Prepharmacy Chemistry Courses as Preparation for Medicinal Chemistry: A Survey of Student Perceptions

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INTRODUCTION

The relevance with which students perceive general and organic chemistry has long been a matter of concern to educators in the health professions (1). Chemistry frequently appears to many of these students as a multitude of unrelated facts to be memorized and rapidly forgotten (2). Although pharmacy is perhaps the health profession that is most intrinsically related to chemistry, it is not unaffected by this problem, as may be observed from the performances of students in medicinal chemistry courses.

The effectiveness of medicinal chemistry in relating pharmacological properties to molecular structure is highly dependent upon

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the students' knowledge of basic chemical principles and their comprehension of organic structural theory and function. These skills are normally acquired in general and organic chemistry courses that are taught during the prepharmacy years simultaneously with courses in mathematics and physics. Many of the basic chemical principles (stoichiometry, equilibrium, acidity-basicity, etc.) are acquired in the first prepharmacy year. The concepts of organic structure and reactivity are taught the following year. The effectiveness with which these concepts are conveyed during the prepharmacy years is of primary concern to educators in medicinal chemistry. This study was undertaken at four schools of pharmacy to ascertain the students' perceptions of their prepharmacy preparation in chemistry.

METHODS

Students (n = 209) who had recently completed their medicinal chemistry program at a southeastern, a mid-eastern, a mid-western, and a southwestern school of pharmacy were surveyed concerning their perceptions of their preparation for these courses. The schools were selected to provide a degree of geographical diversity for the study. The curricula of the participating schools all contained a two-year prepharmacy program during which courses in general and organic chemistry were required. The prepharmacy program was followed by the three-year professional curriculum leading to the B.S. in Pharmacy.

A questionnaire (Appendix A) containing 14 statements concerning the degree to which general and organic chemistry prepared the students for medicinal chemistry, the value of organic chemistry to pharmacy practice, the value of medicinal chemistry in understanding pharmacology, and the degree of memorization used in organic chemistry was constructed. The students were asked to provide their year and semester within the school of pharmacy, their grade point average, and the courses they had taken in general and organic chemistry (including the grades they earned and the colleges where they took the courses). A section for comments concerning the relationship between both general and organic chemistry and medicinal chemistry courses was also provided.

The subjects' responses were rated using a five-point Likert-type scale. Integral values were assigned, with Strongly Disagree = 1 and Strongly Agree = 5. For Question 14, numerical values were assigned, with a = 1 and e = 5. Mean values and standard deviations for Questions 1-14 were computed for each school. The total mean and standard deviations were computed using the means of the four schools to weight each school equally and to obtain a measure of interinstitutional variability. Descriptive analyses were performed to assess the students' perceptions.

RESULTS AND DISCUSSION

The results, indicated in Tables 1-3, demonstrate similarity in the four schools surveyed. As noted in Table 1, the mean grade point average was 3.00, and only marginal differences were noted in the mean grades of the respondents obtained in general and organic chemistry. These results reflect little interinstitutional variation in the abilities of the students surveyed. The mean values obtained for each question in the survey regarding the students' perceptions of general and organic chemistry as preparation for medicinal chemistry are shown in Table 2. When asked if general chemistry served as an adequate preparation for the basic principles of organic chemistry and if organic chemistry provided an adequate background for medicinal chemistry, students gave essentially neutral responses. This may indicate that potential for improvement exists in these areas.

When students were questioned about which general topics within organic and general chemistry need additional emphasis (Questions 2-8), the relative values obtained reflected an interesting trend. Applied and theoretical acid-base chemistry were the areas in which students believed the most additional preparation was needed. Structural organic chemistry was also perceived as an area where additional emphasis was necessary, with a mean value of 3.9. Organic stereochemistry, although an area vital to understanding the molecular basis of drug action, received a mean value of 3.5. A mean response of 3.1 was obtained for the question concerning general synthetic reactions. When the organic reactions were narrowed to those relevant to the therapeutic actions of drugs and

