Original Article

Improving Pharmaceutical Compounding Skills Using Gagne's Instructional Design Model

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Abstract

Compounding is a fundamental skill that pharmacists perform professionally. However, inappropriate learning and superficial training can lead to medication errors. Thus, this study proposed a lesson plan based on Gagne's instructional design to teach basic compounding skills, such as weighing, measuring, and trituration. The study utilized Gagne's model to compose extemporaneous preparations for dermal use. A standardized questionnaire was devised to analyze learners' opinions and feedback regarding the lesson. Fifty students (third-year Doctor of Pharmacy) with 1.3 ± 0.2 years of compounding experience participated in the lesson. The analysis revealed that 83.5% of the respondents correctly identified the role of ingredients and 85.6% identified the correct tools and instruments. The overall view was 4.9 ± 0.2 on lesson concept and realization; 4.8 ± 0.1 for motivation, participation, and climate; and 2.7 ± 0.3 for workload and difficulty. Gagne's instructional design model effectively guided the development of an active and comprehensive lesson plan to teach compounding skills to pharmacy students.

Keywords: Gagne´s instructional design, Pharmaceutical compounding, Pharmacy education, Teaching strategy

Introduction

The introduction of clinical pharmacy caused a paradigm shift in the profession of pharmacy nearly 50 years ago [1, 2]. Traditionally, pharmacists were responsible for preparing and dispensing medications; however, now, they focus on the safe and effective use of medications [3, 4]. The mass production of medication by pharmaceutical companies has diminished medication compounding by pharmacists [2, 5]. Nevertheless, pharmacies still offer compounding services; consequently, pharmacists must master this skill [5]. Furthermore, compounding has been gaining attention because it can provide an individualized approach to patient care. Therefore, pharmacy schools have progressively adapted clinical pharmacy into their curricula [5].

The Pharmacy Board of Australia has defined compounding as the preparation of a single unit of a medication product intended to be used by a specific patient in response to a certain need [5, 6]. The process of combining, mixing, or altering ingredients to produce customized medications for a patient according to a prescription can also be termed compounding [7]. Thus, compounding requires certain skills, especially because medications should be compounded only in case of the unavailability of commercial products, unsuitability of available products, or if the product is made for research purposes. Compounding procedures can be simple or complex. Simple compounding is required to fulfill the previously stated definition from formulations published in major references [5, 6]. Examples of simple compounds include the preparation of topical creams, ointments, and oral liquids. However, complex compounding is beyond the scope of the standard pharmacy curriculum and requires pharmacists to use their expanded knowledge and practice to prepare parenteral, controlled release, or sterile formulations [5-7].

Pharmaceutical compounding is an entrusted professional activity expected from pharmacy students. Thus, pharmacy programs must promote the acquisition of this skill among students (learners) by disseminating the required cognitive and psychomotor skill sets through active learning [7-9]. Currently, compounding skills are taught as part of laboratory sessions in pharmaceutical courses or as a single course in theoretical curricula. However, it is important to engage learners in learning theories and practical applications. A recent study from Louisiana, United States of America [10]

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suggested that the inclusion of continuous exposure to compounding education and training produces competent and confident pharmacy graduates. Further, [8] asserted that providing students with continuous exposure to refine their skills before engaging in real-world practice improves their techniques, reduces compounding errors, and increases confidence. [11] reported that in the absence of repeated exposure, compounding skills are not retained for longer periods. This highlights the importance of including different compounding practices in the curriculum. This should be accompanied by creative teaching strategies that stimulate active learning to facilitate the acquisition of skills and ensure retention.

Subsequently, The Accreditation Council of Pharmacy Education has provided recommendations for pharmacy schools to establish compounding courses after assessing the status of compounding education, determining the appropriate entry-level, and developing a curriculum for basic and advanced compounding [12]. The Center for Advancement of Pharmacy Education has recommended that students develop and retain sufficient compounding skills while simultaneously understanding important quality control procedures and good laboratory practices [13].

Gagne's Instructional Event (GIE) model is widely used in educational settings. It is based on an information-processing model of cognitive events that occur in response to a variety of stimuli [14, 15]. This model comprises multiple steps that focus on achieving learning outcomes [14, 16]. The instructional events are the actions that must be performed by both the instructor and learners during the learning session [9, 15]. The lesson plan centers around predefined outcomes and types of activities that occur during each event. Extant literature highlights that lesson plans have been made to teach psychomotor skills, such as pharmaceutical calculations [1, 17], pharmacotherapeutics [18], and blood pressure measurements [19], for pharmacy practice. However, limited or no data are available on the design of lesson plans for pharmaceutical compounding.

