Reinforcing Concepts by Studying Experts: An Integrated Approach to the Teaching of Pharmaceutics

Emmanuel O. Akala
Gerunda B. Hughes
Tracey L. Rogers

ABSTRACT. The project aimed at enhancing the teaching and learning of pharmaceutics by combining didactic pedagogy and student analysis of research articles in the field of pharmaceutics as a teaching intervention. The students were assigned to groups, and research articles were given to each group together with questions to develop lines of thought. Each group then made a presentation to the class. Students' reactions to the teaching intervention were measured using a Likert-type scale ("strongly disagree" = 1 to "strongly agree" = 5) and five statements related to the use of research articles in the course. Overall results indicate that students' reactions were positive. Seventy-five percent of the students reported that the use of the research articles increased their knowledge and understanding of the subject matter that was being taught. Eighty-seven percent of the students agreed that the questions prepared by the professors on each of the research articles were helpful and should be used in the future. Ninety-two percent of the students agreed that the

Emmanuel O. Akala, R.Ph., Ph.D., is Associate Professor, School of Pharmacy, Gerunda B. Hughes, Ph.D., is Associate Professor, School of Education, and Tracey L. Rogers, R.Ph., Ph.D., was Assistant Professor, School of Pharmacy, Howard University, 2300 4th Street, NW, Washington, DC 20059. Dr. Rogers is now Scientist at Guilford Pharmaceuticals, Inc.

Address correspondence to: Dr. Akala (E-mail: eakala@howard.edu).

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research articles were connected to what they were learning in the various courses in pharmaceutics.

KEYWORDS. Teaching intervention, integrated curriculum, reinforcing concepts, pharmaceutics, studying experts

INTRODUCTION

Each day of the academic year, professors and students enter classrooms and laboratories of institutions of higher learning, each having expectations of what is to take place in the teaching and learning process. More often than not, these expectations are articulated in the form of instructional and student performance objectives. The instructional objectives outline what professors hope to accomplish using a variety of pedagogical strategies. The student performance objectives indicate what should be the intended or expected outcome or effect in student behavior. The two types of objectives are not always synonymous. The extent to which student performance objectives are attained is, in large part, a function of the instructional strategies that professors employ to maximize student learning.

Making decisions about which instructional approaches to use in the classroom is an exercise that should not be taken lightly. Given the variety of approaches from which to choose, the professor must make sound decisions that take into consideration students' learning styles, the appropriateness of the approaches given the objective of the lesson, facilities available for employing a particular style, and how all of these will come together to maximize student learning and performance. Hence, whether they are teaching mathematics or mechanics, history or the humanities, medicine or pharmacy, professors in institutions of higher learning are constantly faced with the challenge of creating and shaping learning environments in which student learning flourishes.

In fact, the problem that this study addresses, that of finding the right instructional approach to teaching pharmaceutics, is an old and even ancient one. It is the eternal problem of teachers, in general, facing students who may be eager to learn but who are underprepared or simply not developmentally ready. On the other hand, there may be students who are well prepared for the challenges of the classroom but are unmotivated. These problems are more acute in higher education because by the time students begin their college experience many styles of learning and thinking have been figuratively "set in stone." Similarly, professors in higher education have developed their own styles of teaching and thinking. Thus, the amount of learning that occurs and the amount of effort that goes into maximizing that learning through good teaching are not always equal.

There are many instructional models from which to choose. These include, but are not limited to, the didactic approach, the concept development approach, the guided discovery approach, and the constructivist approach. In didactic approaches to teaching, the professor acts the role of "conveyor of knowledge," and students are, for the most part, passive recipients of that knowledge. Didactic approaches to teaching and learning are very professor oriented. When concept development approaches are used, students must recognize common similarities and differences in characteristics among examples and, from those commonalities, develop the meaning of concepts from the examples. Guided discovery approaches place the professor in the role of "facilitator of knowledge," with students playing a very active role in the "discovery of knowledge and concepts," as they are guided through the process. Constructivist approaches to teaching and learning are very student oriented. The student is the center of the learning activity, and every instructional activity is intended to help the student better understand what is being taught by co-constructing meaning of concepts using their own experiences and background, where possible or appropriate. Any one of these instructional models may be effective for a given lesson or a given student. The challenge for many professors is selecting the most appropriate strategy or, if necessary, selecting a combination thereof.

