limit, age limit, not recommended, and adding it to the formulary or not).</p>

agonists, beta adrenergic antagonists, and anticoagulants). Two unnamed drug structures (A and B) in each therapeutic class were employed in the P&T exercise. Each substation was manned by a medicinal chemist and a clinical faculty member. In both the morning and afternoon laboratories, four groups were assigned to each substation, with two groups given a structure of one drug and the remaining two groups given a structure of a second drug in the respective drug class. Students were given 25 minutes to consult resources and gather information on the structure and relate it to the scenario and the questions posed in the mock P&T exercise (Table 2). The two groups assigned to the respective drug in each drug class were assigned to a faculty team. Both groups had 25 minutes to present, dialog, and debate why their drug should or should not be included in the formulary. An example for each of the exercises under each of the four activities is provided in Appendix 1.

Students were given an answer booklet to provide their written answers to PSL exercise questions. All 121 students completed the required number of exercises. The students had the option of keeping their answer booklet after the completion of the PSL to evaluate their work individually or with their colleagues. Allowing students to keep the answer booklet was also intended to help them in their review for examination 3 and to facilitate discussion with the faculty members before the examination.

Medicinal chemistry faculty members worked closely with clinical faculty members in the PSL and the laboratory technician to organize activities. Constructing the exercises for the laboratory took less than two hours of faculty time. The preparation for the laboratory, including setting up all stations, required 3-4 hours, and the laboratory activities were completed in two hours.

Pre/post survey questions on self-efficacy were administered electronically through the university's learning management system, Canvas (Instructure, Salt Lake City, UT) to assess student perception of how the PSL improved their ability to meet specific course outcomes

(Table 3). Students were asked to answer based on a scale of 0-100% in increments of 10 ranging from 0 (cannot do at all); 50% (moderately can do) to 100% (highly certain that can do). We define perceptive shift as the measure of difference between prelaboratory and postlaboratory surveys in the proportion of students who were 71-100% confident that they could meet course outcomes. Students were also surveyed on their perception of which PSL activities resulted in specific skill improvement (Table 4). A Likert scale [strongly agree (SA)=5, agree (A)=4, neutral (N)=3, disagree (D)=2, and strongly disagree (SD)=1] was utilized to assess students' general perceptions in achieving course objectives (Table 5). The quality of the work submitted by students was assessed randomly, with a medicinal chemistry faculty member reviewing answers from 20 students. Students were also given the opportunity to share qualitative responses on the activities, and theme analysis was conducted by the investigators (Table 6). Table 7 is a comparison of the mean of student responses on items 1-3, related to achieving course objectives (Table 5) based on the 70% anchor for the perceptive confidence on meeting course outcomes. The mean for student responses on items 1-3 (Table 5) was calculated based on the above Likert scale. Perceptive confidence refers to the confidence level (for example 51-60% confident) at which students felt they could meet specific course outcomes. We set the cut-off point at 70% (ie, student responses were classified as 1-70% and 71-100% perceptive confidence levels). Clinical faculty members were also asked to comment on the medicinal chemistry exercises in general, interactions between the clinical and medicinal chemistry faculty members, and any suggestions for improvement. McNemar test, as well as independent *t* test, were used for data analysis (Tables 3 and 7, respectively). All statistical analysis was conducted using SPSS, v21 (IBM, Armonk, NY). A *p* value less than 0.05 was considered significant. The study was granted

Table 3. Students' Perspective Shift^a (%) in Performing Course Outcomes at the Above 70% Pre-lab and Post-lab Self-Efficacy

Course Outcomes Self-efficacy Questions	Prelab	Postlab	Shift	<i>p</i> value ^b
Q1: Predicting drug action	43	68	25	<0.001
Q2: Predicting some aspects of drug pharmacodynamics	39	67	28	<0.001
Q3: Predicting some aspects of drug pharmacokinetics	40	67	27	<0.001
Q4: Predicting some potential toxicities or patient safety issues	45	66	21	<0.001
Q5: Predicting potential therapeutic use	42	72	30	<0.001
Q6: Making therapeutic recommendations based on the drug structure	34	69	35	<0.001
Q7: Designing an appropriate drug structure to meet a therapeutic need	27	61	34	<0.001
Average for seven questions	39	67	28	

