Teaching Medicinal Chemistry to Meet Outcome Objectives for Pharmacy Students

Naser Z. Alsharif, Christopher J. Destache and Victoria F. Roche
School of Pharmacy and Allied Health Professions, Creighton University, 2500 California Plaza, Omaha NE 68178

Pharmacy practice demands that pharmacists draw upon competencies and outcomes that enable them to perform the functions that support the delivery of pharmaceutical care. Many pharmacy schools have established specific outcome objectives for their students based on published pharmaceutical care functions, practice skills and revised accreditation standards. To meet these objectives, students must examine clinical situations rationally and logically, then gather, organize, interpret and analyze data pertinent to the patient in question. Students must be competent to make judgements and therapeutic decisions based on available data, learn from past problem solving successes and failures, and integrate knowledge to improve the quality of life for patients. Schools and colleges of pharmacy must ensure that the faculty responsible for instructing in the basic pharmaceutical sciences emphasize not only the core science that underpins their discipline, but also the relevance of that science to the contemporary practice of the profession. The Structurally-Based Therapeutic Evaluation (SBTE) of drugs was introduced in the medicinal chemistry courses at Creighton University in 1995, and reported to interested audiences in 1997. We believe that this instructional approach to medicinal chemistry is one way to help faculty bring practical relevance to the scientific classroom, and encourage students to meet practice-based outcomes with an understanding of the scientific rationale behind the practice decisions they will make as professionals.

INTRODUCTION

In keeping with the many changes occurring in health care, pharmacy organizations have recently adopted new principles, skills and standards for pharmacy education and practice. In 1992 the American Pharmaceutical Association (APhA) published a background and position paper entitled “The Role of the Pharmacist in Comprehensive Medication Use Management”(1). APhA believes that pharmacists “should accept additional responsibility and assume greater authority in cooperatively managing patients’ medication use” so as to increase the appropriate use of medications and reduce medication-related problems. In this white paper, twenty practice principles were proposed and ultimately adopted by this organization. The American Association of Colleges of Pharmacy has also established pharmaceutical and educational care outcomes and competencies through the work of the Commission to Implement Change in Pharmaceutical Education(2); also the American Council on Pharmaceutical Education (ACPE) has adopted and published new standards for the evaluation of degree-granting pharmacy education programs(3).

Many pharmacy schools and colleges have established specific outcome objectives for their students based on the above pharmaceutical care functions, practice skills and the revised accreditation standards. At a curriculum retreat designed to map course content against outcome objectives for Creighton University pharmacy graduates (which were based on those articulated by the Commission in Background Paper II), each instructor presented how s/he taught the requisite skills, developed the desired competencies and met the pharmaceutical care standards embraced by the faculty in the teaching of their courses. The Structurally-Based Therapeutic Evaluation (SBTE) of drugs was introduced in the medicinal chemistry courses at Creighton University in 1995, and reported to interested audiences in 1997(4). This teaching approach emphasizes the relevance of medicinal chemistry to the practice of pharmacy, and encourages the inclusion of an analysis of drug chemistry when making rational therapeutic decisions. Students are required to identify the chemical/structural basis for the pharmacological and therapeutic action of drugs, and to analyze and explain the molecular mechanism of action of a drug. In this paper, we provide a brief summary of this style of teaching, and review its use in solving patient-specific therapeutic problems. Finally, the ways in which the SBTE approach meets specific outcome objectives for pharmacy graduates based on pharmaceutical care functions, professional practice skills, and ACPE standards are discussed.

