In-class Exercises Regarding the Roles of Excipients in a Pharmaceutics Course

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Abstract

Objective: To assess student perceptions regarding: 1) exercises designed to enhance student comprehension of the roles of pharmaceutical excipients in dosage forms and 2) the use of resources to identify the roles of excipients.

Description: In-class exercises regarding the roles of excipients were implemented in a foundational pharmaceutics course. The exercises covered the topics of liquid single-phase systems, liquid multiphase systems, drug delivery to the skin, and parenteral, ophthalmic, and nasal dosage forms. Students were introduced to resources to identify the roles of excipients. The exercises included the presentation of pharmaceutical preparations with various fundamental excipients, followed by student polling and class discussion. A survey was administered to evaluate student perceptions regarding the exercises about the roles of excipients and the use of resources to identify the roles of excipients.

Findings: Eighty students participated in the study (response rate = 99%). Student perceptions indicated that the exercises helped them understand the material better and enhanced their performance in the non-sterile compounding course taught concurrently with the pharmaceutics course. Students indicated that the resources they used during the exercises were lecture notes from the course (95%), lists with excipients that the instructor provided (24%), a Web search, e.g., Google, Bing (20%), the sixth edition of the *Handbook of Pharmaceutical Excipients* (18%), Micromedex/Martindale (16%), and the *International Journal of Pharmaceutical Compounding* (6%).

Conclusion. Targeted excipient exercises are a practical approach to enhance student understanding and can be utilized in pharmaceutics and non-sterile compounding courses across various pharmacy curricula.

Keywords: pharmaceutics; dosage forms; excipients; compounding; active learning; pharmacy education

INTRODUCTION

Pharmacists are the only members of a comprehensive interprofessional healthcare team whose education includes the study of the science of pharmaceutics,[1] defined as "the science of preparing, using, or dispensing medicines." The discipline of pharmaceutics and the art of compounding include the appropriate use of pharmaceutical excipients, which are present in most dosage forms and usually constitute the majority of the dosage form mass.[2-4] Furthermore, it is known that the quality and efficacy of medications can be altered by the presence of excipients.[2, 3, 5-7] In general, the package insert,[5] as well as other professional resources, will identify the individual excipients used in the preparation of the dosage forms. A general understanding of the excipients and their roles in dosage forms are important for the compounding of medications and patient care, including consultation,[8-10] particularly as some excipients may exhibit adverse effects.[6, 8, 10-12] Moreover, compounding of dosage forms is part of the Entrustable Professional Activities Practice Manager Domain,[13] and dosage forms or delivery systems that by definition usually include excipients are mentioned in the North American Pharmacist Licensure Examination (NAPLEX) Competency Statements.[14]

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Excipients and their roles are usually taught in foundational pharmaceutics courses[15] as well as non-sterile compounding courses.[16] An enhanced emphasis of the roles of pharmaceutical excipients in a foundational pharmaceutics and/or non-sterile compounding course can ascertain that this material receives adequate attention alongside other important concepts taught in such courses. Direct demonstration of resources that can be used to identify the roles of excipients may familiarize students with those resources. Furthermore, some excipients are multifunctional, i.e., they may have more than one role in a certain preparation or different roles in various preparations. Adequate elaboration regarding the roles of excipients may help students to independently understand the rationale and considerations behind the addition of such excipients to certain dosage forms and preparations. Hence, the enhancement of aspects of the roles of excipients in a foundational pharmaceutics and/or non-sterile compounding course may offer multiple benefits.

A review of the literature revealed various interventions in pharmaceutics courses.[17-30] However, data regarding increased emphasis of the roles of excipients in pharmaceutics courses were absent. Therefore, the study aimed to: assess student perceptions regarding 1) exercises designed to enhance student comprehension of the roles of pharmaceutical excipients in dosage forms and 2) the use of resources to identify the roles of excipients.