Katz and Henry suggested that an effective pedagogy of higher education is one that enables students to adopt the methods of thinking that characterize the person who generated the knowledge (1). In this way, students develop thinking patterns that are most like the experts in their field of study. One way to operationalize this approach to teaching is to have the experts actually teach the course. A major limitation of this approach is that there are more universities and colleges than there are experts in the field who have teaching positions at these various sites. Thus, a practical way to approach the challenge of learning concepts from experts directly is to learn concepts indirectly by studying experts through their research journal articles and other publications. In this way, students read about how experts define and explain basic and complex themes in their field of study. They learn how the experts relate concepts within the subject area of pharmaceutics, for example, and across various courses in pharmaceutics: Pharmaceutical Mathematics, Physical Pharmacy, Biopharmaceutics, Applied Pharmacokinetics, and Pharmaceutical Technology. An integrated approach to teaching that uses "didactic" and "the study of experts" strategies for teaching pharmaceutics is a unique and challenging one, but the positive outcomes in terms of student performance and satisfaction make it an attractive alternative to using didactic approaches only.

In a typical U.S. school of pharmacy, the teaching of pharmaceutics begins with basic pharmaceutics in which students are exposed to the physicochemical principles necessary for the design and use of pharmaceutical products (Physical Pharmacy). Pharmaceutical Mathematics is often taught either before or in parallel to the Physical Pharmacy course. A Pharmaceutical Science Laboratory course is also offered, which gives the students an opportunity to carry out laboratory exercises on some of the topics covered in the Physical Pharmacy lectures.

Following the teaching of basic pharmaceutics is the Applied Pharmaceutics: Pharmaceutical Technology (also called Industrial Pharmacy or Dosage Forms Design), Biopharmaceutics, and Applied Pharmacokinetics. A course in Laboratory Pharmaceutical Technology is also offered by most schools of pharmacy, which affords the students an opportunity to carry out extemporaneous compounding on some pharmaceutical dosage forms. In addition, a visit to the pharmaceutical industry is required, and students must submit a report on the trip. In Applied Pharmacokinetics, students are given case studies/problems to investigate using computer software such as Data Kinetics® and Scientist® (2, 3).

Appraisal of the Present Teaching Method

The primary approach to the teaching of pharmaceutics described above is usually didactic teaching. The lectures in Pharmaceutical Mathematics, Physical Pharmacy, Pharmaceutical Technology, Biopharmaceutics, and Applied Pharmacokinetics are delivered by a team of professors. Students are given handouts and problem sets to solve to aid their understanding of the subject matter. While the approach to the teaching of the main courses in pharmaceutics, as outlined above, provides the depth of information needed to prepare, evaluate, and select the varied and diverse dosage forms to be encountered in professional practice as a pharmacist, it cannot provide a comprehensive and integrated approach to the learning of pharmaceutics.

The Nature of the Problem in the Teaching and Learning of Pharmaceutics

Abate et al. observed that many pharmacy and other health sciences schools employ a transmission model of teaching in which students, as passive learners, simply absorb facts and knowledge transmitted during lectures and readings (4). Furthermore, the content is discipline based, and knowledge is gained in fragments rather than through integration across disciplines. Hence, it is common to hear professors in schools of pharmacy complain that students cannot recall the information taught in one course to apply it in another. A case in point is first-order kinetics taught in Pharmaceutical Mathematics and Physical Pharmacy. Some students find it difficult to understand that the same principle is involved in the use of first-order kinetics in Pharmacokinetics. In fact, it is difficult for some students to see the applicability of basic principles in pharmaceutics to actual scenarios in the clinical environment (e.g., precipitation in an infusion bag caused by physicochemical incompatibility).

Recently, Angelo was quoted as saying:

> [R]esearch on learning to transfer generally is depressing. Most learning is highly context-bound, and few students become skilled at applying what they have learned in one context to another similar context. In fact many students cannot recognize things they have already learned if the context is shifted at all. (5)

Attempts at Solving the Problems

It is now recognized that changes in the traditional methods of instruction will be required to educate future doctoral-level pharmacists who are expected to provide comprehensive patient care. Specifically, teaching methods that promote critical thinking and problem solving, which is defined as the ability to relate new knowledge to the existing concepts, must be employed (4). Moreover, the newly adopted American Council on Pharmaceutical Education (now Accreditation Council for Pharmacy Education) accreditation standards have made it inevitable for schools of pharmacy to change the teaching/learning environment from primarily faculty centered, in which students passively receive information, to student centered, in which students take an active role in the learning process (6). Examples of the attempts at solving the problems in the schools of pharmacy in the U.S. are presented below.