THE STRUCTURALLY-BASED THERAPEUTIC EVALUATION

The Structurally-Based Therapeutic Evaluation (SBTE) is a concept that was initiated in the medicinal chemistry courses at Creighton University. This concept emphasizes the relevance of chemistry to the practice of pharmacy and demands inclusion of chemical knowledge in the making of therapeutic decisions crucial to the provision of pharmaceutical care. While not yet a component of the entire pharmacy curriculum, the technique is utilized extensively in the two semester medicinal chemistry course sequence required of second professional year students. A complete description of this concept has been published(4). In brief, the three major goals of the SBTE approach include identifying the relevance of chemistry to the practice of phar-
SBTE AND PHARMACEUTICAL CARE FUNCTIONS

There are a number of entry-level practice functions that pharmacists must be competent to perform regardless of practice environment. These basic pharmaceutical care activities include participating in the drug-use decision process; counseling patients; detecting and/or preventing unwanted drug effects and/or interactions; selecting appropriate dosage forms, delivery systems and/or administration of a specific drug; and maximizing compliance. The SBTE concept utilizes the relevant knowledge that students acquire in the medicinal chemistry courses to help them apply drug structure information to actual therapeutic situations. As a result, students gain an understanding of how to scientifically evaluate specific patient information in order to recommend appropriate drug entities, dosage forms, and routes of administration, and to counsel patients on their therapies. Students are challenged to recognize the importance of monitoring patients to detect adverse consequences of drug therapy and to be able to logically revise therapeutic plans to prevent, reverse or manage them.

A focused discussion of how the SBTE approach supports these pharmaceutical care functions is presented below through SBTE-based anti-infectives case scenarios. The structures referred to in this case scenarios are found in Figures 1-4. The SBTE-related information presented is identical to what students are held responsible for when studying the penicillin, cephalosporin and quinolone anti-infectives in the medicinal chemistry courses.

1. Participate in the Drug-Use Decision Process

NA, a 35 y/o medicinal chemistry professor comes to your ambulatory care clinic in May 1997 complaining of burning on urination. He has no previous history of urinary tract disease. When describing his symptoms, he complains of frequent voiding of small amounts of urine and bladder pain (intensity ranking: 4 out of 10). A clean-catch mid-stream urine sample shows gram-negative rods on Gram stain (E. coli). Which of the penicillin antibi-
Fig. 2. Chemical structure of an organic salt of Penicillin G

Fig. 3. Mechanism of suicide inhibition of β-lactamase by structure 7.

Structures 1, 6, 8, 10 and 12 are all penicillin antibacterials (as identified by the fused 6-lactam and thiazolidine rings), but only 1 and 8 are orally active. Compound 6 appears orally active at first glance due the presence of the α-COOH (which would remain unionized at acidic pH and withdraw electrons from the adjacent carbonyl oxygen), but undergoes spontaneous decarboxylation in the stomach to structure 10. With no electron-withdrawing group on Cα to protect it, compound 10 undergoes acid-catalyzed decomposition to the inactive penillic and penaldic acids. The esterified analog 8 moves through the stomach intact, but it subsequently hydrolyzes in the blood to form structure 6, which has an extended spectrum of action due to the highly hydrophilic α-carboxylate group. Likewise, compound 12 has a very wide spectrum due to the piperazinedione-containing substituent on Cα. These agents represents therapeutic overkill for NA, as the highly polar but less extensively bacteriocidal (and less expensive) α-amino compound 1 would be highly effective against E. coli. The polar nature of the amino group permits good penetration of the drug into the polar gram negative cell wall. Cell wall penetration is also facilitated by porin channels that extend to the inner layer and by the comparatively small peptidoglycan layer found in the cell wall of gram negative bacteria. The ability of the α-amino group to become cationic at pH 7.4 also ensures sufficient electron-withdrawing power to allow oral bioavailability.

NA’s E. coli organisms have developed resistance to structure 1. Provide a brief SBTE supporting an alternative therapy, choosing from molecules 2, 4, and 9 provided in Figure 1.