^aA measure of difference between prelab and postlab surveys in the proportion of students who were 71-100% confident that they could meet course outcomes

^bMcNemar test

Table 4. Student Perceptions of Skill Development After Pharmacy Skills Lab Exercises

Skill	Pharmacy Skill Lab Exercises (n=121) %			
	Patched-Up Drug	Package Insert	SBTE ^a	P&T ^b Committee
Critical thinking	84	78	86	90
Communication	32	27	34	99
Apply content to practice	77	86	87	88
Integrate medicinal chemistry and pharmacology	77	86	85	90
Predict drug action based on structure	72	87	84	82
Design appropriate therapy to meet patient needs	78	48	68	60
Improvement in examination performance	77	77	77	77
Average for all exercises	71	70	74	84

^aStructurally Based Therapeutic Evaluation

^bPharmacy and Therapeutics

an exempt status by Creighton University Institutional Review Board.

RESULTS

Table 3 provides a summary of student (n=121) responses to the self-efficacy surveys addressing their perceived ability to perform certain course outcomes tasks. Overall, students' perceived self-efficacy shifted upward an average of 28% at the above 70% level for the seven questions related to self-efficacy. The prelaboratory (prelab) self-efficacy average at the above 70% self-efficacy level was 39% for all seven questions. All improvements were significant ($p \leq 0.001$, Table 3). The highest improvement in the postlaboratory (postlab) self-efficacy survey at the 70% level (34% and 35%, respectively) was reported in designing a drug structure to meet a specific therapeutic need (27% vs 61%) and in making therapeutic recommendations based on drug structure (34% vs 69%). The lowest upward shift (21%) was observed with predicting potential toxicities or patient safety issues (45% vs 66%).

Table 4 is a summary of PSL activities that resulted in perceived skill development. The majority of the students (72-90%) indicated that critical thinking, applying content to practice, integrating medicinal chemistry and pharmacology, predicting drug action based on structure, and improvement in examination performance occurred

in all four laboratory activities. However, 27-34% reported honing communication skills in the first three activities, with 99% indicating that communication skills were practiced in the P&T exercise. The SBTE and the P&T exercises were perceived to most directly advance critical thinking skills (86% and 90%, respectively). The average for skills development reporting for all activities and their related exercises was 71%, 70%, 74%, and 84%, respectively (Table 4).

The majority of students (84%, n=111) strongly agreed or agreed that the PSL exercises positively enhanced their perception of the clinical relevance of medicinal chemistry. A majority also responded that the PSL exercises improved their confidence in predicting therapeutic utility from drug structure (76%) and pharmacologic actions from drug structure (75%, Table 5).

Analyses of the qualitative data resulted in the development of two general themes for the PSL: effectiveness and room for improvement. Table 6 shows the two themes with their associated items based on a consensus analysis of the qualitative data. The input from the three clinical faculty members who participated in the PSL reinforced the effectiveness theme and also provided ideas for improvement. Specifically, the clinical faculty members shared that the activities were valuable in helping students understand the main concepts, think critically, and prepare for the examination. They also were

Table 5. General Student Perceptions Related to Skills Lab Exercises Meeting Course Objectives

Course Objectives Item	Frequency (%)				
	SA	A	N	D	SD
The skills lab exercises enhanced my belief in the clinical relevance of medicinal chemistry.	26	58	14	2	1
The skills lab exercises improved my confidence in predicting therapeutic utility from drug structure.	21	55	16	6	2
The skills lab exercises improved my confidence in predicting pharmacologic actions from drug structure.	18	57	17	7	1