To address this research lacuna, this study aimed to create a lesson plan based on the learning needs of basic compounding skills using GIE as the theoretical framework. The lesson plan, which also included a practical session, was created for third-year Doctor of Pharmacy students. GIE provides valuable insights for improving the quality of teaching and learning, course design, and assessments [19].

The recommended method for teaching psychomotor skills is a sequenced stepped teaching approach [16, 20]. Preparing a formulation involves different skill sets, such as understanding the interactions between medicinal ingredients, performing mathematical calculations, and executing the preparation. This multistep task should be taught in a structured, logical manner (i.e. GIE) to enhance the learner's ability to recall, retain, and execute these skills for an extended period after the learning session. The lesson plan proposed in this study was based on the author's experience in teaching the course for two years. The lesson plan was mainly based on two learning theories: constructivism and social learning theory. Constructivism caters to the students' extant knowledge of formula preparation, taught to them during the second and third years. In contrast, social learning theory is practiced through video observation, live demonstration, and collaborative activities during a lesson.

Materials and Methods

The systematic nature of GIE describes a nine-step approach for the instructional delivery of content and activities to ensure that all the objectives are covered while actively engaging learners. This study uses the GIE framework and presents the design of an active learning lesson for third-year Doctor of Pharmacy students. The lesson incorporates a practical session that focuses on teaching the skills required to prepare extemporaneous formulations, using zinc oxide cream as an example. **Table 1** presents the detailed lesson plan design.

Table 1. Detailed lesson plan design

Level		Duration	Activity
1	**Gaining attention** **Facilities used:** Short video displayed on a screen using a projector	8 mins	- The instructor welcomed the students while they settled. - The instructor initiated the discussion by presenting a case scenario of a pharmacist who receives a medication order for a hospitalized patient who developed skin irritation because of his extended stay at the hospital. However, the hospital's pharmacy does not have a pre-packaged manufactured cream. Nevertheless, it has a small preparation room in the back. -The instructor asked the students to suggest solutions.
2	**Informing learners of the objectives** **Facilities used:** PowerPoint presentation displayed on a screen using a projector	4 mins	- The instructor presented the title of the topic and emphasized its importance and relevance in pharmacy practice. - The PowerPoint presentation included the objectives in the form of direct and easy-to-read statements such as: By the end of this practical session, the student will be able to: 1. Define extemporaneous formulations 2. Discuss the feasibility of extemporaneous formulations 3. List the required equipment and chemicals to prepare extemporaneous formulations 4. Calculate the required amounts of chemical ingredients correctly