Resistance is most likely due to the production of β-lactamases by the E. coli strain. Compound 1 does not have the α carbon incorporated into an aromatic ring, and would be expected to succumb to the hydrolytic action of β-lactamase(5,6). Structure 4, however, is an orally active (C3-CH3) cephalosporin with increased resistance to β-lactamase due to the inherently insensitive 3-cephem ring system. Unlike penicillins, cephalosporin antibacterials do not need to have the Cα incorporated into an aromatic ring to gain β-lactamase resistance. In fact, this structural modification inactivates them. Structures 2 and 9 are orally active quinolone antibacterials which, since they do not have a β-lactam ring, are not inactivated by β-lactamase enzymes. Both have C6 fluoro and C7 piperazino substituents, which give them significantly higher potency and a much broader spectrum of clinical action than 4(5,6).

Neither is considered first line therapy for E. coli infections, so 4 should be chosen as the therapeutic alternative.

2. Counsel Patients

After one month of therapy, our poor friend NA is not responding to the first-line agent prescribed for him. He has been prescribed structure 2 for his UTI, and has come to your pharmacy for the filling of this prescription. Appropriately counsel NA on this new medication, and give one-two sentence SBTEs for each piece of pharmaceutical care advice you give.

First, NA may experience dizziness and headache on structure 2. Rarely, hallucination, delirium, or convulsions may occur. NA should be told to contact his physician if these symptoms occur. The piperazine ring of this fluoroquinolone is associated with an increased incidence of central nervous system side effects(5,7). Second, structure 2 can precipitate in the renal tubule, causing painful and potentially fatal crystalluria. NA should be advised to drink a full glass of water (six-eight ounces) with each dose(5,7-9). The SBTE behind this therapeutic advice again involves the piperazine ring, which is strongly cationic at physiological pH. Since the C3 carboxylate
group is anionic at pH 7.4 a zwitterion will form, resulting in decreased water solubility. Third, a significant amount of time (two-six hours) should elapse between taking any fluoroquinolone antibacterial and ingesting any metal-containing drug product or calcium containing food product. The $C_3$ carboxylate and $C_4$ keto groups of the fluoroquinolone are associated with these drug-drug and drug-food interactions(7,8). The oxygen-containing groups chelate divalent and trivalent metal ions found in antacids, multivitamins and dairy products, resulting in both decreased absorption and a decreased plasma concentration of the fluoroquinolone. Fourth, NA should avoid extended exposure to sunlight during, and for several days after, therapy. Structure 2 should be discontinued if NA experiences the signs or symptoms of phototoxicity (rash, burning, itching, redness, etc.). Phototoxicity can result from a specific dose and exposure level for most of the marketed fluoroquinolones. However, the specific agents differ substantially from one another in their potential to induce phototoxicity. The $C_8$ substituent greatly influences the risk of phototoxicity, with \( F > Cl > H > CF_3 > OCH_3 \). This side effect is hypothesized to result through the formation of tissue-damaging free radical and singlet oxygen species(7,10,11). Although structure 2 (which has a hydrogen substituent at $C_8$) should have a low incidence of phototoxicity when compared to other fluoroquinolones (especially structure 11), precautions against exposure to sunlight are still warranted.

3. Monitor Patients to Prevent Drug Interactions

But wait! Upon receiving the prescription for NA’s UTI you review the computerized patient profile and notice that he has a history of asthma, and is currently taking theophylline, 300 mg po, twice daily. Given this new information, provide a complete SBTE of the appropriateness of selecting antibacterial 2 to treat the UTI. Would structure 9 or 11 be a better choice for NA?

The piperazine ring found in many fluoroquinolones has associated with a serious drug-drug interaction with theophylline(7,8,12). Some of these piperazine-containing antibacterials may increase theophylline blood levels by as much as 30 percent, resulting in toxicity (nausea, vomiting, restlessness, irritability, insomnia and headache. Serious cardiac arrhythmia and convulsions could occur at plasma levels greater than 35 mg/l)(6,12). The dose of theophylline may need to be decreased, and theophylline levels monitored closely. The physician should be notified at once. If compound 2 is continued, NA should be counseled about the signs and symptoms of theophylline toxicity, and told to contact his physician if any are noted. Fluoroquinolone-induced interference with theophylline metabolism is believed to underlie this potentially fatal interaction. The 4’-nitrogen atom in the piperazine moiety of 2 is essential to the interaction because it is proposed to bind directly to the CYP450 isofrom which catalyzes theophylline metabolism. Structure 9 has the same unsubstituted piperazine ring as 2 and would offer no therapeutic advantage. Alklylation of the piperazine ring is proposed to cause steric hindrance to the formation of the critical drug-enzyme bond(12). Therefore, compound 11 would show a decreased ability to inhibit theophylline metabolism, and would be a safer therapeutic alternative for NA.