TABLE 1. Characteristics of Respondents

	College A n = 56	College B n = 71	College C n = 38	College D n = 44	Total n = 209
Academic Status; Number (%)					
First Pharmacy Year	0 (0)	1 (1)	0 (0)	0 (0)	1 (0.5)
Second Pharmacy Year	1 (2)	0 (0)	38 (100)	40 (91)	79 (38)
Third Pharmacy Year	54 (96)	70 (99)	0 (0)	4 (9)	128 (61)
No Response	1 (2)	0 (0)	0 (0)	0 (0)	1 (0.5)
Mean Grade Point Average	2.94	3.04	2.98	3.05	3.00
Mean Grade in Selected Courses*					
General Chemistry I	2.98	3.15	3.30	3.22	3.16
General Chemistry II	2.74	3.21	3.29	3.10	3.09
Organic Chemistry I	2.63	2.87	2.95	2.95	2.85
Organic Chemistry II	2.87	2.86	2.63	2.83	2.80

*A+ or A = 4, B+ or B = 3, C+ or C = 2, D+ or D = 1, F = 0

TABLE 2. Students' Perceptions of Chemistry Preparation for Medicinal Chemistry Curriculum

	College A n = 56 (Mean ± SD)*	College B n = 71 (Mean ± SD)*	College C n = 38 (Mean ± SD)*	College D n = 44 (Mean ± SD)*	Total n = 209 (Mean ± SD)*†
1. General chemistry as adequate preparation for organic chemistry	2.3 ± 1.0	3.5 ± 1.2	3.4 ± 1.0	3.4 ± 1.0	3.3 ± 0.3
Need for additional course work coverage in:					
2. structural organic chemistry	4.0 ± 0.8	4.0 ± 0.7	3.7 ± 0.9	4.0 ± 0.9	3.9 ± 0.1
3. theoretical acid-base chemistry	4.4 ± 0.9	4.3 ± 0.7	4.3 ± 0.9	4.1 ± 0.9	4.3 ± 0.1
4. applied acid-base chemistry	4.5 ± 0.6	4.4 ± 0.8	4.3 ± 0.8	4.3 ± 0.8	4.4 ± 0.1
5. organic stereo-chemistry	3.5 ± 1.1	3.7 ± 0.9	3.2 ± 0.9	3.6 ± 0.9	3.5 ± 0.2
6. synthetic organic reactions	3.4 ± 0.9	3.3 ± 1.1	2.8 ± 0.9	3.3 ± 1.0	3.1 ± 0.2
7. organic reactions relevant to drug therapeutic actions and side effects	4.0 ± 0.9	4.0 ± 1.0	3.4 ± 1.1	3.9 ± 1.0	3.8 ± 0.3
8. organic reactions relevant to drug metabolism and decomposition	4.1 ± 0.9	3.9 ± 0.9	3.5 ± 0.9	4.0 ± 0.7	3.9 ± 0.2
9. good understanding of base organic chemistry concepts	3.1 ± 1.0	3.4 ± 1.3	3.5 ± 1.2	3.3 ± 1.1	3.3 ± 0.2

TABLE 2. (Continued)

	College A n = 56 (Mean ± SD)*	College B n = 71 (Mean ± SD)*	College C n = 38 (Mean ± SD)*	College D n = 44 (Mean ± SD)*	Total n = 209 (Mean ± SD)*†
10. organic chemistry adequately prepared *for medicinal* chemistry	2.7 ± 1.0	3.3 ± 1.3	3.2 ± 1.0	3.1 ± 1.1	3.1 ± 0.2
11. greater benefit with pharmaceutically-oriented organic chemistry	4.6 ± 0.6	4.3 ± 1.0	4.4 ± 0.7	4.3 ± 0.7	4.4 ± 0.1
12. organic chemistry relevant to practice of pharmacy	3.6 ± 1.1	3.7 ± 0.8	3.4 ± 1.0	3.6 ± 1.1	3.6 ± 0.1
13. medicinal chemistry *contributed to understanding* of pharmacology	4.0 ± 0.8	4.1 ± 0.7	3.7 ± 1.0	3.9 ± 0.9	3.9 ± 0.2

*1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
†Total mean and standard deviation computed on the means of the four schools in order to weight equally each school

their side effects or to those reactions relevant to drug metabolism and decomposition, notably higher levels of perceived need were observed. The students' perceptions were measured at a mean of 3.3 as to whether they had developed a good understanding of the basic concepts of organic chemistry from their organic course work. This observation may indicate that many of those surveyed believe basic concepts were neither well understood nor retained. Further evidence of a possible deficiency in the comprehension of basic organic chemistry may be seen in the results of Question 14 (Table 3). From 39.3% to 48.8% of the students memorized reactions and had little understanding of the mechanisms involved.