			5. Prepare useable basic zinc oxide cream - The instructor encouraged the students to take notes during the session.
3	**Stimulate recall of prior learning** **Facilities used:** PowerPoint presentation displayed on a screen using a projector	10 mins	- The instructor continued with a PowerPoint presentation, which included different types of questions on related topics, for example: • A direct question to define a formulation • A bingo chart to list the general requirements of a formula • A table with two columns namely, pre-packaged, and extemporaneous formulations. The rows contained characteristics such as components, labeling, production, general use and expiration date, etc • The students completed the first column from previous knowledge. The second column was left empty until the end of the session.
4	**Presenting stimulus** **Facilities used:** PowerPoint presentation displayed on a screen using a projector	25 mins	• The instructor presented new content such as definitions of extemporaneous preparations, requirements, general use, and other formulation considerations through PowerPoint slides. • The instructor utilized different teaching strategies to stimulate learning: 1. Using vocal intonation and body language while explaining new information 2. Employing visual support, including PPT slides with the following: • Images of required tools and chemicals • Tables of required chemicals with structures and general uses • A schematic representation of preparation steps for zinc oxide cream 3. Encouraging students to take notes during the session 4. Pausing between topics to answer students' questions or quickly review the material.
5	**Providing learning guidance** **Facilities used:** - Short educational video displayed on a screen using a projector - Laboratory equipment - Live demonstration	12 mins	- The students watched and observed a short educational video (3 mins) demonstrating the procedure for preparing zinc oxide cream. - The instructor commented on the video and discussed it with the students. - The instructor performed the task in front of the students. The students participated by repeating the process, which they recorded in their notes or saw in the video. - While performing the task, the instructor offered tips, answered queries, and asked questions to stimulate attention.
6	**Eliciting performance** **Facilities used:** - Laboratory equipment and tools	35 mins	- Students formed groups of three to collaborate and plan how to perform the procedure: collecting tools and chemical ingredients, performing the required calculations to weigh each chemical ingredient, and finally following the steps mentioned in their notes. - Students were allotted sufficient time and equipment to practice preparing zinc oxide cream according to the procedure.
7	**Providing feedback**	8 mins	- The instructor observed the students while they worked on their assigned laboratory benches, asked them how comfortable they were in performing the procedure, and addressed inquiries regarding the procedure.
8	**Assessing performance** **Facilities used:** - Activity sheet - Zinc oxide cream product	10 mins	- The instructor assessed the performance using two approaches: • The first approach involved an activity sheet that contained questions linking previous laboratory sessions with the new lesson. For example: • A mathematical challenge to prepare the cream in different quantities, using the rules of reducing or increasing formulas (taught in 2nd-year pharmaceutical calculation course) • One-sentence questions/answers to state the reasons for including certain ingredients into this formula (zinc oxide cream) based on their knowledge regarding pharmaceutical excipients (taught in 2nd-year pharmaceutic courses) • A list of the general uses of zinc oxide cream based on their knowledge regarding semi-solid dosage forms (taught in the 3rd-year pharmaceutic course) • The second approach involved group collaboration for preparing the cream and submission of a summary report. Then, the instructor examined the quality of the product according to a rubric (see appendix). • The instructor discussed the issues (if any) immediately and asked the students to think of ways to avoid the issues.
9	**Enhancing retention and transfer** **Facilities used:** - Group laboratory report	7 mins	• The instructor concluded the session by summarising the learning outcomes and the main points of the lesson. • Each group had to complete a summary report, which included calculation steps, a list of tools and chemicals, a preparation process, and trouble-shootings during the performance. • The report was collected by the instructor for evaluation. It was given back to the students in the following week.

Prerequisite Knowledge and Skills

Learners had previously received didactic instructions based on semi-solid dosage forms (during lectures) and had attended practical sessions to prepare formulations (prior pharmaceutical courses). For the proposed session, the learners were organized into groups of three to facilitate active learning, collaboration, and knowledge exchange. Before the session, the assigned materials (handouts, activities sheet, and report sheet) were distributed among the learners at least one week in advance. The materials included introductory information, such as guidelines for preparing formulations and mathematical principles used in pharmaceutical preparations. In addition, to curate a learning experience, the instructors were made aware of the strategies that impart active learning and the importance of learning outcomes.

The Nine Sequenced Steps of GIE

Gaining Attention

When students arrive in class, they must be interested in initiating communication. Learners' attention is gained by beginning the session with a multimedia video showcasing a scenario involving a pharmacist who receives a medication order that is not available in the hospital pharmacy. The instructor can ask students to suggest solutions to the problem. Consequently, brainstorming induces sufficient curiosity that motivates students to learn.

Informing Learners of the Objectives

Objectives are tasks aimed at achieving the primary goal of a learning session [9]. The objectives must be built around the goal, according to Bloom's taxonomy (2002 revision). Clear, measurable objectives define the instruction and performance assessment [9, 20]. Further, learning objectives should focus on inducing performance, which is the goal of a lesson. Here, the primary goal was to teach pharmacy students the skills required to prepare extemporaneous formulations. Early in the lesson, students should encounter an easy-to-read list of learning objectives to inform them of what to expect and motivate them to succeed.

Stimulate Recall of Prior Learning

Connecting new information with previous knowledge and personal experiences can facilitate learning. Foundational knowledge helps integrate new learning into existing cognitive structures (i.e. schemas) [8]. In addition, recalling previously learned concepts, such as the differences between creams and ointments, makes new learning sessions more meaningful and relatable. The instructor can engage the students in interactive discussions to reflect on previous experiences acquired during summer training or laboratory sessions.

Presenting Stimulus

In this event, new content is presented in an organized and attractive manner to capture learners' attention. A PowerPoint presentation containing texts, images, and a video demonstrating procedural steps are shown to the students. The use of different instructional strategies supports learning at different levels through observation and collaboration.