4. Select the Appropriate Dosage Form

After one year, NA comes to his primary care physician for renewed urinary tract symptoms. The physician informs you that NA has syphilis (T. pallidum) of less than one year’s duration, and he wants to give a single intramuscular (IM) injection of the drug product drawn in Figure 2. As the clinical pharmacist, give a complete SBTE for why this product is effective in this dosage regimen.

This product is an organic salt of penicillin G, as identified by the protonated procaine counterion. This organic salt is less water soluble than the inorganic sodium or potassium salts. It is marketed as a suspension in water or in oil. Since the drug is marketed as an aqueous suspension, it can not be administered IV and is only given by the IM route. Upon IM injection, a depot of drug is formed in the tissue and absorption proceeds slowly. This results in an increase in duration of action and enhanced patient compliance, since effective therapy can be achieved with a single injection. In addition, this dosage form is less expensive when compared to aqueous crystalline penicillin G therapy, which would require hospitalization and IV administration for ten to fourteen days. Further, because T. pallidum multiplies slowly, a single intramuscular injection of this long-acting organic salt provides the prolonged, low level exposure to penicillin required for eradication of the treponeme(13).

5. Maximize Compliance

NA’s wife, FA, a 28 y/o research scientist, has cut her hand on a piece of glass in the laboratory and is subsequently diagnosed with a P. aeruginosa-induced cellulitis. FA’s busy schedule makes her routinely noncompliant with medication (she just doesn’t remember to take multiple doses of drugs). She has taken her prescribed antibiotic though (structure 8), and has suffered a true allergic reaction to this drug. Which of the remaining antibacterial structures out of choices 1, 3, 4, 9, and 10 could now be used to treat her infection? (assume oral or IV therapy). Give a brief SBTE explaining why you did or did not choose compound 4, addressing both allergenicity and antibacterial spectrum.

Compound 8 is a penicillin, therefore penicillin structures 1 and 10 must be avoided. Compound 3 is a naphthyridine derivative and structure 9 is a quinolone (identified by the fused benzodihydropyridin-4-one-3-carboxylate system), and no cross allergenicity with 8 would be expected. Compound 3 is effective against E. coli, and is used primarily for the treatment of urinary tract infections. The carboxylic acid group is significantly ionized in vivo and the anion is highly resonance stabilized, promoting drug accumulation in the kidney and rapid urinary excretion. Compound 3 is extensively metabolized to inactive metabolites, and must be dosed four times a day. The
need for multiple doses would be problematic in a noncompliant patient, but the biggest concern is the ineffectiveness of compound 3 against P. aeruginosa. Compound 9, on the other hand, has the C₆ fluoro and C₇ piperazino substituents, which give it a significantly higher potency and much broader spectrum of clinical action than 3. Fluoroquinolone 9 has four active metabolites (all resulting from enzymatic transformation of the piperazino ring) and a long duration of action (5, 6). It can be dosed every twelve hours, and could be used as an alternative to 8 to treat FA. Enhanced compliance would be anticipated, as the twice a day dosing regimen would be more convenient for her.

