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RESEARCH ARTICLE

Improving students' perceptions of pre-lab assignments and corresponding group discussions within a pharmacy compounding lab

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Abstract

Objective: To enhance students' perceptions of their learning within a pharmacy compounding lab. **Methods:** During a previous course evaluation, the participating students rated their 'pre-lab assignments' and 'group discussions in lab' as having relatively low levels of benefit upon their learning. As a result, several modifications were made to these items over the subsequent three-year period. First, the completion of the pre-lab assignments was changed from 'prior to each lab' to 'at the beginning of each lab' and the group discussions were eliminated (Year-1). Then, the pre-lab assignments were revised to fully integrate the application questions with the lab activities (Year-2). Finally, the group discussions were reincorporated into the labs (Year-3). Upon the conclusion of each year, the students (n=150-152) were asked to rate how beneficial each course item was to their learning using a four-point scale. **Results:** The useable response rates were 92-97%. After Year-1, the mean level of benefit (MLB) for the pre-lab assignments decreased from 2.3±0.8 to 2.0±1.1 (p<0.05); however, after Year-2, the MLB increased to 2.8±0.6 (p<0.05). In addition, after Year-3, the MLB for the group discussions in lab increased from 2.1±0.9 to 2.5±0.7 (p<0.05) with no change in the MLB for the pre-lab assignments (p>0.05). **Conclusions**: The combination of having students complete their pre-lab assignments 'at the beginning of' instead of 'prior to' each lab and ensuring any application questions are fully integrated with the lab activities appears to enhance their perceptions of not only the pre-lab assignments, but of the group discussions in lab as well.

Introduction

While student perceptions do not provide a direct measurement of learning, such perceptions have been an important tool for assessing and improving educational experiences (Genn, 2001; Mayya & Roff, 2004; Till, 2004; Alotaibi & Youssef, 2013). In addition, several studies have reported that an explicit relationship exists between students' perceptions of their educational environment and their approaches to learning (Ramsden & Entwistle, 1981; Entwistle *et al*., 1989; Pimparyon *et al*., 2000; Genn, 2001). For example, when students perceive teaching positively, they tend to approach their learning from more of a meaning orientation (i.e. an intrinsic, evidence-based approach that interrelates ideas and results in a deep learning). Mayya & Roff (2004) and Pimparyon *et al*. (2000) also found that high academic achievers (i.e. those students with a higher grade point average (GPA) tended to perceive the same teaching and learning significantly more positively than low academic achievers, suggesting a potential correlation with academic success. Furthermore, including students within quality improvement efforts enables their voices to be heard, which further enhances their engagement within their educational environment (Till, 2004). Because of this, student perceptions have played a key role in evaluating the educational experiences within Midwestern University College of Pharmacy-Glendale's (MWU-CPG's) pharmacy compounding labs.

At MWU-CPG, pharmacy compounding is taught as part of two successive required courses, Pharmaceutics I & II, which take place within the first year of the College's accelerated three-year Doctor of Pharmacy (Pharm.D.) curriculum. Both of these courses integrate the disciplines of physical pharmacy, dosage forms, pharmacy compounding, and pharmaceutical calculations and are preceded by Pharmaceutical Calculations and followed by Biopharmaceutics & Pharmacokinetics. The content of these courses is presented through both lecture and lab formats that are closely coordinated and organised in a modular format, beginning with the general concepts of drug product administration, preparation, stability, and performance and continuing through the application of these concepts to a variety of non-sterile and sterile dosage forms. In addition, the course sequence is completed by a diverse group of students, many of who may be categorised as non-traditional (Peirce College, 2019). Such students seem to be especially attracted to the College's accelerated programme, but also tend to have a greater number of competing responsibilities outside of school.

A previous evaluation of the non-sterile products portion of MWU-CPG's integrated pharmaceutics course sequence demonstrated that the participating students perceived the hands-on compounding activities to be highly beneficial to their learning, while the written pre-lab assignments and corresponding group discussions in lab were perceived as being relatively less beneficial, even though all of these exercises were designed to enable the students to repeatedly use the course content and prepare for the course assessments, which is typically their biggest concern (Bowman & Aphaisuwan, 2018). These differing results were attributed to the fact that since the completion of the pre-lab assignments and preparation for the corresponding group discussions did not correlate with the course assessments as directly, these exercises may have been perceived as being less beneficial, especially given the amount of time they consistently required outside of class. This supposition was supported by the lab instructors' observations that some students would seemingly complete the pre-lab assignments by simply copying from the past years' answer keys without checking for changes and participate in the corresponding group discussions by merely reciting their copied answers without actively listening or participating. This became particularly evident as the routine of the labs was established, which is when the students start to realise what they can 'get away with', and the students' exam schedules began, which are especially stressful due to the College's quarter-based curriculum. It should be noted that the pharmacy compounding labs were kept relatively the same due to faculty workload and that the answer keys were provided to ensure each student received all of the correct information from lab, while acknowledging that this certainly created the potential for mere copying to occur in future years.

With the quality of compounded preparations being evermore scrutinised, maximising the educational experiences of students within pharmacy compounding labs may be more important than ever (Kochanowska-Karamyan, 2016; Bilger *et al*., 2017; Mudit & Alfonso, 2017; Kosinski *et al*., 2017). Therefore, the objectives of this study were to improve student perceptions of the pre-lab assignments and the corresponding group discussions within MWU-CPG's non-sterile compounding labs and to determine if any such improvements impacted student performance. The long-term goal of this work is to further elucidate how pharmaceutics-related concepts may be best incorporated into contemporary Pharm.D. curricula and taught to current student pharmacists.