Provide Learning Guidance

This event demonstrates the appropriate actions required to correct the performance by using examples, graphical representations, and live performances. This would help students learn meaningful information using skills stored in their long-term memory [19, 20]. Students first watch a video and observe the steps and techniques involved in preparing zinc oxide cream, before preparing it themselves. The instructor may perform the task and give students some tips, answer questions, and ask some questions to guide students' attention toward the task.

Eliciting Performance

This step is implemented after a short break and constitutes a major part of the session. Eliciting performance is important for applying what has been learned to reinforce new skills and knowledge and confirm the understanding of the lesson concepts [9, 20]. In this lesson, preparing zinc oxide cream is used as an example of an extemporaneous formulation. Students are divided into groups of three to collaborate and plan the performance of the procedure. They are also provided with the time and equipment to practice preparing zinc oxide cream according to the procedure.

Providing Feedback

Providing meaningful and timely feedback ensures reinforcement and assessment of correct performance, identifies gaps in understanding, and ensures the attainment of proficiency [19]. After the learners practice the newly learned skills, the instructor supervises them while they work on their assigned laboratory [21] benches. Feedback during the session should be constructive and actionable to provide learners with opportunities to improve in specific areas.

Assessing Performance

At this step, learners should demonstrate knowledge retrieval and the achievement of learning outcomes. Literature suggests several methods for assessing learner performance, such as administering pre-and post-tests, formative assessment throughout the session, and collaborative projects or presentations [9]. This study assessed the progression of competencies and skills. In this lesson, the instructor assesses the performance using two different approaches. First, the instructor uses an activity sheet containing questions linking previous laboratory sessions to the new lesson. The second method involves group collaboration in preparing the cream, wherein students submit a summary report. Then, the instructor examines product quality according to a rubric.

Enhancing Retention and Transfer

The instructor concludes the session by summarising the outcomes and main points of the lesson. This step supports

students in retaining more information by providing opportunities to internalize new knowledge. At the end of the lesson, after the students present the product and receive immediate feedback, each group completes and submits a summary report.

Evaluation

At the end of the session, participants were asked to complete a questionnaire (answered on a five-point Likert scale) to evaluate their opinions on readiness to transfer and apply the gained knowledge to their daily practice (Kirkpatrick's evaluation level I and II). The questionnaire was adopted and modified from [19]. It was divided into the following three sections: lecture concept and realization; motivation, participation, and climate; and workload and difficulty level. Students could select one out of five options (1=strongly disagree, 2=disagree, 3=undecided, 4=agree, and 5=strongly agree) for sections 1 and 2. Options for section 3 (workload and difficulty level) were: 1=very low, 2=low, 3=undecided, 4=high, and 5=very high. The questionnaire was assessed for face validity by two instructors from the Department of Pharmaceutics, College of Pharmacy, Umm Al-Qura University.

After explaining the purpose of the study, assuring participants of confidentiality, and obtaining informed consent, the questionnaire was electronically distributed among students to collect information regarding their experience of the proposed lesson. This study was reviewed and waived from obtaining ethics approval by the ethics committee of Umm Al-Qura University (DJGS140623).

Results and Discussion

Fifty respondents (30 women and 20 men) participated in the lesson. The average age was 20 ± 2.1 years with 1.3 ± 0.2 years of compounding experience. Previous exposure to some practical techniques improved the retention of prior and new information, which added to advanced experience. The questionnaire presented to the participants after the lesson focused on three main categories. The first category was understanding the lecture concept through attractive, sequential, and relevant content. In other words, this category was mainly concerned with the actual learning process. The participants highly rated items within the category, with the highest rating for the clarity of learning outcomes at the beginning of the lesson (5 ± 0.0), and the lowest rating for sufficiency of time to perform each activity (4.3 ± 0.3). The overall rating for lecture conceptualization was 4.8 ± 0.3.

The second category covered motivation and participation because motivation fuels learners' behavior and participation is the link between the learner and activity [22]. The participants found the lesson motivating (4.5 ± 0.5) because of the appropriate use of media and sufficient assistance from the instructor. The overall rating for all items in this section was 4.4 ± 0.5. The third category examined workload and difficulty levels to assess how students cope with and handle stress. The average rating of each item in this category was mostly low (2.7 ± 0.3), which indicates that students easily acquired new knowledge and prepared the cream. Descriptive analyses of each item in the three sections are presented in **Table 2**.