Lectures and Discussion Groups

Brazeay et al. reported that one college of pharmacy combined aspects of active student-centered learning through large group settings (lectures) with small group settings (discussion groups) in the development and implementation of the doctor of pharmacy curriculum (7). In addition, faculty members in the college have been encouraged to include clinical correlates or case studies to enhance student learning of concepts in basic pharmaceutical sciences.

Problem-Based Learning

Shih and Kauf incorporated problem-based learning (PBL) into a lecture-based pharmacoeconomics course (8). PBL focuses on how to learn rather than what to learn. Results showed that a high percentage of the students found the method to be an interesting, useful, and stimulating method to learn pharmacoeconomics.

Multimedia Classroom Presentation

A method of teaching the pharmacology of ACE inhibitors used a multimedia classroom presentation in the formal class setting followed by a consortium period in which the students were divided into groups of 20 to 30 students (9). A guided method of discussing case reports was employed in the consortium period. The advantage of the case reports was that students had the opportunity to apply the basic sciences taught in the lecture setting. Further, the consortium period instilled intellectual confidence in the students.

Facilitated Learning

Sprague et al. recently presented the development and implementation of an integrated cardiovascular disease module in a Pharm.D. curriculum (10). The cardiovascular disease module integrated pathophysiology, pharmacology, medicinal chemistry, pharmacokinetics, therapeutics, and pharmacy practice. The cardiovascular disease module used facilitated learning. This method of teaching involved the use of traditional formats of lectures to deliver information and self-directed study, which in turn involved dividing students into small groups to analyze and dissect clinical case studies during the breakout group discussion. The faculty member served as a moderator to the students' presentations and made sure the correct answers were discussed by the students. Each group received a different case report to study. At the completion of the module, student groups were responsible for peer and self-evaluation.

The literature is replete with efforts to introduce innovation in pharmacy education. In fact, Roche summarized the results of these efforts (while discussing integrated education and the challenges and opportunities for schools and colleges of pharmacy in the next decade) in a paper presented at the NABP/AACP combined District 7 and 8 meeting in September 22, 2000:

> Pharmacy education is now embracing the concept of student centered learning, where faculty members facilitate (rather than control) the acqui-

> sition and sharing of knowledge within the learning community. In these efforts, the development of critical thinking, problem solving skills and the ability to apply biomedical, pharmaceutical, social/administrative and clinical science concepts to promote health, are paramount. (11)

Moreover, it is believed that active learning is very important in the achievement of ability-based outcomes in higher education. Active learning engages students in the process of their learning; it is the central key to successful learning because students are physically, mentally, and emotionally involved during the time they devote to the study of a topic, learn more rapidly, learn more deeply, and are better able to put into practice what they learn (12, 13). Faculty also get a real and valuable return from their willingness to employ active learning in their courses: increased student attention during the class, more consistent attendance, longer retention of course materials, increase in perception that the professor of the class cares about them as a person, etc. (13).

RATIONALE FOR THE PROJECT

The principle of reinforcing concepts by studying experts is not completely new. The concept was included as part of the pharmacy administration curriculum (14). Following lectures on principles of economics, students were expected to collect newspaper, magazine, and research articles that described the applicability of the principles taught in the class. These exercises, a form of active learning, facilitated the learning and retention of the principles of economics.

This concept is applicable to the study of pharmaceutics because there are many research papers which bring the various topics in pharmaceutics (Pharmaceutical Mathematics, Physical Pharmacy, Pharmaceutical Technology, Biopharmaceutics, and Pharmacokinetics) to bear in the investigation of a particular pharmaceutical problem. Not only will such papers give the students the opportunity to see the interrelationship among the various topics taught in courses that constitute pharmaceutics, but the students will also be able to see the applicability of the subject matter in the real world of pharmaceutical research to develop a formulation presentable to the ultimate consumer (the patient). This strategy will go a long way to achieve the objective of an integrated curriculum in which disciplinary boundaries, once rigidly defined and defended, blur. Further, it will offer an opportunity for active learning (often viewed as a continuum from simple tasks on one end to complex tasks on the other with neither end considered to be better than the other) which can maximize students' intellectual engagement (13). These considerations provide the rationale for this project.