Methods

MWU-CPG's pharmacy compounding labs are specifically designed to develop the basic skills necessary for the practice of pharmacy compounding and to make the physical pharmacy, dosage form, and pharmaceutical calculations concepts presented in lecture more meaningful by directly applying this knowledge to the preparation of pharmaceutical delivery systems. These course objectives are achieved through a variety of different lab exercises, all of which are centred upon the compounding of a prescription for a particular patient case (Appendix A). Each class of students completes these exercises within one of three different lab sections (~50 students/section) at preassigned tables, which have six-eight compounding stations and their own designated lab instructor. The lab instructors have consisted of a variety of faculty and staff, community pharmacists, and upper level students, who are rotated amongst the lab tables on a week-to-week basis and have a variety of specific duties including assigning weekly lab scores upon the conclusion of each lab based upon the level of each student's timeliness, attire, preparation, completion, and cleanup. This grading is primarily intended to be motivational in nature, and thus, it constitutes only 10% of the overall course grade and almost all students attain an average score of greater than 90%. Answer keys containing detailed explanations for each of the lab exercises are also provided to the students after each lab.

In total, 13 different non-sterile labs take place during MWU-CPG's integrated pharmaceutics course sequence with powders, capsules, suppositories, ointments, solutions, suspensions, and emulsions being the specific dosage forms prepared (Appendix B). Student learning within these labs is formally assessed through two different lab practicals (2.5 hours each); one at the end of Pharmaceutics I and one at the end of the non-sterile products portion of Pharmaceutics II. Each lab practical is worth a total of 100 points and constitutes 22.5% of the overall course grade. The practicals are open-book and each requires the students to compound two different prescriptions, which are similar to those prepared during the corresponding labs. The prescriptions are graded based upon the quality of each student's calculations, compounding procedures, final products, prescription documentation, and prescription labelling. Up to 10 points can be deducted from each of these sections based upon the following scale: 2.5-point deduction for any error deemed legally or professionally unacceptable, 5-point deduction for any error that could potentially cause patient harm, 10-point deduction for not attempting the section. All grading is completed by the course coordinator/instructor to ensure both accuracy and consistency and the graded materials are either returned or made available to the students shortly afterwards to provide additional learning opportunities.

For the classes of 2013-2015, the students received a separate lab packet prior to each lab that required the completion of a series of written pre-lab assignments. These assignments typically included 1) some short background reading to supplement the lecture material relative to the lab exercises; 2) the completion of specific questions such as calculations and procedures in preparation for the hands-on compounding activities; and 3) the completion of additional questions that evaluated the appropriateness of the prescription to be compounded and further applied the lecture material to the lab exercises (i.e. the practice of pharmacy). Each lab section was scheduled for 2.5 hours and began with the lab instructors immediately discussing the completed pre-lab assignments and demonstrating any new techniques applicable to the subsequent compounding activities with their designated group of students using an interactive, question-and-answer format to ensure each student was fully prepared. The students then completed the compounding activities primarily on an individual basis with their designated instructor providing additional evaluation and assistance, as needed.

Table I: Summary of the modifications made to MWU-CPG's non-sterile compounding labs during the current study

Student Cohort	Modifications
Class of 2016	Students started receiving their lab packets and completing the pre-lab assignments at the beginning of each lab, instead of prior to, with their designated lab instructors providing individual guidance, instead of facilitating a group discussion of assignments completed beforehand
Class of 2017	The specific compounding questions and the additional application questions were integrated throughout the pre-lab assignments
Class of 2018	The lab instructors started to once again discuss the completed pre-lab assignments with their designated group of students; this time, just after individually guiding their students' completion of the pre-lab assignments at the beginning of each lab

As noted previously, these students perceived the hands-on compounding activities to be highly beneficial to their learning, while the pre-lab assignments and corresponding group discussions were perceived as being relatively less beneficial (Bowman & Aphaisuwan, 2018). Therefore, over the subsequent three-year period, a series of modifications were made to the non-sterile compounding labs in an attempt to enhance students' perceptions of the pre-lab assignments and corresponding group discussions (Table I). With the Class of 2016, the students started receiving their lab packets at the onset of each lab, instead of prior to. The labs then began with the students immediately completing the pre-lab assignments and their designated lab instructors providing individual guidance, instead of facilitating a group discussion of the assignments completed beforehand. Appropriate references were also provided, and each group of students was allowed to work together; however, they were prevented from utilising any of the past years' answer keys. With the class of 2017, the specific compounding questions and the additional application questions were integrated throughout the pre-lab assignments. With the class of 2018, the lab instructors started to once again discuss the completed pre-lab assignments with their designated group of students; this time, just after individually guiding their students' completion of the pre-lab assignments at the beginning of each lab. This modification required that each lab section also be scheduled for 3 hours, instead of 2.5 hours.

Results

Students' perceptions of their educational experiences within MWU-CPG's non-sterile compounding labs were determined during the current study using the same survey instrument that was utilised during the previous evaluation of the College's integrated pharmaceutics course sequence (Bowman & Aphaisuwan, 2018). The instrument includes a matrix question that asks students to indicate how beneficial each course design element was to their learning using a four-point scale or if an element was not utilised and several open-ended questions that ask students to provide the design element that was most beneficial, the element that was least beneficial, and what should be added to the course sequence to improve student learning. To minimise response burden and maximise the overall response rate, paper copies of the instrument were individually distributed to each student cohort (n=150-152) by the course coordinator as they finished their second lab practical (i.e. completed the non-sterile products portion of the course sequence). Upon distribution, the purpose of the survey was verbally described, and each student was asked to voluntarily and anonymously complete the instrument, directed to submit his/her completed instrument via a collection bin near the exit of the laboratory, and thanked for their participation. Completion of the instrument took ~5-10 minutes and submission served as informed consent to participate in the study.