Students' responses to Question 11 indicated that they strongly believe more pharmaceutically-oriented organic chemistry courses would be of greater value to pharmacy students than the courses as they are currently taught. This result reflects a need as well as a potential mechanism for improvement in prepharmacy chemical education.

When students were asked if an understanding of the basic concepts of organic chemistry is relevant to their future practice of pharmacy, a value of 3.6 was obtained. However, the students believed to a greater extent (mean value = 3.9) that medicinal chemistry did contribute to their understanding of the molecular basis of pharmacology.

LIMITATIONS

The survey was conducted only among undergraduate students at four colleges of pharmacy who had completed their medicinal chemistry course work. Expansion of this study to other students and alumni in other areas of the country would increase the validity of the findings. Also, because the survey instruments were distributed in class, it was not possible to determine the actual number distributed and the response rate.

The lack of control for many variables that could have an impact on the students' perceptions of their chemistry courses was another limitation of the study. Examples of external variables include the teaching ability of the instructor and the size of the class, as well as each student's intellect and secondary educational background. Be-

TABLE 3. Students' Reported Incidence of Memorizing and Understanding Reactions While Studying Organic Chemistry

Response	College A n = 56 No. (%)	College B n = 72 (No. (%)	College C n = 38 No. (%)	College D n = 43 No. (%)	Total n = 209 No. (%)
Memorized and always understood reaction mechanisms	2 (3.6)	10 (13.9)	4 (10.5)	4 (9.3)	20 (9.6)
Memorized and understood reaction mechanisms a majority of the time	31 (55.4)	29 (40.3)	15 (39.5)	18 (41.9)	93 (44.5)
Memorized and understood reaction mechanisms a minority of the time	20 (35.7)	26 (36.1)	14 (36.8)	17 (39.5)	77 (36.8)
Memorized but never understood reaction mechanisms	3 (3.6)	6 (8.3)	3 (7.9)	4 (9.3)	15 (7.2)
Never memorized nor understood reaction mechanisms	1 (1.8)	1 (1.4)	2 (5.3)	0 (0.0)	4 (1.9)

cause of these potential external variables, it was only possible to compare the results of the participating schools in a relative manner.

Finally, this study only measures students' perceptions about the effectiveness of prepharmacy chemistry courses in preparing them for medicinal chemistry.

CONCLUSIONS

The results of this survey demonstrate a commonality in the experiences of prepharmacy students in general and organic chemistry at four universities. The degree to which the students thought that general chemistry prepared them for organic chemistry may be perceived as marginal, as was the preparative value of organic chemistry for medicinal chemistry. Many students did not think they had adequately learned the basic concepts of organic chemistry. Although many students recognized the potential value of a pharmaceutically-oriented organic chemistry course, they rated relevance of organic chemistry to their professional careers lower.

The survey results suggest that several modifications of the existing prepharmacy chemistry courses may be beneficial not only to pharmacy students but also to students in other health professions. First, an increased emphasis might be placed on structural organic chemistry, organic acid-base chemistry, and the functional groups found in drug structures. Second, the use of biochemical and pharmaceutical examples in the teaching of organic reactions would create an increased appreciation of the relevance of the material to pharmacy. The latter modification was suggested in a symposium on the teaching of organic chemistry, where it was recommended that organic chemistry instructors make frequent use of medicinal chemistry texts. It was noted that these texts contain a number of examples of solubility phenomena, etc., which, when presented in a health-related context, seem to increase student interest (2).

