TEACHERS' TOPICS

An Elective Course to Engage Pharmacy Students in Research Activities

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Submitted February 3, 2011; accepted May 15, 2011; published September 10, 2011.

Objective. To implement problem-based learning exercises in a pharmacy research elective course and assess the impact on students' knowledge and confidence in their ability to analyze, design, and present basic research projects relevant to clinical areas.

Design. Hands-on learning activities, including discussions on experimental design, development of collective diagrams, research planning, results analysis, data evaluation, and presentation design, were incorporated into the course and developed as team-based learning experiences.

Assessment. Students gave a seminar presentation to peers and faculty members at the end of the semester and created posters for presentations at professional meetings. Students who decided to work on a continuation project during the following semester were expected to produce data that might be sufficient for the development of manuscripts for submission to scientific journals.

Conclusions. Feedback from students revealed an appreciation and renewed interest in analyzing clinical issues with a much wider focus as well as increased understanding of and confidence in using data derived from basic science research.

Keywords: research, elective, problem-based learning, scientific writing, team-based learning.

INTRODUCTION

In recognition of the essential role of pharmacists in health care and their broad base of knowledge in drug and cellular metabolism, the National Institutes of Health (NIH) established a Web site for pharmacists to provide information about research programs and funding.¹ The NIH aim is to increase the number of pharmacists involved in biomedical research to ensure their valuable contribution to translational research efforts. Academic institutions also have placed curricular emphasis on research in the form of defined research tracks² or by offering research electives.^{3,4} In order for research to become a career option for pharmacy graduates, early and meaningful exposure is crucial.³

Besides improving the involvement of pharmacists in the translational research process, research training provides the foundation for a better understanding of biopharmaceuticals and targeted therapies based on the expectation that a growing percentage of new drug approvals will involve biopharmaceuticals.⁵ Because many biotechnology drug products are proteins, pharmacists need to be concerned with specific requirements of storage, handling, and preparation. Thus, pharmacists can benefit from the study of the biochemical and physiological mechanisms targeted by

biopharmaceuticals, as well as their production processes in order to comprehend their therapeutic use.⁶

Most PharmD programs require coursework in research methodology, biostatistics, literature evaluation, and drug information analysis.⁷ These courses provide valuable skills that can be used in an integrated manner in a research elective course. The aims of the course described here concur with those described by Ascione in the University of Michigan research requirement model,⁸ which is based on more than 30 years of experience in research-related coursework. The first aim is to improve problem-solving skills and to teach the scientific method of analysis; the second is to encourage the development of lifelong learning skills.

In 2007, 25% of the PharmD programs required research experience, but only 3.7% required experience in data collection and analysis.⁹ These results concur with those in another study in 2009, which examined research skills training in 83% of US colleges and schools of pharmacy. The conclusion was that further studies are needed to determine the most effective way to offer research skills training to PharmD students.¹⁰ The research elective described herein seeks to present problem-based learning techniques that enhance problem-solving skills as well as project management that target efficient data collection and analysis. The main objective of this study was to present and evaluate an elective course design that provides students a meaningful experience as part of a

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research team that is contributing new findings in a particular field.

DESIGN

The research elective offered students an opportunity to learn about laboratory research through experimental conception, design, and execution by working independently with a faculty mentor on a selected research project. Each stage of the process followed Bloom's taxonomy of learning.¹¹ After completing this course, students were expected to be able to:

- (1) Search the literature efficiently and evaluate current published information.
- (2) Formulate a hypothesis based on current knowledge on a specific topic.
- (3) Identify the questions that need to be answered in order to test the hypothesis.
- (4) Propose an experimental design based on available techniques.
- (5) Collect and analyze data while evaluating progress in the testing of the hypothesis.
- (6) Determine the significance of the results obtained and possible clinical relevance.
- (7) Design and write a presentation targeting a specific audience.