The collected data were analysed in aggregate using descriptive statistics within Microsoft Excel 2016 (Microsoft, Inc., Redmond, Washington). Statistical analysis was conducted using GraphPad Prism 7 for Mac OS X, Version 7.0d (GraphPad Software, Inc., La Jolla, CA) and consisted of either one-way ANOVA and Tukey's multiple comparisons tests or unpaired, two-tailed, *t*-tests. The overall response rate for each student cohort was 97-99% (n=148-149); however, any instrument containing either no response or multiple responses to an individual course design element was eliminated from the analysis, which resulted in usable response rates of 92-97% (n=140-146). Each lab design element was utilised by 97-100% of respondents (n=138-146), and for ease of evaluation, a mean level of benefit (MLB) was calculated for each design element by assigning a numerical value to each of the utilised response options (i.e. very beneficial=3, beneficial=2, somewhat beneficial=1, and not beneficial=0) (Bowman & Aphaisuwan, 2018). Table II contains the MLBs resulting amongst each student cohort. With respect to the written pre-lab assignments, the MLB amongst the class of 2016 cohort (i.e. completion of the pre-lab assignments at the beginning of each lab, instead of prior to, and elimination of the corresponding group discussions) decreased from 2.3±0.8 to 2.0±1.1 ($p<0.05$); however, the MLB amongst the class of 2017 cohort (i.e. integration of the specific compounding questions and the additional application questions throughout the pre-lab assignments) increased to 2.8±0.6 ($p<0.05$). With respect

Table II: The mean level of benefit for each lab design element amongst each student cohort

Lab Design Element	Mean Level of Benefit* (±SD)			
	Classes of 2013-15† (n=420)	Class of 2016 (n=138-141)	Class of 2017 (n=139-140)	Class of 2018 (n=145-146)
Coordination between Lecture and Lab	2.8±0.4	2.8±0.5	2.9±0.4	2.9±0.4
Pre-Lab Assignments	2.3±0.8‡	2.0±1.1‡	2.8±0.6¶,§	2.8±0.4¶,§
Group Discussions in Lab	2.1±0.9‡	--- ǀ	--- ǀ	2.5±0.7‡
Hands-on Compounding Activities	2.8±0.5	2.8±0.5	2.8±0.5	2.8±0.6
Lab Answer Keys	2.9±0.4	2.9±0.3	3.0±0.4	2.9±0.3
Interactions with Lab Instructors	2.8±0.5	2.8±0.4	2.8±0.5	2.8±0.4
Lab Practicals	2.6±0.6	2.5±0.6	2.7±0.6	2.7±0.6

* calculated by assigning a numerical value to each of the utilised response options (i.e. very beneficial=3, beneficial=2, somewhat beneficial=1, and not beneficial=0)

† (Bowman, 2018)

‡ statistical difference ($p<0.05$) with each of the other student cohorts

¶ statistical difference ($p<0.05$) with the Classes of 2013-15 cohort and with the Class of 2016 cohort

§ no statistical difference ($p>0.05$) between the Class of 2017 cohort and the Class of 2018 cohort

ǀ the lab instructors provided individual guidance, instead of facilitating a group discussion

Table III: The frequency by which each lab design element was provided as a response to the 'most beneficial' and 'least beneficial' open-ended questions amongst each student cohort*

Lab Design Element	'Most Beneficial'				'Least Beneficial'			
	Classes of 2013-15† (n=420)	Class of 2016 (n=141)	Class of 2017 (n=140)	Class of 2018 (n=146)	Classes of 2013-15† (n=420)	Class of 2016 (n=141)	Class of 2017 (n=140)	Class of 2018 (n=146)
Coordination between Lecture and Lab	9.8%	13%	19%	19%	0.2%	0.7%	0.7%	0.7%
Pre-Lab Assignments	0.7%	0.0%	2.0%	0.7%	12%	17%	13%	6.2%
Group Discussions in Lab	1.2%	---‡	---‡	2.1%	5.0%	---‡	---‡	4.1%
Hands-on Compounding Activities	29%	36%	25%	22%	0.0%	3.5%	1.4%	0.0%
Lab Answer Keys	9.8%	10%	7.9%	11%	0.2%	0.0%	0.0%	0.7%
Interactions with Lab Instructors	3.6%	5.7%	1.4%	4.8%	0.5%	0.7%	0.0%	3.4%
Lab Practicals	1.9%	3.5%	4.3%	2.7%	0.2%	2.0%	1.4%	0.7%

* calculated as a percentage relative to the number of useable survey instruments from each cohort

† (Bowman, 2018)

‡ the lab instructors provided individual guidance, instead of facilitating a group discussion

to the corresponding group discussions in lab, the MLB amongst the class of 2018 cohort (i.e. the lab instructors once again discussing the completed pre-lab assignments with their designated group of students) increased from 2.1±0.9 to 2.5±0.7 (p<0.05), while the MLB for the pre-lab assignments remained the same (p>0.05). In addition, the MLBs for each of the other lab design elements remained at >2.5 throughout the current study.