The prepharmacy student should be made aware early in the curriculum that medicinal chemistry can serve as a unifying factor in interrelating the vast (and ever-increasing) amount of pharmacological knowledge. Victoria Roche has noted that, "Once the students are introduced to the idea of actually utilizing their chemical expertise as a basis for solving therapeutic problems . . . they respond

with enthusiasm to the idea of actually utilizing medicinal chemistry in their professional practice" (3). The effective use of general and organic chemistry as preparation for medicinal chemistry is vital to this process.

As exploratory research, this study suggests that the subject merits further investigation with increased controls. Potential studies might include a comparison of an experimental group of persons taking pharmaceutically-oriented organic chemistry courses with a control group taking the traditional organic chemistry curriculum and a regression of student characteristics across different schools to determine statistical significance of results. Whatever the results, it must be remembered that schools of pharmacy have little control over the content of general and organic chemistry courses. Political battles must also be fought to make prepharmacy course work more adequately prepare students for their professional curriculum.

REFERENCES

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APPENDIX A: SURVEY QUESTIONS

Subjects were asked to rate their agreement to Questions 1-13 according to the five-point Likert-type scale indicated in the text.

1. The general chemistry courses I have taken adequately prepared me for my organic chemistry courses.
2. Structural organic chemistry (e.g., functional groups, the nature of covalent and noncovalent bonded interactions in organic molecules) should be stressed more in organic chemistry to better prepare me for medicinal chemistry courses.
3. The theoretical basis of acid-base chemistry (e.g., why certain functional groups are acidic or basic) should be stressed more in organic chemistry courses to better prepare me for medicinal chemistry courses.
4. The application of acid-base chemistry [e.g., the determination of the acidic and basic sites in organic molecules and the prediction of the predominant ionic form(s) at pH's typically encountered in pharmacy practice] should be stressed more in organic chemistry courses to better prepare me for medicinal chemistry courses.

APPENDIX A (continued)

5. Organic stereochemistry (e.g., enantiomers, diastereomers, thermodynamically preferred conformations of organic molecules) should be stressed more in organic chemistry courses to better prepare me for medicinal chemistry courses.
6. Synthetic organic reactions should be stressed more in organic chemistry courses to better prepare me for medicinal chemistry courses.
7. The organic reactions relevant to the therapeutic action(s) and side effects of drugs should be stressed more in organic chemistry courses to better prepare me for medicinal chemistry courses.
8. The organic reactions relevant to the metabolism and decomposition (shelf-life) of drugs (e.g., oxidations, hydrolyses) should be stressed more in organic chemistry courses to better prepare me for medicinal chemistry courses.
9. I developed a good understanding of the basic concepts of organic chemistry from my organic chemistry courses.

10. Overall, the organic chemistry courses I took adequately prepared me for my medicinal chemistry courses.

11. Organic chemistry courses which are more pharmaceutically oriented would be of greater value to pharmacy students than the organic chemistry courses currently taught.

12. An understanding of the basic concepts of organic chemistry is relevant to my future practice of pharmacy.

13. The medicinal chemistry courses I have taken contributed to my understanding of the molecular basis of pharmacology.

14. When studying organic chemistry, to what extent did you memorize the organic reactions without understanding the reaction mechanism?

    a. I memorized the reactions and always understood the reaction mechanisms.

    b. I memorized the reactions and understood the reaction mechanisms the majority of the time.

c. I memorized the reactions and understood the reaction mechanisms a minority of the time.

d. I memorized the reactions but never understood the reaction mechanisms.

e. I never memorized the reactions nor understood the reaction mechanisms.

15. What is your overall GPA?

16. What year and semester of pharmacy school are you currently attending?

Semester	Year
a. First	a. First pharmacy year
b. Second	b. Second pharmacy year
	c. Third pharmacy year

17. What grade did you earn and at which college did you take each general and organic chemistry course? (Please include grades for courses repeated and/or failed.)

	Course Name	Grade	Credit Hours	College
a.	Gen. Chem. I			
b.	Gen. Chem. II			
c.	Org. Chem. I			
d.	Org. Chem. II			

18. Please write below any comments concerning general chemistry, organic chemistry, and medicinal chemistry courses you have taken and the relationships between them.