The research elective was offered to second- and third-year PharmD students and counted as 2, 3, or 4 credit hours. Faculty members who were engaged in a research project at the time of the study offered a variable number of basic or clinical research positions to students depending on the number of questions their study was intended to answer. Laboratory space and funding for research supplies are provided to faculty members through a research startup package from the university and/or through extramural funding. Also, other university departments sometimes collaborated with pharmacy faculty members to meet specific project requirements.

Students were encouraged to informally visit faculty members' laboratories to observe the dynamics of working projects to determine whether the research topic was the right choice before registering for the course. Students interested in our laboratory research on cancer historically have belonged to 3 distinct groups: students enrolled in the elective course for the first time, students interested in pursuing a second project who are enrolled for a second time, and visiting students who are exploring the possibility of joining a research team. Before the beginning of the semester, a meeting was held with each prospective student to introduce the working projects. In this introduction, the knowledge gap that the project intended to answer, the long-term goal of the study, and the clinical relevance of the project were stated clearly.

At the time this study was conducted, the author's laboratory had 2 projects under way. Project 1 was designed to study human epidermal growth factor receptor 2 (HER2) cell signaling in carcinogenesis (Figure 1). The long-term goal of this project was to identify mechanisms associated with early stages of the disease in cancers driven by HER2. The long-term goal of the second project was to test new compounds derived from plants that had ethnobotanical importance in the treatment of cancer. The purified and characterized compounds were tested against a panel of cancer cell lines as described by the NIH/ National Cancer Institute Developmental Therapeutics Program.¹³ The discovery and validation of new antineoplastics is an important component of translational research, thus satisfying one of the project's research objectives.

Students were provided an example of introductory information and development of the hypothesis for each of these projects, as illustrated for project 1 in Figure 1. The purpose of this strategy was to clearly define the clinical implications of each project before addressing the detailed techniques used and to provide essential information the students would need to select a project. The first meetings were held to review background literature and the work of other laboratories, as well as the latest contributions of our research projects. This interactive session sought to engage students in the analysis of current research and the evaluation of new projects for the purpose of identifying knowledge gaps or deficiencies. Research projects should have *clinical relevance*, ie, a working hypothesis in basic research should have potential application in a clinical area.

The research projects that the students worked on were developed following the scientific method. At the beginning of each meeting, an update of each experiment was presented to each team, which was normally composed of 2 to 4 members, to encourage monitoring of progress on the project. This was essential because the actual laboratory experiments sometimes had to be completed by a faculty mentor or technician rather than a student.

Several techniques were used to encourage active student participation. For example, students were invited to "share the white board," ie, all members of the team were encouraged to actively participate in discussions and this often involved members drawing and sharing diagrams or flowcharts on a white board as they clarified ideas or tried to troubleshoot protocols. Team members also were encouraged to discuss their ideas and maintain open communication via e-mail and texting. This strategy reinforced the importance of communicating rather than dismissing new ideas or queries, which are part of the problem-solving process. Use of a laboratory notebook was essential to the project.

Figure 1. Design for a project included as a research option in an elective course to encourage pharmacy students involvement in research activities.

Under the guidance of the faculty mentor, team members defined and selected questions that tested hypotheses. Again, open discussion within the team was essential in refining the aims into a set of guidance points for the project. The aims needed to be straightforward and attainable based on the techniques and expertise available to the group. Widening the range of expertise through consultation and collaboration with university researchers was considered a potential opportunity for teams to develop more solid projects. Once the specific aims of the project were defined, students were asked to select one project based on their own interests and to maintain close communication with other students working on the same project.

Each student was presented with general techniques to complete each step. Protocols were designed and dis-

cussed by all members of the team, aided by collective drawings and flowcharts. Special emphasis was given to the principles behind each technique to encourage comprehension of the process and subsequent suggestions for modifying protocols. This strategy provided a dynamic environment in which students' confidence was nurtured by encouraging active participation in the experimental design through team problem solving.