METHODOLOGY

Sample

The sample consisted of 62 students (those who responded to all questions) who were enrolled in the Pharmaceutical Technology course during the fall semester of the academic year. Forty-eight (77%) of the students entered the Pharm.D. program with 2-year prepharmacy courses, and 14 (23%) were college graduates. Twenty-six (42%) of the students were males, and 36 (58%) were females. All students enrolled in the course were taking it for credit with a letter grade (e.g., A, B$^+$, B, C$^+$, C, or F). All the students were taking Biopharmaceutics concurrently with Pharmaceutical Technology and had successfully completed Pharmaceutical Mathematics and Physical Pharmacy.

Instrumentation

To measure students' perceptions of the effectiveness of the teaching intervention on the Pharmaceutical Technology and Biopharmaceutics courses, a five-item survey with a Likert-type scale was administered at the end of the semester. Each statement in the survey addressed some aspect of how the use of the research articles on pharmaceutics facilitated students' learning of the material. For each of the statements in the survey, students were asked to indicate the extent to which they agreed or disagreed with the statement. The response metric ranged from "strongly disagree" = 1 to "strongly agree" = 5.

The five statements in the survey are indicated below. Following each statement is the hypothesized "effect" of the use of the research articles on learning.

1. The reading of the research articles increased my knowledge/understanding of the various courses in Pharmaceutics that I studied in the Pharm.D. degree program. (*increased knowledge and understanding*)
2. The questions on each of the research articles for developing lines of thought are helpful and should be provided in the future. (*helpful/recommended for future use*)
3. The research articles are related to the materials in the courses in pharmaceutics: Physical Pharmacy, Pharmaceutical Technology, and Biopharmaceutics. (*connected to what is learned in the present course*)
4. The research articles are not difficult to comprehend. (*easy to comprehend*)
5. The research articles helped me to see the importance of and the interconnection among the various subjects studied separately in pharmaceutics: Physical Pharmacy, Pharmaceutical Technology, and Biopharmaceutics. (*connected to what is learned in other courses*)

Procedures

Organization of Students in Groups to Study Research Articles

a. During the first lecture of the semester, students were given a general overview about the teaching intervention and specifically the use of the research article as a teaching/learning tool. Each of the three professors involved addressed the class. A handout was distributed to the class (Appendix 1).
b. Recent research articles (the research articles constitute a teaching tool) in pharmaceutical sciences were selected. The basis of selection was the application of multiple concepts in pharmaceutics in the investigation of a pharmaceutical problem by the authors of the research article. The intention was to enable the students to see the interconnection among the various subjects that constitute pharmaceutics as explained to the students in Appendix 1. Further, during the study and analysis of the research articles, the students would be able to reinforce the concepts learned in the pharmaceutics courses. The uniqueness of the intervention was that the learning was taking place while concepts were being applied to solve real pharmaceutical problems.
c. Students were told the nature of the intervention on the first day of lecture; each of the three professors involved addressed the class.
d. Students were divided randomly into 7 groups of 10 students each, except 2 groups had 11 students.
e. Ten research articles were given to each group to study and analyze, but eventually only one was presented by each group to the class. The selection of the research article to be presented to the class was done by ballot.
f. Questions for developing lines of thought were provided by the professors for each research article. As an example: Imad Naasani et al. Improving the oral bioavailability of sulpiride by sodium oleate in rabbits. *J Pharm Pharmacol*. 1994; 47:469.

   i. Suggest a reason why the delay in gastrointestinal transit time due to food and propantheline bromide caused an improvement in the oral bioavailability of sulpiride from the human intestine.
   ii. Comment on the drop volume method used in the paper to determine surface tension. In which course did you study surface tension?
   iii. Under results and discussion, the authors gave three reasons for poor bioavailability of drugs. Identify the three reasons and comment on them.
   iv. Discuss the two mechanisms by which sodium oleate improved the bioavailability of the drug.

v. Micellar solubilization, investigated in the paper, was studied in Physical Pharmacy, and bioavailability, also investigated in the same paper, was studied in Biopharmaceutics. Give your opinion of the "single thread" that runs through all the courses in pharmaceutics. Can you identify such interrelationships in other articles studied?