Structure 4 is a cephalosporin antibiotic (identified by the fused β-lactam and dihydrothiazine rings). The structural similarity between the penicillin and cephem ring systems causes a 10-15 percent cross allergenicity between these β-lactam antibiotics. Since cross allergenicity is not a significant risk, structure 4 can be used to treat patients with documented penicillin allergy, but the patient should be cautioned to watch for signs of allergic reaction (urticaria, pruritis, etc.) An oral test dose of 4 could be given before the patient leaves the clinic to assess allergy risk. Compound 4 would have been a possible therapeutic alternative for husband NA in the early stages of his E. coli infection if he had been the one who experienced an allergic reaction to a penicillin (compound 1). However, the α-amino group of 4 does not provide sufficient polarity for activity against the P. aeruginosa organism, so it will not be a viable therapeutic choice for FA.

If NA’s urine had also cultured P. aeruginosa along with E. coli back in May, 1997, would antibiotic 1 still have been appropriate therapy? How about structures 5, 6 or 8? Please be sure your therapeutic choice would be orally active.

Structure 1 is ampicillin, which contains the α-amino group. Although it is orally active as previously discussed and is considered to be broad in its spectrum of action, it is not polar enough to allow for P. aeruginosa coverage. While compound 5 has a spectrum of activity that includes E. coli, the thienyl ring is not as polar as the thiazole ring which is present in third generation cephalosporins. Compound 5 also lacks a polar group (such as methoxyimino) on the α-carbon, a structural feature commonly found in the third generation cephalosporins. Both the thiazole ring and the methoxyimino group are needed for pseudomonal coverage. In addition, compound 5 is not orally active due to the presence of the acid-labile C₃-acetoxyethyl group. This structural feature hydrolyzes in strong acid to produce an intermediate alcohol which subsequently lactonizes to an inactive form. Structure 6 (which is called carbenicillin due to the presence of the α-carboxylic acid group) has very broad coverage, but is not orally active due to complete acid-catalyzed decarboxylation to the acid labile Penicillin G.

Structure 8 is the indanyl ester of 6. As previously noted, the ester protects the side chain from decarboxylation in stomach acid which allows good oral bioavailability, but a free α-COOH will ultimately be exposed by plasma esterases. Since the α-carboxylate group is more extensively ionized at pH 7.4 than the α-amino group of compound 1, the spectrum is extended to include P. aeruginosa. The highly charged nature of the drug also promotes concentration in the urine at the expense of plasma. Compound 8 is used primarily for the treatment of UTI, and would have been a good therapeutic choice for NA.

**SBTES AND PROFESSIONAL PRACTICE SKILLS**

The professional practice skills described in the Commission’s Background Paper II(2) that are required of entry level practitioners include solving problems and making decisions; learning from problem-solving experiences; and communicating/teaching/educating/collaborating. The SBTE approach to medicinal chemistry instruction hones these essential skills, as can be seen from the continuation of the anti-infective example.

1. **Solving Problems and Making Decisions**

NA is feeling much better thanks to your sound, chemically-based clinical interventions. VR is NA’s 6 y/o daughter who has recently recovered from a cold. She wakes up irritable at 4:00 AM with a temperature of 101.7°F, and says her left ear hurts. She is taken to the neighborhood urgent care center for examination. Otoscopic examination reveals an inflamed ear drum, and otorrhea is suspected. Hemophilus influenza (a gram negative organism) is one of the most common causes of acute otitis media and structure 1 is prescribed. After three days on structure 1, however, little VR is no better. Provide a structurally based explanation for this inadequate therapeutic response. Would her condition improve if structure 7 was added to her regimen?

It is a good possibility that the bacteria are producing β-lactamases which are inactivating this agent. The fact that the C₆ of this penicillin antibiotic is not incorporated into an aromatic ring again leads to a prediction of β-lactamase sensitivity. Structure 7, however, is a β-lactamase inhibitor (identified by the oxazolidine ring system, the exocyclic allylic alcohol and the lack of the C₆ amide side chain). The β-lactamase enzyme attacks the carbonyl carbon of the β-lactam ring in the usual fashion, but now electron movement through the oxazolidine ring and olefinic side chain results in a stable ring-opened opened (Figure 3)(5). The lack of the C₆ side chain found on all penicillin antibacterials eliminates any steric hindrance to the attacking lactamase. Since the structure of 7 is irreversibly altered when it binds covalently to the attacking enzyme, it is called a suicide inhibitor. Antibiotic 1 would remain intact in the presence of β-lactamases if compound 7 was coadministered (or, preferably, incorporated into the dosage form), and would now be effective in treating VR’s otitis media.