Abbreviations: Strongly Agree (SA)=5, Agree (A)=4, Neutral (N)=3, Disagree (D)=2 and Strongly Disagree (SD)=1

Table 6. General Themes and their Associated Items from Qualitative Student Responses

Effectiveness	Room for Improvement
Well-designed;	Consider increase time for exercises;
Enhanced critical thinking;	Reevaluate the number of exercises;
Reinforced concepts learned during lecture;	Reevaluate the number of students per group;
Improved confidence about content knowledge;	Consider group work for all exercises;
Emphasized clinical knowledge;	Consider making the exercises required for distance students;
Helped in examination 3 preparation and performance;	Consider mechanisms to provide feedback for students;
P&T exercise was most enjoyable and challenged communication skills.	Better coordination with clinical faculty members.

vocal about how the activities provided opportunities for meaningful interactions between faculty members from both disciplines.

DISCUSSION

The results are strengthened by being anonymous, having requested input on nongraded exercises and having all students complete the surveys. Students' overall positive quantitative data (Tables 3, 4, 5, and 7) and themes from qualitative responses (Table 6) indicate a perceived effectiveness of the medicinal chemistry PSL. The pre/postlaboratory survey data indicate that the PSL activities contributed to positive student perceptions of their self-efficacy in meeting course outcomes (Table 3). In addition, the results indicate that purposefully constructed PSL exercises encouraged students to learn and apply knowledge gained in class.

The improved self-efficacy data is of particular importance (Table 3). Self-efficacy is a person's belief in his or her ability to succeed in completing a task based on his/her perceived competency.¹⁶ Bandura, following his seminal paper in 1977,¹⁶ described these beliefs as determinants of how people think, behave, and feel.^{16,17} In addition, Bandura and others demonstrated that self-efficacy could have an impact on everything from psychological states, behavior, and motivation, and it could positively influence achievement.^{17,18} However, Schunk cautioned that self-efficacy alone could not ensure high quality performance; feeling confident about one's abilities could only augment performance if the requisite knowledge and skills were firmly in place.¹⁹

In the medicinal chemistry courses, students are provided with opportunities that can assist in content mastery, including in-class activities and online resources

Table 7. Comparisons of the Mean of Student Responses on Items 1-3, Table 5 Based on the 70% Anchor for the Perceptive Confidence^a on Meeting Course Outcomes

Course Outcome	Campus Student		
	Perceptive Confidence %	Mean of Total Responses on Items 1-3 ^b	<i>p</i> value ^c
Predicting drug action	0-70 71-100	10.7 12.3	<0.001
Predicting some aspects of drug pharmacodynamics	0-70 71-100	10.8 12.2	0.001
Predicting some aspects of drug pharmacokinetics	0-70 71-100	10.9 12.2	0.002
Predicting some potential toxicities or patient safety issues	0-70 71-100	10.7 12.3	<0.001
Predicting potential therapeutic use	0-70 71-100	10.6 12.2	<0.001
Making therapeutic recommendations based on the drug structure	0-70 71-100	10.7 12.3	<0.001
Designing an appropriate drug structure to meet a therapeutic need	0-70 71-100	10.8 12.4	<0.001

^aPerceptive confidence (classified as 1-70% and 71-100%) refers to the confidence level that students felt they could meet specific course outcomes

^bMean responses based on the Likert Scale: strongly agree (SA)=5, agree (A)=4, neutral (N)=3, disagree (D)=2, and strongly disagree (SD)=1