Students were not limited to answering the professors' questions. They were asked to analyze the paper and make a presentation to the class based on their understanding of the paper and its relatedness to all they have learned in pharmaceutics.

Group Presentation of Research Articles

Each group was assigned time to give a presentation. The order of presentation was determined by ballot. The faculty served as the moderators to the students' presentations and made sure that correct facts were discussed by the students. Students were stopped, as necessary, for corrections during the presentations. The students were responsible for self-, peer, and group evaluation. Faculty awarded marks to the groups on the basis of the science and the quality of the presentations. The ingenuity of the students in preparing for the presentation was remarkable. Students went an extra mile to look for pieces of information in books and journals to enhance their analysis and presentations, as demonstrated during the presentations.

Evaluation of the Intervention
(Analysis of Research Article and Group Presentation)

a. A questionnaire/survey was administered to each student to obtain feedback about the effectiveness of the teaching intervention.
b. Students were given evaluation forms to evaluate their peers' performances in the group during the analysis of the paper and preparation for the presentation. They were asked to evaluate the performances of their colleagues in other groups during the presentations (Appendix 2).

Design and Data Analysis

The authors administered the instrument. The two professors from the School of Pharmacy were the course instructors; the course is usually team taught by the professors. The professor from the School of Education participated to ensure that the intervention was administered as planned: reading of all articles by each member of the class, randomized assignment of students to groups, randomized allocation of the research articles to be analyzed by each group. The return of the students' survey (shown in Appendix 3), whose purpose was to identify potential problems in the intervention from the students' perspective, was made anonymous so that students could express themselves freely. However, the identity of the student was revealed in the return of the answers to the five-item survey with a Likert-type scale to facilitate the comparisons to be made in the analysis of the data: gender and level of education before entering the Pharm.D. program. Further, student identity was revealed in the peer grading with the hope that students would be able to know the level of participation of their peers and grade them accordingly. As shown in Table 1, the percentage of the total mark carried by the intervention is 10%, which is too small to pressure the students to respond in such a manner as to please the professors.

Variables investigated in this study were students' perceptions of the usefulness of the teaching intervention, gender, and classification. Students' perceptions of the usefulness of the teaching intervention was operationalized by their response on a Likert-type scale ("strongly disagree" = 1 to "strongly agree" = 5) to five statements related to the use of research articles in the course. The five statements examined students' perceptions of the extent to which the research articles: (a) increased their knowledge and understanding of pharmaceutics, (b) were helpful and should be used in future classes, (c) were connected to what they were learning in Biopharmaceutics and Pharmaceutical Technology during the current semester, (d) were easy to comprehend, and (e) were connected to what was learned in other courses in pharmaceutics.

Data were analyzed using computer software (15). Descriptive statistics such as percentages were used to describe and summarize the data. Means and

TABLE 1. Course Evaluation.

Examinations	***Percentage of the Final Grade***
Four Examinations* (each carrying 22.5%)	90%
Final Examination** 22.5%	Optional
Journal Reading, Analysis, and Presentation***	10%
Total	100%

*Examinations during the semester are based on materials covered during a specified period and are not comprehensive to the date of the examinations.
**The final examination is comprehensive and is based on all lecture materials covered throughout the semester. Further, the final examination is optional for students who have successfully completed all four semester examinations. They may take it to improve their grades (the lowest of the five examinations will be dropped). The final examination is required for students who have missed one of the four examinations (it serves as a makeup examination).
***2.5% for the peer grading within the group, 2.5% for grading by other groups, 5% by professors for presentation and answers to oral questions by members of the groups.

standard deviations were calculated to provide measures of central tendency and variability, respectively. Inferential statistics were used to compare subgroups in the sample.

Overall Results for the Entire Sample

For each statement, descriptive statistics were calculated to provide summary information about the nature of the students' responses. These statistics included the range of responses, the minimum and maximum values (on a scale from 1 to 5), the percentage of students who responded at each point on the Likert-type scale, the mean, and the standard deviation for the entire sample.

Comparison of Subgroups

The sample was divided by gender (male or female) and classification (prepharmacy or college graduate). The data were then analyzed using an independent *t* test (Table 3 for sample size) to determine whether there were significant differences in the mean values of the responses between the subgroups on each statement in the survey.