Amongst each student cohort, the responses provided for the 'most beneficial' and 'least beneficial' open-ended questions were tallied based upon their relevance to a particular design element. The percentage of each tally relative to the number of usable survey instruments was then calculated (Table III). Throughout the current study, the frequency by which the pre-lab assignments or the corresponding group discussions was provided as a response to the 'least beneficial' question was greater than the frequency by which each was provided as a response to the 'most beneficial' question, which is opposite to each of the other lab design elements, particularly the hands-on compounding activities. In addition, amongst the class of 2016 cohort, the frequency by which the pre-lab assignments were provided as a response to the 'least beneficial' question increased from 12% to 17%; however, amongst the class of 2017 cohort, the frequency decreased to 13%. Furthermore, amongst the Class of 2018 cohort, the frequency by which the corresponding group discussions were provided as a response to the 'least beneficial' question decreased from 5.0% to 4.1%, while the frequency by which the pre-lab assignments were provided as a response to this question decreased to 6.2%.

The responses provided for the 'what should be added' open-ended question were similarly tallied based upon their relevance to an identified theme, which was established when analogous comments were provided by at least five different respondents. The primary lab-related theme identified during the previous evaluation of the College's integrated pharmaceutics course sequence was 'incorporation of additional lab activities and/or sessions' (n=33) (Bowman, 2018). In comparison, the primary lab-related themes identified during the current study were 'incorporation of additional lab activities and/ or sessions' (n=25) and 'completion and/or review of the pre-lab assignments prior to lab' (n=24).

Student performance within MWU-CPG's non-sterile compounding labs was also evaluated during the current study using the scores from each of the two non-sterile lab practicals (Table IV). The lab practical scores were analysed in aggregate using descriptive statistics within Microsoft Excel 2016 (Microsoft, Inc., Redmond, Washington). Statistical analysis was conducted using GraphPad Prism 7 for Mac OS X, Version 7.0d (GraphPad Software, Inc., La Jolla, CA) and consisted of one-way

ANOVA and Tukey's multiple comparisons tests. The individual scores from the first lab practical ranged from 62.5-100, while the mean scores ranged from 88-90 and were not statistically different (p>0.05). Similarly, the individual scores from the second lab practical ranged from 70-100, while the mean scores ranged from 94-95 and were not statistically different (p>0.05). The MWU-Glendale Institutional Review Board found that this study fulfilled the criteria for exempt review (IRB Code AZ#931).

Table IV: Summary of the non-sterile lab practical scores amongst each student cohort*

	First Lab Practical†			
	Classes of 2013-15 (n=449)	Class of 2016 (n=150)	Class of 2017 (n=151)	Class of 2018 (n=154)
Mean (±SD)	89 (±7)	88 (±6)	90 (±6)	88 (±6)
Maximum	100	97.5	100	100
Minimum	62.5	67.5	62.5	70
	Second Lab Practical†			
	Classes of 2013-15 (n=450)	Class of 2016 (n=150)	Class of 2017 (n=152)	Class of 2018 (n=150)
Mean(±SD)	94 (±4)	94 (±4)	95 (±4)	95 (±5)
Maximum	100	100	100	100
Minimum	75	77.5	77.5	70

* the first lab practical took place at the end of Pharmaceutics I and the second took place at the end of the non-sterile products portion of Pharmaceutics II

†no statistical difference between each of the student cohorts (p>0.05)

Discussion

The initial modification of having MWU-CPG's students receive their lab packets and complete the written pre-lab assignments at the beginning of each non-sterile compounding lab, instead of prior to, was made to prevent the students from simply copying from the past years' answer keys. It should be noted that such copying could also be prevented by changing the labs each year; however, this would significantly increase faculty workload and ultimately not prevent similar peer-to-peer copying. In addition, this modification does not prevent the students from memorising the past answer keys before coming into lab; however, this did not seem to occur to any significant degree during the current study and would still constitute a degree of learning beyond mere copying. Another supposed benefit of making the initial modification was that it would reduce the students' workload outside of class, which seemed to be a contributing factor in some students simply copying from the past keys, particularly as their exam schedules began. However, to allocate sufficient time for the completion of the pre-lab assignments at the beginning of lab, the corresponding group discussions in lab needed to be eliminated. Instead, the lab instructors provided individual guidance to their designated group of students as the pre-lab assignments were being completed. This ultimately affords more control over the learning process and provides the students with an opportunity to have their questions immediately addressed (Kratochwill *et al.*, 2016). As a result, the students appeared to be more engaged with the pre-lab assignments, which seemed to better prepare them for the subsequent hands-on compounding activities. However, the current study findings indicate that the student cohort who initially experienced these modifications actually perceived the pre-lab assignments to be less beneficial to their learning than did the preceding cohort.

This negative change in student perceptions was attributed to the fact that the pre-lab assignments had remained organised in a fashion that separated the specific compounding questions from the additional application questions. This supposition was supported by the lab instructors' observations that many of the students only wanted to complete the compounding questions and hands-on compounding activities while in lab and viewed the application questions simply as 'busy work' that prevented them from leaving once they were 'done', despite regular reminders from the course coordinator/instructor to the contrary. This mindset became particularly evident as the routine of the labs was established and the students' exam schedules began. Such a mindset might be indicative of a learner who simply desires more flexibility to learn on their own schedule and at their own pace (Neville *et al.*, 2015; Kratochwill *et al.*, 2016), but may also be indicative of a leaner who is trying to minimise their effort by simply getting the answers from the keys provided after each lab. In either case, this also placed extra burdens upon the lab instructors, who needed to regularly field student requests to leave prior to the completion of the application questions, deal with irate or annoyed students, and police students who were trying to sneak out of the lab. It should be noted that the lab instructors are able to deduct points from each student's weekly lab score for lack of completion; however, this often creates an uncomfortable situation for some of the instructors as well, especially those who are students themselves. While this issue was somewhat anticipated, it was not initially addressed because there was still some uncertainty about having sufficient time to complete all of the lab exercises and keeping the compounding questions separate from the application questions provided greater flexibility in adjusting the labs, if needed.