Table 2. Descriptive results of the rating scale item according to the categories

Item	mean ± SD
Category 1: Lecture concept and realization	
Easy to follow	4.8 ± 0.2
Learning outcomes are clear	5 ± 0.0
The sequence of topics is coherent	4.7 ± 0.4
The study content is relevant	4.9 ± 0.5
Connection between theory and practice	4.9 ± 0.2
Sufficient time for each activity	4.3 ± 0.3
Instructor preparedness	4.7 ± 0.4
Instructor's poise and attitude	4.8 ± 0.5
Category 2: Motivation, participation, and climate	
Lesson is motivating	4.5 ± 0.5
Sufficient opportunities to ask questions	3.9 ± 0.6
The instructor's answers were clear and sufficient	4.8 ± 0.5
Appropriate use of media and facilities	4.7 ± 0.3
The usefulness of additional materials	3.9 ± 0.5
Category 3: Workload and level of difficulty	
The workload for preparation and follow-up	2.6 ± 0.3
Level of difficulty	2.1 ± 0.2
Number of new topics presented	2.9 ± 0.4
Amount of previous knowledge of the topic	3.1 ± 0.3

This study used a systematic approach to develop unique learning experiences that connect prior knowledge with new structured teaching strategies to support learners' internal cognitive processes. It recommended a sequenced stepped teaching approach for the dissemination of psychomotor skills among pharmacy students [16, 20]. Preparing a formulation involves different skill sets, such as understanding the interaction between medicinal ingredients, performing mathematical calculations, and executing the preparation. This multi-step task should be taught in a structured, logical manner (for example, GIE) to ensure the learner's ability to recall, retain, and execute these skills for an extended period after the conclusion of the learning session.

During the development of this lesson, GIE was slightly altered to improve students' experiences. For example, before the session, assigned materials (handouts, activities sheets, and report sheets) were distributed among learners one week in advance. Providing such materials facilitated the retrieval

of information from long-term memory [8, 9]. In addition, using a real-world example such as that used in this lesson can be effective in managing orders and making decisions [14, 16]. Finally, providing timely feedback after the completion of a task enhances retention and learning [14-17]. The findings of this study demonstrated the lesson plan's effectiveness for teaching compounding in the pharmacy curriculum.

Therefore, it can be concluded that GIE provides a framework for delivering content while considering the learning conditions. However, it cannot be standardized for every session and topic because of certain limitations, such as the necessity of instructors' training before the implementation of GIE. Training should include various aspects of active learning, outcome-based learning, and the design of effective GIE. In addition, GIE assumes that all students have the same level of knowledge, which could be challenging for both the instructor and learners because GIE is structured and detailed to deliver specific content within a predesigned context. Consequently, it is difficult to apply GIE to teach large groups. Moreover, GIE is more suited for teaching psychomotor skills than approaches that depend on knowledge or memory such as lectures and seminars.

Some examples of specific limitations include problems that might occur during step six of GIE (eliciting performance), in which the laboratory may become noisy owing to constant movement and student discussions. This could hinder the learning environment and cause distraction and anxiety, which could interfere with students' performance and motivation to accomplish the task within the allocated time. Furthermore, step seven of GIE (providing feedback) should be immediate and individualized, which is difficult to carry out promptly because some individuals require more time than others. To avoid these limitations, it may be necessary to split the cohort, using an additional laboratory and soliciting help from other facilitators. However, the cost and availability of such resources may be infeasible. Step eight of GIE (assessing performance) may also be challenging because it may not accurately assess each student's performance; some skills may require repetition or further knowledge to develop fully. Overall, however, the nine steps of GIE can be modified to suit the content, learners' level of knowledge, availability of instructors, and availability of facilities.

Conclusion

This research reports how GIE can be applied to teach psychomotor skills and cognitive knowledge. The lesson proposed in this study was effective and comprehensive in teaching the theoretical concepts and practical skills required for compounding. The results indicated the effectiveness of the lesson. Thus, this instructional design model, which enhances learning outcomes and ensures the retention and mastery of compounding skills over time, could close the gap between classroom and workplace practice. Future research should focus on contextualizing compounding lessons with other related topics such as dispensing medication and the pharmaceutical industry.

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