RESULTS AND DISCUSSION

Table 2 presents the percentage of students ($n = 62$) who responded in each score category to each of the five statements that were used to measure students' perceptions of the effectiveness of the teaching intervention. The results indicate that a majority of the students either agreed or strongly agreed with the statements. Nearly 92% of the students agreed that the research articles were connected to what they were learning in the present course, indicating that the research articles chosen by the professors were relevant to the background of the students in pharmaceutics. Further, 87% of the students agreed that the questions prepared by the professors on each research article were helpful for developing lines of thought and should be used in the future. Thus, guidance because of the technical complexity of some of the articles would help students in the analysis of the research articles.

Table 3 presents the means and standard deviations for statements about the teaching intervention (i.e., use of research articles) for the overall group and by each subgroup according to gender and classification. The highest mean among the statements for the overall group was 4.51 (on a scale of 1 to 5). It was obtained for the statement that measured students' perceptions of whether the research articles were connected to what was learned in the present course.

TABLE 2. Percentage of Students Who Responded in Each Score Category for Survey Statements.

Statement	SA	A	N	D	SD
1. The reading of the research articles increased my knowledge/understanding of the various courses in pharmaceutics that I have studied so far in the Pharm.D. degree program. *(increased knowledge and understanding)*	38.7	37.1	19.4	4.8	0
2. The questions on each of the research articles for developing lines of thought are helpful and should be provided in the future. *(helpful/recommended for future use)*	40.3	46.8	11.3	1.6	0
3. The research articles are related to some of the materials in the courses in pharmaceutics: Physical Pharmacy, Pharmaceutical Technology, and Biopharmaceutics. *(connected to what is learned in the present course)*	59.6	32.3	8.1	0	0
4. The research articles are easy to comprehend. *(easy to comprehend)*	14.5	43.5	24.3	12.9	4.8
5. The research articles helped me to see the importance of and the interconnection among the various subjects studied separately in Pharmaceutical Technology, Physical Pharmacy, and Biopharmaceutics. *(connected to what is learned in other courses)*	48.4	25.8	24.2	1.6	0

The scale is represented by SA = strongly agree, A = agree, N = neutral, D = disagree, and SD = strongly disagree. The sum of percents in each row is 100.

This statement was also the statement with the least amount of variability (SD = 0.64). The statement with the smallest mean (3.50) and the largest variability (SD = 1.05) was the statement that measured students' perceptions of the difficulty of the research articles. For that statement, over 42% of the students were either neutral or disagreed that the research articles were "easy to comprehend." The reason for this is that some of the research articles are appropriate for Ph.D.-level students. This problem can be circumvented if professors provide further background reading materials beyond what the students have learned in various courses.

When independent *t* tests (Table 3 for sample size) were conducted on subgroups by gender and classification, the results revealed that no significant differences in the mean responses to any of the statements were found between those who entered the Pharm.D. program with two-year prepharmacy courses and college graduates. It appeared that the level of preparation before entering the Pharm.D. program might not affect the outcomes of the intervention. We were surprised by this result because of the

TABLE 3. Means and Standard Deviations for Statements About Teaching Intervention by Group.

Statement	**Overall (*n* = 62)**	**M (*n* = 26)**	**F (*n* = 36)**	**P (*n* = 48)**	**G (*n* = 14)**
1. The reading of the research articles increased my knowledge/understanding of the various courses in pharmaceutics that I have studied so far in the Pharm.D. degree program. *(increased knowledge and understanding)*	4.09 (.88)	3.96 (.95)	4.19 (.82)	4.08 (.87)	4.14 (.95)
2. The questions on each of the research articles for developing lines of thought are helpful and should be provided in the future. *(helpful/recommended for future use)*	4.25 (.72)	4.23 (.81)	4.27 (.66)	4.25 (.70)	4.28 (.82)
3. The research articles are related to some of the materials in the courses in pharmaceutics: Physical Pharmacy, Pharmaceutical Technology, and Biopharmaceutics. *(connected to what is learned in the present course)*	4.51 (.64)	4.53 (.58)	4.50 (.69)	4.52 (.65)	4.50 (.65)
4. The research articles are easy to comprehend. *(easy to comprehend)*	3.50 (1.05)	3.19 (1.02)	3.72 (1.03)	3.41 (1.08)	3.78 (.89)
5. The research articles helped me to see the importance of and the interconnection among various subjects studied separately in Pharmaceutical Technology, Physical Pharmacy, and Biopharmaceutics. *(connected to what is learned in other courses)*	4.20 (.87)	4.2 (.81)	4.19 (.92)	4.2 (.88)	4.14 (.86)