2. **Learning from Problem-Solving Experiences**

PN, a 42 year old African-American male is admitted to the hospital with a chief complaint of abdominal pain. He has not been able to keep food down for 48 hours. Additionally, he complains of watery diarrhea. Laboratory tests are obtained and
of enzyme inhibition, perhaps by the strong negative compound tamase inhibitor for reasons similar to that described for administration. Structure provides a site for the formation of water soluble salts for IV into an aromatic ring. The carboxylic acid group at C3 pro-
be substituted with this polar group and be incorporated 12 exhibit very potent anti-pseudomonal activity. Compound ria(5). Overall, piperazinedione-containing penicillins attachment to the penicillin-binding proteins of the bacte-
the peptidoglycan chain, which provides more points of antibacterial coverage by mimicking a longer segment of gram negative cell wall. It is also believed to enhance enhancing penetration through the polar channels of the α
ing C α
inhibitor(13). The highly polar piperazinedione-contain-
extended spectrum penicillin(12) and a β-lactamase sensitive since C α
is a cephalosporin antibiotic. It has a thienyl group at Cα and an α-methoxy group at C3. Both of these groups add hydrophilic character above and beyond what is found in many cephalosporin antibiotics, which will broaden the spectrum of action and increase gram negative coverage. The thienyl group is also present in ticarcillin, which is a previously studied penicillin antibi-
otic with increased anaerobic coverage compared to less polar analogs. Lessons learned about relating the presence of a thienyl group to gram negative and anaerobic coverage in the penicillins can now be applied to the cephalosporins, as structure 5 permits good coverage against B. fragilis and E. coli.

3. Communicating/Teaching/Educating/Collaborating

You are now working in the IV room at one of the local hospitals. A physician calls and asks about the use of a newly marketed combination antibiot-
ic product (Zosyn®) for one of his patients (CD). Zosyn® contains both structures 12 and 13 in com-
bination. The M.D. is still waiting for a culture and sensitivity report and wants you to tell her, in general terms, about the antimicrobial coverage of this combination product. While the other pharmacists are scrambling for the package insert and reference books, you take one look at the structure and, based on the knowledge you gained of SAR of the β-lactam antibiotics, give an SBTE for the overall antimicrobial coverage of this new drug.

Zosyn® is a combination product containing an extended spectrum penicillin(12) and a β-lactamase inhibitor(13). The highly polar piperazinedione-containing Cα substituent enhances gram negative action by enhancing penetration through the polar channels of the gram negative cell wall. It is also believed to enhance antibacterial coverage by mimicking a longer segment of the peptidoglycan chain, which provides more points of attachment to the penicillin-binding proteins of the bacte-
ria(5). Overall, piperazinedione-containing penicillins exhibit very potent anti-pseudomonal activity. Compound 12 is β-lactamase sensitive since Cα cannot simultaneously be substituted with this polar group and be incorporated into an aromatic ring. The carboxylic acid group at C3 pro-
vides a site for the formation of water soluble salts for IV administration. Structure 13 is readily classified as a β-lact-
amase inhibitor for reasons similar to that described for compound 7. The sulfoxide moiety enhances the potency of enzyme inhibition, perhaps by the strong negative inductive effects that enhance the electrophilic character of the lactam carbonyl carbon, thereby speeding the attack by the nucleophilic lactamase serine residue.

Ten minutes later, a floor nurse calls down to the TV room to ask if he can run structure 1 (in sodi-
um salt form) in the same line with gentamicin sulfate (Figure 4). How do you respond?