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THE CONTEXT FOR THE WORK

The Pharmaceutics II course in South College School of Pharmacy is a four-credit-hour course (i.e., 40 contact hours) taught during Spring Quarter of the first professional year as part of the accelerated, three-year program. Following a discussion about routes of drug administration and a general lecture about pharmaceutical excipients, the course covers a variety of dosage forms, including liquid single-phase systems (e.g., solutions, syrups, elixirs), liquid multiphase systems (e.g., suspensions, emulsions), drug delivery to the skin, rectal and vaginal dosage forms, transdermal drug delivery, powders and granules as dosage forms, extended-release dosage forms, ophthalmic dosage forms, nasal and otic dosage forms, parenterals, pulmonary delivery systems, and oral transmucosal dosage forms. In addition, the course covers biotechnology drugs, pharmaceutical stability, and packaging. Other pharmaceutics topics, including tablets and capsules, are covered in the Pharmaceutics I course, a three-credit-hour course taught during the previous quarter.

The Pharmaceutics II course grade is based on four equally weighted examinations administered during the quarter (70%), a comprehensive final examination (20%), and equally weighted quizzes administered at the end of each 2-hour lecture (10%). Active learning is achieved through 1) the frequent use (i.e., every seven minutes on average) of polling by an online student response system, iClicker Cloud (Macmillan Learning, New York, NY), and 2) discussions consisting of open-ended questions with subsequent annotation of PowerPoint presentations using an XPPEN Star 05 digital drawing tablet (XPPEN Technology CO, Shenzhen, China). Annotated lecture notes with correct answers to the polling questions are uploaded to the learning management system, Canvas (Instructure, Inc., Salt Lake City, UT). Quizzes are administered through Canvas, while examinations are administered through an online examination software, ExamSoft (ExamSoft Worldwide LLC, Dallas, TX).

THE INNOVATION

Since the inception of the Pharmaceutics II course in 2012, excipients and their main roles were mentioned throughout lecture notes on various topics, as well as in a small number of exercises that took place during the lecture about drug delivery to the skin. The pharmaceutical preparations for those exercises were taken from the United States Pharmacopeia (USP).[31] To potentially improve pharmaceutical patient care by South College School of Pharmacy graduates and enhance student performance in the non-sterile compounding course and the NAPLEX, it was decided to increase the emphasis on the roles of excipients in the pharmaceutics courses.

During the academic year 2019-2020 students received lists of excipients and their roles for the first time. The list for the Pharmaceutics I course included excipients used in tablets and capsules. In addition, in-class exercises regarding the roles of excipients were substantially expanded in the Pharmaceutics II course (but not in the Pharmaceutics I course). In-class exercises were administered for select topics (Table 1) after the discussion of each topic was completed. Preparations that contained excipients most relevant to student knowledge were identified. Several preparations included multifunctional excipients (e.g., ethyl alcohol, glycerin, propylene glycol, citric acid, and cetostearyl alcohol). Except for the commercial product, Intralipid, the new exercises included preparations obtained from the *International Journal of Pharmaceutical Compounding*. A comprehensive list of preparations used for the in-class exercises is seen in Table 1.

Prior to the first exercise, students were introduced to resources available for identification of the roles of excipients. Those resources were the sixth edition of the *Handbook of Pharmaceutical Excipients*, freely available on the Web, and library resources such as Micromedex/Martindale and the *International Journal of Pharmaceutical Compounding*. Two examples of in-class exercises about the roles of excipients are shown in Table 2.[32, 33] Each exercise started with the presentation of the preparation. Excipients with roles that were more obvious to the students, for example those that require mostly recall from previous lectures, were noted on the lecture notes as seen in Table 2 and were usually not subject to polling. Instead, the instructor asked for their roles using open-ended questions and the answers were annotated on the lecture notes. Excipients with roles that were less obvious to the students, for example multifunctional excipients, were subject to polling using multiple-choice questions with five answer choices. Some preparations included one polling question, while others (such as the examples in Table 2) had two polling questions on two excipients. Polling was followed by a discussion regarding the correct answer. Additional examples of in-class exercises and examination questions are available from the author upon request.