Even though the students did end up spending more time in lab than in previous years, the vast majority were able to complete all of the lab exercises within the allotted time. Therefore, the subsequent modification to the non-sterile compounding labs was to integrate the compounding questions and the application questions throughout the pre-lab assignments in order to prevent the students from viewing the application questions simply as 'busy work'. Since the application questions had been designed to evaluate the appropriateness of the prescription to be compounded and further applied the lecture material to the lab exercises, the necessary revisions were completed with relative ease. These revisions have also resulted in the pre-lab assignments having a much better flow, which has enhanced the relevance of the application questions and better guides the students through the appropriate thought processes. As a result, the students seem to no longer view the application questions simply as 'busy work', which has also lessened the extra burdens that had been placed upon the lab instructors. Furthermore, the current study findings indicate that the student cohort who originally experienced this modification perceived the pre-lab assignments to be more beneficial to their learning than did each of the preceding cohorts and to have an MLB on par with each of the other lab design elements. However, a relatively high percentage of these students continued to provide the pre-lab assignments as the design element that was least beneficial to their learning.

This finding was attributed to the fact that a small portion of the students still seemed to focus on the specific compounding questions and hands-on compounding activities considerably more than the additional application questions, which again became particularly evident as the routine of the labs was established and the students' exam schedules began, despite each lab instructor's continual emphasis of the importance of the application questions. In addition, some students seemed to struggle with fully understanding the pre-lab assignments when completing them solely on their own or with the amount of help that each lab instructor could provide solely on an individual basis. It should also be noted that some of the more experienced lab instructors continued to express a preference for facilitating group discussions, particularly since these discussions better enabled the instructors to ensure all of their designated students were 'on the same page' prior to completing the hands-on compounding activities. Therefore, the final modification to the compounding labs was to have the lab instructors once again discuss the completed pre-lab assignments with their designated group of students; this time, just after individually guiding their students' completion of the pre-lab assignments at the beginning of each lab. This also provided the students with an opportunity to once again learn in a peer-to-peer manner. It should be noted that this modification also required each lab section to be scheduled for 3 hours, instead 2.5 hours, which was accommodated within the College's block schedule without much difficulty.

As a result of this modification, the students seem to have a more balanced focus upon the specific compounding questions and hands-on compounding activities and appear to have a fuller understanding of the pre-lab assignments. The students also seem to be more engaged in the corresponding group discussions. Furthermore, the current study findings indicate that the student cohort who experienced the totality of the lab modifications continued to perceive the pre-lab assignments as having a MLB on par with each of the other lab design elements and that a relatively lower percentage of this cohort provided the pre-lab assignments as the design element that was least beneficial to their learning. However, the frequency by which the pre-lab assignments were provided as a response to the 'least beneficial' question was still greater than the frequency by which they were provided as a response to the 'most beneficial' question. The study findings also indicate that the same cohort perceived the corresponding group discussions to be more beneficial to their learning than did the previously evaluated cohort. However, the MLB for the group discussions was still not on par with each of the other lab design elements and the frequency by which the discussions were provided as a response to the 'least beneficial' question was still greater than the frequency by which they were provided as a response to the 'most beneficial' question.

Ultimately, the current study findings demonstrate that the modifications made to the pre-lab assignments and the corresponding group discussions did improve the students' perceptions of how beneficial these design elements were to their learning. It should be noted that these modifications also appear to have had no negative impact upon the students' perceptions of the other lab design elements. However, these improvements did not increase the students' performance on either of the two non-sterile lab practicals. Such a lack of affect may be attributed to the fact that the mean score for each of these assessments was already relatively high (Neville *et al*., 2015). It should also be noted that the modifications made to the pre-lab assignments and the corresponding group discussions did not deteriorate student performance either. Nevertheless, such metrics have been reported to not adequately capture the educational experiences of students alone (McLaughlin *et al*., 2013). For example, students' perceptions appear to have a direct correlation with the degree to which they approach their learning from a meaning orientation and therefore such perceptions have an essential role in assessing and improving educational experiences (Ramsden & Entwistle, 1981; Entwistle *et al*., 1989; Pimparyon *et al*., 2000; Genn, 2001; Mayya & Roff, 2004; Till, 2004; Alotaibi & Youssef, 2013).