Penicillins like structure 1 and gentamicin are usually ordered in combination for treating gram negative infections, as their effect is additive or synergistic. However, they should always be run in separate lines. Gentamicin contains a number of nucleophilic functional groups (pri-
mary and secondary amines, and alcohols) which can attack the electrophilic carbonyl carbon of the β-lactam ring of the penicillins, resulting in inactivating polymerization and precipitation of both drugs from the IV solution. This chemically-based delivery problem is obviously avoided if the drugs do not come in contact prior to administration to the patient. In addition you avoid proton transfer reactions that could result in either unionized or zwitterionic structure 1 (ampicillin), both of which would have poor water solubility. The unionized gentam-
icin that would also result from proton transfer would retain water solubility due to the large number of polar functional groups.

SBTES AND ACPE STANDARDS

The newly revised ACPE standards(3) seek, among other things, to ensure that all pharmacy curricula:
1. provide knowledge, skills, attitudes, and values for the provision of pharmaceutical care (Standard 8);
2. instill professional competencies (monitoring, com-
municating with and counseling patients, and appro-
priately modifying drug therapy) as well as the ability to identify, assess and solve problems (Standard 10);
3. provide sufficient basic and pharmaceutical science instruction to serve as a foundation and support for the clinical and intellectual objectives (Standard 11);
4. address ways by which curricular content is taught and learned with attention to teaching efficiencies and effectiveness, as well as innovative ways and means of curricular delivery (Standard 12);
5. provide evidence that the educational process involves students as active, self-directed learners and shows transition from dependent to independent learning as students progress through the curriculum (Standard 12); and
6. evaluate cognitive learning (Standard 13).

We believe that the SBTE approach to medicinal chemistry instruction as exemplified by the anti-infective case scenarios, coupled with a new requirement for group presentations of clinically relevant and complex case study problems in class, address all of these standards in a posi-
tive manner. We hope our readers will agree.

CONCLUSION

The delivery of pharmaceutical care at the doctoral level demands that pharmacists draw upon competencies and outcomes that enable them to perform the functions that support the delivery of pharmaceutical care. Students must learn to examine clinical situations rationally and
logically, then gather, organize, interpret and analyze data pertinent to the patient in question. Students must be competent to make judgements and therapeutic decisions based on available data, learn from past problem-solving successes and failures, and integrate knowledge to improve the quality of life for patients. Schools and colleges of pharmacy must ensure that the faculty responsible for instructing in the basic pharmaceutical sciences emphasize not only the core science that underpins their discipline, but also the relevance of that science in the contemporary practice of the profession.

It goes without saying that, just as the pharmaceutical science faculty should be charged with incorporating practical relevance into their foundational courses, clinical faculty should be expected to reinforce the basic biomedical and pharmaceutical science principles that underpin drug action, and upon which rational therapeutic decisions are based. Faculty should ensure that capstone therapeutics courses and experiential rotations/clerkships hold students responsible for knowing molecular mechanisms of drug action and key SAR of the drugs being discussed in class or utilized on the service. This consistent and positive reminder of the “big picture” of drug action will best prepare student to master the expected outcomes of the professional program.

In closing, we believe that the SBTE approach is one way to help chemistry faculty do their part to help students accomplish their program’s outcome objectives, as well as meet the pharmaceutical care functions, professional practice skills and ACPE standards for the education and development of practitioners of the highest quality. Supporting our belief is the fact that, with few exceptions, half or more of the 103 senior students who experienced the SBTE concept in their second professional year claimed their preparation to meet the outcome objectives discussed in this paper was “very good” or “excellent.” Active learning experiences provided in the medicinal chemistry courses (including the SBTE method of clinical problem solving) must certainly have contributed to that favorable opinion. While we have anecdotal evidence that some students continue to use their knowledge of chemistry in solving therapeutic problems in other courses, on rotation and in the workplace, it would be enlightening to critically research the direct impact of the SBTE learning tool on students’ future success in clinically-oriented course work, perceived ability to meet Creighton’s outcome objectives for graduates, and actual competence in practice. The authors plan to investigate at least the first two of these pedagogical goals in the coming year.


References