Students were taught the parameters used to analyze data through the inclusion of positive and negative controls in their experimental design. The selection of these controls was openly discussed and selected by teams based on past work or the published work of other laboratories. Students used appropriate software or equipment to collect and prepare data for qualitative and/or quantitative analysis, such as calculation of standard deviations,

generation of graphs with error bars, and the measurement of intensity of fluorescence signals for analysis of molecular expression. This process was guided and closely monitored by the faculty mentor.

EVALUATION AND ASSESSMENT

Students were required to submit a draft of a seminar presentation to the faculty member for review 3 weeks before the end of the semester. The drafts were permitted to be part of a team presentation and could address a new technique, experimental design, or data showing novel findings. Each student was responsible for a defined portion and the team was responsible for integrating the topics to render a seamless presentation.

Ideally, each student on a team would design and prepare a poster presentation, but this was not possible in all cases because of the limited amount of quality data collected by students taking the elective for the first time. Because of these constraints, students in teams combined their data for a single team poster. This still provided students with an opportunity to learn the format of and content needed for a professional poster under the guidance of the faculty mentor.

Each team researched and identified a suitable scientific or professional meeting for the presentation of their data. Options were discussed and evaluated by all team members as part of the selection process. Abstracts were written by the students, given to their faculty mentor for revision, and then submitted to the selected organization for consideration. Posters were drafted and each team participated in internal meetings or poster presentations within the university, giving them an opportunity to practice and refine their presentation skills and clarify any uncertain aspects of the research project. Each team developed a final version of their poster and presented it at a national meeting. A summary of student research activities during 2010 is shown in Table 1.

Table 1. Pharmacy Students' Productivity in an Elective Course to Encourage Student Research Activities

Activity in 2010	New Compounds	
	HER2 Team, Project 1	Team, Project 2
Internal meetings/poster presentations	2	2
National meetings/abstract submissions	2	5
National meetings/abstract acceptances	1	5
Publications	1	-

Abbreviations: HER2 = human epidermal growth factor receptor 2

Students who had been working on a continuation project from the previous semester (Table 2) and had sufficient data to develop a manuscript draft for submission to a scientific journal were given the option to have their drafts evaluated by the faculty mentor in place of a seminar presentation. This revision process allowed students to participate in writing a manuscript and provided a learning activity that exercised critical-thinking skills.

A summative evaluation administered by the college was used to determine whether this course accomplished its goals of providing opportunities in the areas of background analysis, general project planning, scientific writing, problem solving, and other skills associated with critical thinking (Table 3). Seven students participated in this elective during 2010 and all completed the questionnaire. All participants strongly agreed or agreed (85.7% and 14.3%, respectively) that the course provided an opportunity to analyze background information (Table 2). All students strongly agreed that the course developed their ability to plan projects efficiently. They also strongly agreed or agreed that the course provided training in scientific writing (55.1% and 42.9%, respectively). Most strongly agreed or agreed that it offered opportunities to expand their problem-solving abilities (71.0% and 14.3%, respectively).

Seven abstracts were peer-reviewed and 6 were accepted for poster presentations at national scientific meetings. Critiques and suggestions provided by the reviewers, which addressed focus, methodology, and presentation, were useful to students in the completion of their posters. One of the abstracts was not accepted because it presented data suitable for a meeting specifically on tumor biology. This outcome provided an invaluable lesson for the project team on meeting abstract selection criteria and sparked discussions on abstract writing. A manuscript with contributions from 2 students was published in a peer-reviewed journal in 2010, and 2 additional manuscript drafts were under review.

DISCUSSION

Translational research has proven to be a key component to efficiently bring new laboratory discoveries to the clinical setting. Open communication and feedback between basic scientists and healthcare professionals is the basis of the bench-to-bedside approach. Offering health-science students an opportunity to experience, analyze, and discuss basic research projects is critical to the infrastructure of translational research, as this discovery experience affords them a higher degree of confidence to establish links with related clinical fields.