^cIndependent student *t* test

from interactive lesson handouts, case studies, SBTE scenarios, and practice examinations.^{7-11,20} Faculty members also model in class and in voluntary examination review sessions how to provide chemically-based explanations and therapeutic evaluations when applying course content to practice. Enhancing self-efficacy in students who take advantage of these learning opportunities and dedicate themselves to meaningful understanding of course content may stimulate a commitment to work hard to accomplish and master tasks and not fear failure. While we are not able to link individual student self-efficacy perceptions to examination performance because the feedback was solicited anonymously, the literature¹⁷⁻¹⁹ supports a presumption of augmented performance by those who coupled the confidence-enhancing benefit of the skills laboratory with solid study of the content. We did see improved performance on examination 3 (post-PSL), with increased scores compared to examination 1 and 2. While other factors may have contributed to the improved performance, this can be a result of the increased confidence the majority of the PSL participants claimed as a result of engaging in the learning activities. This, along with the quality of the random sample of student work evaluated, may support the strategy taken by pharmacy programs to include skills laboratory courses in the curriculum to meet ACPE expectations and program-specific competencies. In addition, faculty members endeavor to exhibit positive and enthusiastic attitudes in and out of class to encourage students to engage in the content.²⁰⁻²² Further, efforts are always exerted to establish a classroom where students are comfortable sharing their opinions.²⁰ All of the above are strategies that Bandura identified as major sources of self-efficacy.¹⁶⁻¹⁸ The positive themes from students' qualitative comments (Table 6) lend support to the effectiveness of the above efforts.

One rewarding aspect of the PSL was the interaction that resulted among faculty members within and outside departments. Whether in the process of coordinating the activities or supervising and running the P&T exercises, the activities provided an opportunity for collegial and professional interactions and better understanding and respect for the role both pharmaceutical science and clinical faculty members play in helping students meet course-anchored learning objectives and curricular educational outcomes. The three clinical faculty members involved in the medicinal chemistry PSL also confirmed their appreciation for the experience and believed the session challenged students to think critically. Thus, it is a worthwhile effort for the pharmaceutical faculty members to coordinate with clinical faculty members in PSL.

Student appreciation of the clinical relevance of medicinal chemistry and meeting educational outcomes

(Table 1) were key to developing the medicinal chemistry PSL. Demonstrating the clinical relevance of content in biomedical and pharmaceutical science courses to practice is critical to documenting curricular and professional value.^{7-11,20,23-25} The majority of students' responses (Table 5) indicated that all PSL exercises enhanced perceptions about the clinical relevance of medicinal chemistry. The effectiveness theme from the qualitative student responses also emphasized this point. (Table 6).

It is encouraging to see that the majority of students indicated that all exercises addressed the skills associated with the educational outcomes identified for the medicinal chemistry course (Table 4). In reviewing students' answers from their submitted answer booklets, students were generally able to demonstrate many of the core competencies listed in Table 1 including 3.4-3.6 and 6.2. While all students were required to communicate their responses to the different exercises in writing, the P&T exercise was successful because it allowed the students to also communicate verbally among themselves and with the faculty teams. This activity was rated most highly by students, and was valued in helping them meet communication competencies (Table 4).

This study has limitations. Because the decision was made not to assign a grade for student work, the knowledge level related to the exercises was not assessed. Also, students were not given feedback except for the few who sought out faculty members during and after the exercise. Moreover, as the study is based on student perception, exaggeration, feelings at the time of completing the survey, or embarrassment about perceived understanding could have interfered with participants' responses.²⁶

There are a number of ways to improve future offerings of the PSL. Students could be allowed to complete the first three exercises in pairs since many suggested this (Table 6) because of the perceived value of working in groups. Also, students could be requested to present at the end of the PSL to challenge them to practice communication skills, dialog more about their findings with faculty members and peers, and receive feedback. In addition, the format of the PSL could include a summative question-and-answer session with faculty members. A final possibility is to make the P&T exercise groups smaller (eg, three) to allow more opportunities for individual student contributions. However, the number of available medicinal chemistry and clinical faculty members to serve on evaluation teams will impact the ability to alter the size of the groups.