Examinations 1 through 4 included questions about the roles of excipients related to dosage forms covered in each examination. Moreover, Examination 2 included questions about the list of excipients regarding solid dosage forms that were first introduced during the Pharmaceutics I course, and Examination 4 was comprehensive regarding the roles of all excipients taught in the course. A total of 240 examination questions were administered during the course, and of these 240 questions, 41 discussed the roles of excipients. Of these 41 questions, 35 included preparations. Furthermore, of these 35 questions, nine contained multifunctional excipients.

Following approval as “exempt” by the South College Institutional Review Board, a student survey regarding the exercises was developed by the author and administered in Spring Quarter of 2021. Students who wished to volunteer for the study signed an electronic Consent Form. The first part of the survey, which was about the benefits of the exercises, had a 5-point Likert scale structure. The second part of the survey, which was about the use of resources to identify the roles of

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excipients, had a Select All That Apply format. The survey was reviewed by three faculty members from the school of pharmacy. After the implementation of comments as appropriate, the survey was pre-tested[34, 35] with seven students from the second professional year. The finalized survey was administered via Qualtrics (Qualtrics Labs, Inc., Provo, UT) near the course completion.

CRITICAL ANALYSIS

Eighty of the 81 students enrolled in the course participated in the study (response rate = 99%). Survey results indicated that students thought highly of the exercises. For example, 96% of the students strongly agreed (71%) or somewhat agreed (25%) with the statement, "In-class exercises concerning the roles of excipients helped me to better understand the roles of excipients in formulations." Ninety-five percent of the students strongly agreed (74%) or somewhat agreed (21%) with the statement, "In-class exercises concerning the roles of excipients helped me to better understand the material and apply the information in the PSC 6330 Pharmacy Dispensing and Compounding Lab (taught in Spring Quarter)." In addition, survey results indicated that the resources students used during the exercises were lecture notes from the course (95%), lists with excipients that the instructor provided (24%), a Web search, e.g., Google, Bing (20%), the sixth edition of the *Handbook of Pharmaceutical Excipients* (18%), Micromedex/Martindale (16%), and the *International Journal of Pharmaceutical Compounding* (6%).

Excipients and their roles in dosage forms are important for pharmaceutical patient care, and instruction of those topics typically takes place in pharmaceutics and non-sterile compounding courses. A literature review showed that earlier (ie, pre-2009) reports about interventions in pharmaceutics courses included case studies,[25, 36, 37] problem-based learning,[25, 38] conceptests,[39] distance education,[40] and the use of interactive digital images.[21] Later (ie, post-2009) course interventions included an initial integration of pharmacy practice concepts,[28] the use of a patient simulation software,[18] flipped-classroom model[23, 24] concept maps,[20, 29] continuing professional development with portfolio,[27] problem-based learning,[22, 26] productive failure,[19, 20] and model-based instruction.[17] A recent article suggested the integration of nanomedicine into pharmaceutics topics. [41]

The exercises' design regarding the roles of excipients can be divided into the identification of preparations that may be subject to those exercises, and the construction of multiple-choice questions regarding the roles of excipients in the preparations. The identification of preparations was challenging and time-consuming. It was important to provide exercises on various course topics that cover the most essential excipients, while leaving out the less critical excipients, to optimize class time and not overwhelm the students with less important information. Table 1 provides a listing of 23 preparations that can serve as a foundation for the implementation of exercises in any pharmaceutics or non-sterile compounding course, as time allows. The polling questions design for each preparation is much less time-consuming and more straightforward compared to the identification of the preparations. Examples of such polling questions appear in Table 2, and the author can provide additional examples upon request. The main study limitations are that the sample size was relatively small, and that it was conducted in only one institution with an accelerated program. These factors may affect the generalizability of the results.