The scale is represented by M = males, F = females, P = prepharmacy, G = college graduate. Numbers in parentheses are the standard deviations. The numerical scale from which the means and standard deviations were calculated is such that 1 = "strongly disagree" and 5 = "strongly agree."

heterogeneity of the class. Some of the Pharm.D. students entered the program with a college degree in biology, chemistry, biochemistry, engineering, or computer science and were expected to have some advantages over other students in terms of reading and analysis of the research articles. Furthermore, for the gender analysis, significant differences in the mean values of the responses between males and females were found only for the statement that measured students' perceptions of the difficulty of the research articles. Female students (mean = 3.72, SD = 1.03, $n = 36$) thought that the research articles were easier to comprehend than the male students (mean = 3.19, SD = 1.02, $n = 26$) ($t = -2.0$, $df = 60$, $p < .05$). We cannot attribute any factor to this result at the moment; probably it is due to intelligence.

LIMITATIONS OF THE INTERVENTION

The formal class time devoted to the lectures was three hours per week. There was no formal time for reading, analysis, and preparation for the presentation. Each group arranged the time to meet for the assignment and to consult with the professors, if necessary. The presentations lasted two days (three hours per day) and were carried out during the free periods of the students. Although it is difficult to estimate with absolute certainty, the students must have spent about 25 hours or more on the intervention (first to read all the articles and second to analyze the particular article allocated to their group by ballot). This is one of the limitations of the intervention. The students complained that it placed too great a demand on their time. The solution planned for this problem is to design a one-credit course in pharmaceutical sciences (pharmaceutics and other courses) for the intervention. The intervention will be incorporated in the new curriculum that is in the pipeline in the School of Pharmacy.

The students functioned well as a group, if the extra effort they put into retrieving information from the Internet and the library to aid their analysis and presentation is any indication. However, the main problem reported by the group leaders was absence by some students at group meetings. Further, some students wanted to join their friends in other groups (they wanted the freedom to choose their groups). Although this tendency was discouraged, the fact that some of the students preferred groups other than those assigned randomly to them could be considered a limitation, as it is difficult to estimate its impact on their performance.

The peer grading method was not as effective as expected. Students who complained about their group members ended up awarding pass marks to such members in their evaluation. This defeated the objective of ensuring that everybody participated at the same level, which is the main advantage of the peer grading approach. Students were unwilling to fail their classmates.

Another major limitation of the intervention is the absence of a control group, which could allow for *in situ* measure of the effect of the intervention. It is difficult to divide the class into two and teach one group with the intervention and the other without the intervention. In addition to the problems for the faculty members, it is possible for contamination to result if a control group is used, as it is difficult to ensure that the students in the intervention group will not share their notes and information with those in the control group.

The students could have been biased in their responses by the fact that the instructors passed out and collected the survey.

CONCLUSION

This project investigated the combination of didactic pedagogy and student analysis of research articles in the field of pharmaceutics as a teaching intervention which could enhance the teaching and learning of pharmaceutics. The teaching intervention was found to be successful in achieving the goals of this project. It appears that the students have gained an insight into the interrelationship among the various subjects that comprise pharmaceutics. They have started to learn to work in groups, as seen in the results of their analyses and oral presentation. The students were made active throughout the teaching and learning of the course in that they consulted other learning materials apart from textbooks and lecture notes, and they had the opportunity to see the applications of some theoretical principles to solutions of research problems in pharmaceutical sciences.

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APPENDIX 1

Pharmaceutical Technology
Group Reading and Presentation

A new intervention in the teaching of Pharmaceutical Technology involves reading, analysis and critical appraisal of some research articles that are relevant to Pharmaceutical Technology and other courses in pharmacy in general and basic pharmaceutics, in particular Biopharmaceutics, Pharmacokinetics, Physical Pharmacy, and Pharmaceutical Mathematics. We believe that, by the time the semester runs out, you will have covered enough topics in Pharmaceutical Technology and Biopharmaceutics to be able to comprehend the materials in the articles. The objective is to study research articles relevant to the applications of the concepts given in the lectures to the solutions of pharmaceutical problems to enable you to see the "single thread" that runs through the various courses.