Core competency 2.1 (Table 1) emphasizes ongoing professional growth and life-long learning. While both the quantitative (Table 3, 4, 5) and some qualitative responses (Table 6) supported advancement of this competency, considering that examination 3 was two days away from the PSL, comments from a few students reflect apathy and/or a lack of personal responsibility for learning (eg, "I was not prepared for the exercises," "Offer the PSL one day before the exam."). Thus, to further emphasize the role of students as self-directed learners, two major changes were implemented for the fall 2014 offering: (1) A 5-minute online mini-quiz was offered at a maximum of two per week. Students were given five minutes at the end of the in-class lecture to complete the mini-quizzes. The mini-quizzes were designed to promote student in-class attentiveness and retention of key concepts; (2) A 15-minute online, closed book, 10-question comprehension and application quiz (CAQ) was given, which was designed to challenge students to review the content of the prior week over a 5-day period, during which time the students could take the online CAQ. Students were required to apply the knowledge gained through the readings and class sessions in a manner similar to what is expected on course examinations. While the input from students on these new course requirements was predominantly positive, efforts such as these are needed to ensure that students are accountable for their learning and that they are prepared to consistently demonstrate and apply what they learned when called upon to do so.²⁷ The literature also shows that faculty members who challenge students, demonstrate fairness, and reward/recognize students for meeting academic challenges in ways other than just awarding grade can go a long way to motivating students to develop a culture of accountability during the professional program and upon graduation.^{24,27-30} This may also emphasize in students' minds the need for life-long learning, thus honoring core competency 2.1.

More time will be spent to ensure that the clinical faculty members are informed about the goals of the medicinal chemistry PSL, the key scientific concepts behind each exercise, and the expectations from clinical faculty members to help students meet course educational outcomes to reinforce the relevance of chemistry to practice and to help students develop practice-based skills (Table 6). In addition to coordinating with clinical faculty members in the pharmacy program, more effort is needed to reach out to the pharmacology faculty members (housed in the school of medicine) to further synchronize content and/or explore the possibility of a truly integrated medicinal chemistry-pharmacology course and PSL sessions.

Skills laboratories are now common in pharmacy education. The exercises presented in this paper can be

easily adopted or adapted to meet the specific student learning needs. Faculty members seeking to implement a laboratory of this type must commit to working collaboratively and must be sincere in their appreciation of the importance of drug chemistry to therapeutic decision-making.

CONCLUSION

Pharmacy Skills Labs can serve as a valuable opportunity to address course related educational outcomes and specific skill development and help students assess their self-efficacy in meeting them. For pharmaceutical science faculty members, the PSL can also be used to emphasize students' self-directed learning, the relevance of their discipline, integration of scientific and clinical concepts, and promotion of collegial and professional relationships with colleagues across disciplines and departments.

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Appendix 1. Examples of the Medicinal Chemistry Pharmacy Skills Lab (PSL) Exercises

Patched-Up: Given the structures in Figures 1a-1c, construct an adrenergic beta antagonist (ABA) that is a good choice for a patient with hypertension and a history of asthma. As you draw your structure, please identify by number the structural features used for you (ABA).

Figure 1a-1c

Package Insert: You are the pharmacist working at a community, clinic, or hospital pharmacy. You are asked by a nurse about a new drug that just came on the market. While the other pharmacists are scrambling to find information about the new drug, you take one good look at the structure in the package inserts (Figures 2a and 2b) and you proceed to explain key information about the new drug.

Figure 2a, 2b

Structurally-based therapeutic evaluation (SBTE): S.O. is a 55y/o male who was admitted to the hospital for knee surgery. Following the surgery, he developed a deep vein thrombosis in the calf of his operated leg. Physician wants to start structure 1 intravenously (Figure 3a). Following few days on structure 1, the patient INR is stable and > 2 . The patient was stabilized on oral therapy in the hospital and is ready for outpatient discharge. Which of the structures in Figure 3a and Figure 3b is a good choice for S.O.?

Figure 3a, 3b

Pharmacy and Therapeutics (P&T): Review carefully the instructions provided for the P&T exercise and debate and defend why, your assigned structure from Figure 4 should or should not be included on the formulary based on the indication provided. Use for hypertension.

Figure 4