The current study findings also confirm those of the previous course evaluation, particularly in that the participating students perceived the hands-on compounding activities to be highly beneficial to their learning (Bowman & Aphaisuwan, 2018). In addition, a small number of respondents in the current study did indicate a preference for completing and/or reviewing the pre-lab assignments prior to lab, with most specifying that this would either help them better prepare for the labs or help them not feel confused or rushed while in lab. Kratochwill *et al*. (2016) also discussed the appreciation students had for being able to learn at their own pace. Achieving this is one of the more challenging aspects of the current approach to the non-sterile compounding labs, as each student needs to complete the pre-lab assignments, corresponding group discussions, and hands-on compounding activities at relatively the same pace. Another significant difficulty that still remains with the labs is a lack of preparation on the part of some students. Similar to the flipped classroom described by McLaughlin *et al*. (2013), students need to learn, or at least review, the appropriate lecture material ahead of time in order to fully engage with the lab exercises. However, despite regular reminders from the course coordinator/instructor, a certain portion of the students consistently neglected to do so, particularly as the routine of the labs was established and the students' exam schedules began. Ultimately, this places an even greater burden upon the lab instructors, who need to provide extra attention to these students while not neglecting the other students within their designated group. A possible solution to this problem may be to institute a quiz regarding the appropriate lecture material at the start of each lab. However, this would require the creation, implementation, and grading of an additional set of assessments, which would significantly increase faculty workload and further lengthen the time needed for each lab section, while placing an even greater emphasis upon grades as a motivator and further raising student stress levels.

Overall, the current study does demonstrate that the educational experiences of the students within MWU-CPG's non-sterile compounding labs were enhanced, which is especially important given the greater scrutiny that the quality of compounded preparations is under (Kochanowska-Karamyan, 2016; Bilger *et al*., 2017; Kosinski *et al*., 2017; Mudit & Alfonso, 2017). However, despite having a relatively large sample size and a relatively high response rate, which are indicative of the effectiveness of the survey methodology employed, the current study is limited to a single course sequence at a sole college of pharmacy and therefore its findings may not be generalisable to the entire student pharmacist population. In addition, while most aspects of the reported lab design should be easily incorporated into a majority of other pharmacy programmes, MWU-CPG does offer a relatively unique Pharm.D. curriculum, which could limit their transferability to other settings. The survey methodology employed may have also introduced collection bias into the study results. Finally, there appears to be some lack of consistency with the degree to which failing students' perceptions correlate with their approaches to learning (Meyer *et al*., 1990; Entwistle *et al*., 1991); however, the current study did not differentiate student perceptions based upon academic performance. Therefore, similar research amongst additional cohorts of student pharmacists is needed.

Despite these limitations, this paper provides valuable insights for others offering pharmacy compounding training or attempting to enhance students' perceptions of their educational experiences within lab-based courses, particularly amongst accelerated pharmacy curricula and non-traditional students, thereby helping to further narrow the perceived gap in the reporting of curricular models for hands-on, face-to-face, compounding instruction (Robertson & Shrewsbury, 2011). The findings of the current study have also helped guide the author's own course improvement efforts. In particular, MWU-CPG's non-sterile compounding labs are currently being revised to incorporate the Pharmacists' Patient Care Process (PPCP) with the intention of improving student understanding of the PPCP and enabling an even greater application of the course material to practice (Joint Commission of Pharmacy Practitioners, 2014). In addition, the non-sterile lab practicals will be subsequently updated to further mirror the written pre-lab assignments with the intent of further improving students' perceptions of both the pre-lab assignments and the corresponding group discussions in lab.

Conclusions

With the quality of compounded preparations being evermore scrutinised, maximising the compounding knowledge and skills of student pharmacists may be more important than ever. In addition, students' perceptions appear to have a direct correlation with the degree to which they approach learning from a meaning orientation. Therefore, several modifications were made to the pharmacy compounding labs within a pharmaceutics course sequence over a three-year period in order to enhance students' perceptions of both their pre-lab assignments and their corresponding group discussions, which had previously been rated as having relatively low levels of benefit towards their learning. The results of this study demonstrate that the combination of having the students complete their pre-lab assignments 'at the beginning of' instead of 'prior to' each lab and ensuring any application questions were fully integrated with the lab activities enhanced their perceptions of not only these assignments, but of their corresponding group discussions as well. While these improvements did not increase the students' performance on either of the lab practicals within the course sequence, this study does provide valuable insights for others offering lab-based pharmacy compounding training and helps to further narrow the perceived gap in the reporting of curricular models for hands-on, face-to-face, compounding instruction.

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References

Alotaibi, G., & Youssef, A. (2013). Development of an assessment tool to measure students' perceptions of respiratory care education programs: item generation, item reduction, and preliminary validation. *Journal of Family and Community Medicine*, **20**(2), 116-122. https://doi.org/10.4103/2230-8229.114770

Bilger, R., Chereson, R., & Salama, N.N. (2017). Should torsion balance technique continue to be taught to pharmacy students? *American Journal of Pharmaceutical Education*, **81**(5), Art. 85. https://doi.org/10.5688/ajpe81585

Bowman, B.J., & Aphaisuwan, H. (2018). An evaluation of student performance and perceptions within an integrated pharmaceutics course sequence. *Currents in Pharmacy Teaching and Learning*, **10**(4), 473-485. https://doi.org/10.1016/j.cptl.2017.12.011

Entwistle, N., Kozeki, B., & Tait, H. (1989). Pupils' perceptions of school and teachers II – relationships with motivation and approaches to learning. *British Journal of Educational Psychology*, **59**, 340-350. https://doi.org/10.1111/j.2044-8279.1989.tb03108.x

Entwistle, N.J., Meyer, J.H.F., & Tait, H. (1991). Student failure: disintegrated patterns of study strategies and perceptions of the learning environment. *Higher Education*, **21**, 249-261. https://doi.org/10.1007/BF00137077

Genn, J.M. (2001). AMME Medical Education Guide No. 23 (Part 2): Curriculum, environment, climate, quality and change in medical education – a unifying perspective. *Medical Teacher*, **23**(5), 445-454. https://doi.org/10.1080/01421590120075661

Joint Commission of Pharmacy Practitioners. (2014). Pharmacist patient care process (online). Available at: https://jcpp.net/wp-content/uploads/2016/03/PatientCareProcess-with-supporting-organizations.pdf. Accessed 5th March, 2019

Kochanowska-Karamyan, A.J. (2016). The oldest, most symbolic, and still vital part of pharmacy. *International Journal of Pharmaceutical Compounding*, **20**(5), 367-374.