The pharmacy students felt that this course provided them an opportunity to acquire skills in key aspects of

Table 2. Continued Student Participation on Research Projects in an Elective Course to Encourage Pharmacy Students' Research Activity

	Spring 2010	Summer 2010	Fall 2010	Spring 2011
Returning students from previous semester, %	33.3	33.3	50.0	57.0
Returning students, Team 1, %	33.3	—	16.6	14.2
Returning students, Team 2, %	—	33.3	33.3	42.8

research, from conception to data analysis. The students accomplished a sequential set of activities that allowed them to present their findings at meetings or to submit to peer-reviewed journals for publication. As shown in Table 1, the experience of having their material peer reviewed was a valuable indicator of students' progress.

Although students participating in the elective were not guaranteed funding to present their research at a conference, the college maintains an account for this purpose. When funds were available, student requests for travel support from the Office of Student Affairs generally were approved.

Team-based problem solving provided a dynamic environment in which options were analyzed, discussed, and evaluated. One method of evaluating the effectiveness of these discussions was to determine whether the students felt comfortable presenting their work at scientific meetings. Based on the summative evaluation results, all of the students strongly agreed or agreed that the course provided them the necessary foundation to comfortably present their work.

We also investigated whether the students felt that what they learned in this course was incorporated into their

skills set or segregated because of the specificity of the research topic. The summative evaluations showed that all students strongly agreed (85.7%) or agreed (14.3%) that the course expanded their knowledge base and enabled them to apply theoretical concepts learned in the classroom, indicating that the input of this course successfully integrated with and enhanced their problem-solving skills.

Two common constraints for pharmacy students in developing a research project are time availability and level of comfort with a hands-on project.³ Thus, laboratory hours must be flexible, all techniques must be introduced to each student individually, and their applications must be reviewed often. Members of the research team who decided to continue working for a second semester were expected to assist new members with learning, but the returning students' tutoring of their peers was carefully observed by the faculty mentor.

Two factors that may have affected the number of students who decided to take this course were similar to factors presented by Surratt and colleagues: lack of student awareness about the research elective course and lack of time for the course in students' schedules.¹² To address the first factor, Gatton College of Pharmacy

Table 3. Pharmacy Students' Responses to a Survey on a Research Elective Course (N = 7)

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Overall Rating, Mean (SD) ^a
This course exercises my ability to analyze background information.	0	0	0	1	6	4.9
This course develops my ability to plan projects efficiently.	0	0	0	0	7	5
This course allows me to apply theoretical concepts learned in the classroom.	0	0	0	1	6	4.9
This course expands my areas of knowledge. ^b	0	0	0	0	6	5
This course offers training in scientific writing.	0	0	0	3	4	4.6
This course provides the necessary foundation to allow me to comfortably present my work at scientific meetings.	0	0	0	2	5	4.7
This course offers sufficient opportunity to expand my problem-solving abilities. ^b	0	0	0	1	5	4.8
This course provides a practical, hands-on approach in research project development.				0	7	5

^a The median and mode for all items was 5.

^b Only 6 of the 7 students responded to this item.

participated in a research forum organized by the university's office of research for all graduate and undergraduate university students in the Appalachian region. This forum increased pharmacy students' awareness about and interest in the college's research projects. To address the difficulty of fitting a research elective into an already demanding and rigorous curriculum, we provided students with a flexible schedule for the course that allowed for more efficient follow up on laboratory experiments and provided an incentive for students to manage their coursework more efficiently. We also encouraged informal student participation, allowing prospective students to freely explore the research the elective before registering for it.

CONCLUSION

Feedback obtained from students revealed an appreciation for and renewed interest in analyzing clinical issues with a much wider focus as well as an increased understanding of and confidence in using data derived from basic science research. The percentage of students engaged in continuation projects varies between 33% and 57%. Combined with the positive student feedback, these high values support the notion that hands-on data collection and analysis are critical to developing students' confidence working with data from scientific research and having a meaningful research experience.

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