CONCLUSION

The study provides a practical approach to enhance student understanding of the roles of pharmaceutical excipients in dosage forms. This approach can be utilized in pharmaceutics and non-sterile compounding courses across various pharmacy curricula.

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Table 1. Preparations used for in-class exercises regarding the roles of excipients

Topic	Preparations[a]
Solid dosage forms[b,c]	N/A
Excipients[b]	N/A
Liquid single-phase systems (e.g., solutions, syrups, elixirs)	Aminocaproic Acid 250-mg/mL Oral Solution, Bromhexine Hydrochloride 0.8-mg/mL Syrup
Liquid multiphase systems (e.g., suspensions, emulsions)	Amoxicillin 125-mg/5-mL and 250-mg/5-mL Suspensions, Chloramphenicol Palmitate 150-mg/5-mL Suspension, Intralipid, Progesterone Oral Suspension (40-mg/mL), Ribavirin 40-mg/mL Suspension
Drug delivery to the skin	Benzoyl Peroxide 10% Gel, Chlorhexidine Gel, Hydrogen Peroxide Cream, Hydrophilic Petrolatum, USP, Hydrophilic Ointment, USP, Polyethylene Glycol Ointment, NF, Potassium Nitrate/Benzocaine/Tetracaine Dental Gel, Pramoxine 1% Cream, Yellow Ointment, USP, White Ointment, USP
Parenteral dosage forms	Diclofenac Sodium 25-mg/mL Injection, Dimenhydrinate 50-mg/mL Injection
Ophthalmic dosage forms	Gatifloxacin 0.5% Ophthalmic Solution, Phenylephrine Hydrochloride 2.5%-Ophthalmic Solution, Scopolamine Hydrobromide 0.25% Ophthalmic Solution
Nasal dosage forms	Scopolamine Hydrobromide 0.2% Nasal Spray

[a] Except for Intralipid and a few preparations from the USP (where indicated), all other preparations are from the *International Journal of Pharmaceutical Compounding*.

[b] Students were required to know the general roles of excipients taught in lectures about this topic, although there were no in-class exercises during those lectures.

[c] The lecture about this topic occurred in the Pharmaceutics I course, while the other topics were covered in the Pharmaceutics II course.

NF=National Formulary; USP=United States Pharmacopoeia

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Table 2. Examples of exercises regarding the roles of excipients

Example 1: Aminocaproic Acid 250-mg/ml Oral Solution[32]

Rx *for 100 mL*

Aminocaproic acid		25 g
Methylparaben		200 mg
Propylparaben[a]		50 mg
Edetate disodium[b] ←		300 mg
Sodium saccharine		200 mg
Citric acid, anhydrous[b] ←		200 mg
Raspberry flavor		qs
Bitterness suppressor		qs
Sorbitol 70% solution	qs	100 mL

What is the most likely role of citric acid, anhydrous, in the preparation?

a. To adjust the pH of the solution
b. In the preparation of effervescent granules and tablets
c. Chelating agent, complexing agent[c]
d. Flavor enhancer for liquid formulations
e. Preservative

Example 2: Ribavirin 40-mg/mL Suspension[33]

Rx *For 100 mL*

Ribavirin		4 g
Tragacanth[b] ←		1.25 g
Alcohol 95%[b] ←		1.9 mL
Benzoic acid[a]		100 mg
Propylene glycol[a]		2.5 mL
Methylparaben		80 mg
Propylparaben		20 mg
Purified water	qs	100 mL

What is the most likely role of alcohol in the preparation?

a. Preservative
b. Cosolvent
c. Tranquilizer
d. Wetting agent[c]
e. Emulsifying agent

[a] An excipient in the preparation that was subject to an open-ended question presented to the class where the correct answer was annotated to the lecture notes.

[b] ← indicates an excipient in the preparation that was subject to student polling.

[c] correct answer.

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