Kosinski, T.M., Brown, M.C., Valdovinos, K., & Zavala, P.J. (2017). Acquisition and retention of sterile compounding accuracy skills. *American Journal of Pharmaceutical Education*, **81**(6), Art. 115. https://doi.org/10.5688/ajpe816115

Kratochwill, L., Almagambetova, E., Corigliano, A., Birnie, C., & Chablani, L. (2016). The use of podcast as a teaching tool for a pharmacy compounding pre-laboratory lecture: a survey based study. *Pharmacy Education*, **16**(1), 38-41

Mayya, S.S., & Roff, S. (2004). Students' perceptions of educational environment: a comparison of academic achievers and under-achievers at Kasturba Medical College, India. *Education for Health*, **17**(3), 280-291. https://doi.org/10.1080/13576280400002445

McLaughlin, J.E., Griffin, L.M., Esserman, D.A., Davidson, C.A., Glatt, D.M., Roth, M.T., Gharkholonarehe, N., & Mumper, R.J. (2013). Pharmacy student engagement, performance, and perception in a flipped satellite classroom. *American Journal of Pharmaceutical Education*, **77**(9), Art. 196. https://doi.org/10.5688/ajpe779196

Meyer, J.H.F., Parsons, P., & Dunne, T.T. (1990). Individual study orchestrations and their association with learning outcome. *Higher Education*, **20**, 67-89. https://doi.org/10.1007/BF00162205

Mudit, M. & Alfonso, L. F. (2017). Analytical evaluation of the accuracy and retention of compounding skills among PharmD students. *American Journal of Pharmaceutical Education*, **81**(4), Art. 64. https://doi.org/10.5688/ajpe81464

Neville, M.W., Palmer, R., Elder, D., Fulford, M., Morris, S., & Sappington, K. (2015). Evaluating the effects of flexible learning about aseptic compounding on first-year students in a pharmacy skills laboratory. *American Journal of Pharmaceutical Education*, **79**(6), Art. 91. https://doi.org/10.5688/ajpe79691

Peirce College. (2019). Who are adult learners (online). Available at: https://www.peirce.edu/degrees-programs/additional-resources/adult-learners/who-are-adult-learners. Accessed 17th April, 2020

Pimparyon, P., Roff, S., McAleer, S., Poonchai, B., & Pemba, S. (2000). Educational environment, student approaches to learning and academic achievement in a Thai nursing school. *Medical Teacher*, **22**(4), 359-364. https://doi.org/10.1080/014215900409456

Ramsden, P., & Entwistle, N.J. (1981). Effects of academic departments on students' approaches to studying. *British Journal of Educational Psychology*, **51**, 368-383. https://doi.org/10.1111/j.2044-8279.1981.tb02493.x

Robertson, J.L. & Shrewsbury, R.P. (2011). Video teleconferencing in the compounding laboratory component of a dual-campus doctor of pharmacy program. *American Journal of Pharmaceutical Education*, **75**(9), Art. 181. https://doi.org/10.5688/ajpe759181

Till, H. (2004). Identifying the perceived weakness of a new curriculum by means of the Dundee Ready Education Environment Measure (DREEM) Inventory. *Medical Teacher*, **26**(1), 39-45. https://doi.org/10.1080/01421590310001642948

Appendix A

An example of a pharmacy compounding lab at MWU-CPG

LAB #7

SUPPOSITORIES II

Lab Exercises:

Prior to lab

- Complete the questions for the phenytoin prescription. When needed, use the appropriate references.

At the beginning of lab

- Begin the suppository mold calibration activity; your lab instructor will illustrate an example of overheated cocoa butter.
- Once the suppositories from the suppository mold calibration activity are hardening in the refrigerator, meet with your instructor to discuss the assigned activities as a group.

Complete the suppository mold calibration activity; have a lab instructor verify completion.

Complete the calculations and compounding procedure for the phenytoin prescription. ***(Note: the information determined from the suppository mold calibration activity must be used to complete these items)***

Compound, package, document, and label the prescription for phenytoin. ***Print two labels: one for your write-up and one for your product.***

Have your instructor verify that you have satisfactorily completed the prescription for phenytoin and have cleaned up your laboratory station before leaving.

Suppository Mold Calibration:

Spray a paper towel with a small amount of lubricant, wipe down the inner surface of the aluminum molds, and close the molds

Break the cocoa butter into small pieces and weigh approximately 15-20 g in a 100-mL beaker.

Fill a casserole dish with hot water from the faucet and melt the cocoa butter by occasionally immersing the beaker into the dish and stirring slowly until it softens to an **opaque, creamy liquid**; be sure to change the water often to ensure proper melting, but **DO NOT** overheat the cocoa butter.

Pour the softened cocoa butter into the suppository mold cavities and be sure to overfill each mold cavity with excess cocoa butter ***(fill as many cavities as the quantity of cocoa butter will allow)***; if the cocoa butter hardens before pouring can be completed, simply reimmerse the beaker in hot water to remelt.