You have been assigned randomly into groups. You should appoint a group leader today. The research articles already selected by the professors are distributed to you. Questions for developing lines of thought accompany each research article. The articles should be analyzed and critically appraised by the time the semester runs out as follows:

i. Students should identify the experiments in each research article that are related to the topics covered in the courses.
ii. Students should appraise the approach to the experiments vis-à-vis the information received in the lectures.
iii. Students should discuss the experimental procedures, the analysis of the results, the discussion and conclusion of the authors.
iv. The students' write-up will be presented to the class at a date to be announced later. It will probably be fixed for the lunchtime because food and drinks will be provided.

APPENDIX 1 (continued)

v. Extra credit will be given to the group that can identify a suitable research article in the library and analyze it as indicated above.
vi. The professors will ask questions to find out the understanding of the contents of the research articles and to see whether the students can discern how the principles covered in the topics learned in the courses can be used to investigate a particular pharmaceutical problem.

APPENDIX 2

Pharmaceutical Technology
Group Reading and Presentation

Group Presentation Grade Assignment Sheet

Title of Paper: ________________________________

1. This is a confidential report on each member of your group to be submitted to the course oordinator. This report is due on the day of presentation. Each member of your group, including yourself, should be given a score based on his/her participation in the preparation and presentation of the paper assigned to you.
2. List the members of your group using the first and the last names, including yourself. You should be prepared to justify whatever score you give any member of your group; consequently, you should be honest and fair in giving the score. The score ranges from 0 to 100. Things to keep in mind are as follows: What is the level of participation of the member in the group efforts? How helpful is the member in accomplishing the assignment given to the group? Add to the list.
3. Give a score to the presentation given by other groups. You should be fair in doing this and bear in mind that professors are going to award marks to each group based on the quality of the presentations and how members respond to questions asked during the presentations.

Group Member's Name	Score	Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Group	Score	Comments
1		
2		
3		
4		
5		
6		
7		

APPENDIX 3

Responses to Questions Posed in the Students' Questionnaire/Survey

The purpose of the students' survey is to assist in identifying potential problems from the students' perspective at the early stage of this teaching intervention.

1. **What did you like MOST about this group reading, analysis, and presentation?**
   a. The information given in the lectures made me understand the research articles.
   b. Great: it must be continued.
   c. It is informal and the atmosphere was relaxed.
   d. Cooperation among group members helps in the understanding of the materials.
   e. Students have the opportunity to interact; how each member contributed to the group's success was interesting.
   f. The introduction provided in the research article shows how the different subjects are interconnected.
   g. It is actually related to what we have been studying, and this was very enlightening.
   h. Working together with group members and sharing ideas for an organized presentation.
   i. The food was excellent.

APPENDIX 3 (continued)

j. Having the opportunity to apply what we learned in lectures.

k. The correlation between dissolution and bioavailability studies.

l. It was very informative and interesting.

m. It was a good experience to read scientific research articles about what was taught in the class and to present the materials to the class.

n. Opportunity to search and learn something new.

o. The questioning time was enjoyable because it made the topics more understandable.

p. The presentations allowed for creativity; individual groups devised the best method to present the work.

q. It made me realize the practical application of the topics learned in class.

r. It promoted class unity.

s. It shows interconnection among various subjects.

2. What did you like LEAST about this group reading and presentation?

a. The problem of getting members of the group to do the work assigned to them.

b. The presentation was close to the end of the semester (examination period).

c. The self-appointed group leaders who took up the job of handing out assignments and who did not announce meetings but tried to penalize the group members for their own lack of organization.

. d. Nothing.

e. Not being able to choose my own group members.

f. Some of the articles were too long and difficult to comprehend.

g. Lack of cooperation among group members.

h. Because of heavy workload for this semester, there was no time to apply oneself to the project as necessary.

i. I learned many things from reading the articles which I did not know before.

j. Nervousness before presentation.

3. Give one or two suggestions that can help improve this group reading and presentation.

a. Ask each member of the group to write a one-page summary of the contents of the article.

b. The presentation should be done after the examinations.

c. The presentation was after a major holiday; hence, students did not have enough time to get together to put finishing touches to their assignments.

d. Let the class pick their own group members.

e. To make sure that every member of a group participates equally, devise a means to evaluate individual understanding of the research articles.

f. The research articles did not provide all the pieces of information needed to comprehend their contents.