Place the mold in the refrigerator for at least 10-15 minutes to harden the suppositories.

Once hardened, scrape any excess cocoa butter from the surface, remove the suppositories, and weigh all of the "perfect" suppositories to calculate their average weight:

- Total weight of the suppositories: _____________
- Number of suppositories weighed: _____________
- Average blank suppository weight: _____________

Case: *FD is a 23 month old, 29.6 lb pediatric patient suffering from seizures.*

Additional Information: *In cocoa butter, the DF for phenytoin is 1.3 and the DF for phenytoin sodium is 1.9.*

Prescription / Documentation / Labeling:

Alyosha Karamozov, MD
110 W. Camelback Road, Phoenix, AZ 85300
(602) 555-5784

Name: Fyodor Dostoyevski **Date: 10/15/12**
Address: 567 N 59th Ave., Glendale, AZ 85308

R_x **Phenytoin 180 mg**
Cocoa Butter qs
M.ft. dtd supp #6

Sig. i pr hs

Refill 4 times

Alyosha Karamozov

Back of the Prescription

Prescription Label Here

Auxiliary Label Here

Auxiliary Label Here

Auxiliary Label Here

Calculations:

Compounding Procedure:

1. Spray a paper towel with a small amount of lubricant, wipe down the inner surface of the aluminum molds, and close the molds.

2. Weigh ________ phenytoin sodium and ________ cocoa butter *(after breaking into smaller pieces)* using a(n) ________________ balance.

3. Place the cocoa butter in a 100-mL beaker and using a hot water bath slowly melt the cocoa butter to an opaque, creamy liquid with gentle stirring.

4. Gently stir the phenytoin sodium into the cocoa butter until uniform.

5. When pourable, quickly pour the mixture into at least ________ mold cavities being sure to fill each cavity with excess mixture.

6. Chill the suppositories until solid (~10-15 min) and scrape off the excess from the tops.

7. Remove the suppositories, wrap in foil, and dispense in a plastic baggie.

Additional Questions:

1. Phenytoin is the active ingredient in which brand name product(s)? In what route(s) of administration / dosage form(s) is(are) the brand name product(s) available? What is the therapeutic category for phenytoin?

   Brand Name Product(s):

   Route(s) of Administration / Dosage Form(s):

   Therapeutic Category:

2. Which of the products indicated in your response to question #1 contain phenytoin as the sodium salt? Which contain the free acid form?

3. For the products that contain phenytoin as the sodium salt, determine the amount of phenytoin within each of the products:

4. What is the concern with switching a patient from a product containing the sodium salt form to a product containing the free acid form, or visa versa?

5. What is a potential advantage of preparing the commercially-available products using the free acid form?

6. Is the prescribed dosage form appropriate for this patient? (why/why not?) What are the advantages and disadvantages of this dosage form compared to the commercially available forms?

7. What are the uses for the excipient(s) used to compound the prescription?

8. Why should cocoa butter be used instead of PEG to compound this product?

9. Why should the sodium salt form of phenytoin be used to compound this prescription?

10. Based upon the given density factor, which has a greater density, phenytoin sodium or cocoa butter?

Appendix B

Outline of the activities included within the non-sterile compounding lab portions of MWU-CPG's Pharmaceutics I & II courses

Pharmaceutics I	Lab #1	Prescription Interpretation, Basic Calculations, and References	1) translate the subscription and signa portions of prescription drug orders 2) complete pharmaceutical calculations involving fundamental mathematical skills, systems of units, expressions of concentration, and general dosing 3) locate appropriate information via key pharmaceutical resources
	Lab #2	Prescription Documentation & Labelling and Metrology of Solids	1) document the filling of prescription drug orders 2) prepare prescription labels 3) complete pharmaceutical calculations involving least weighable quantity, percentage error, and the aliquot method 4) use and care for prescription and electronic balances
	Lab #3	Powders	1) handle and weigh powders 2) blend powders via geometric dilution by trituration 3) prepare a divided powder
	Lab #4	Capsules I	1) experimentally determine the capsule capacity of a common pharmaceutical excipient 2) prepare capsules via the punch method
	Lab #5	Capsules II	1) prepare capsules using manufactured tablets as an ingredient source 2) participate in a demonstration of hand-operated capsule-filling machines
	Lab #6	Suppositories I	1) prepare PEG suppositories via the double-casting method 2) wrap suppositories in foil
	Lab #7	Suppositories II	1) calibrate a non-disposable suppository mold using a common base 2) prepare cocoa butter suppositories

	Lab #8	Ointments I	1) prepare an ointment base via fusion with emulsification 2) prepare an ointment via spatulation using a eutectic mixture 3) package an ointment within an ointment jar
	Lab #9	Ointments II	1) prepare an ointment using an official USP formulation containing both solid and liquid ingredients 2) participate in a demonstration of unguators and ointment mills
Pharmaceutics II	Lab #1	Solutions I	1) handle and measure liquids via both cylindrical and conical graduated cylinders 2) prepare a syrup vehicle using an appropriate flavoring 3) prepare an electrolyte solution 4) evaluate various measuring devises for dosing accuracy
	Lab #2	Solutions II	1) calibrate a medicine dropper 2) complete a liquid aliquot 3) prepare a solution using a co-solvent system
	Lab #3	Suspensions	1) prepare a pediatric suspension via levigation
	Lab #4	Emulsions	1) prepare an emulsion via the dry gum method 2) prepare an emulsion using a span/tween mixture