Original Research Article

Enhancing Learning Methodologies in the Clinical Pharmacokinetic Course Through Student-Driven Insights and Suggestions

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ABSTRACT

The clinical pharmacokinetics (CPK) course can be quite challenging and difficult for students to understand its applications, as it involves a combination of abstract yet complex concepts and mathematical calculations. Studies have reported that the conventional lecture-based learning process in CPK often results in a poor understanding, especially when it comes to apply the knowledge to real cases. This study aimed to identify strategies to improve the current learning methodology by using self-developed, validated online questionnaires among 37 fourth-year undergraduate pharmacy students who failed their CPK course in mid-semester test at UiTM Puncak Alam, Selangor. We analysed and interpreted the data through descriptive analysis. The majority of students (91.9%) found online quizzes to be the most engaging tool for learning CPK, with 89.2% choosing to include feedback and marks for their answers. Most of them preferred new learning materials that covered both basic concepts and applications-based (86.5%), featuring colourful pictures and diagram interfaces (70.3%) and being accessible anytime and anywhere (83.8%). These preferences have proven to be more effective in enhancing knowledge. The students understood the topics better, which helped improve their engagement and grades. While developing and incorporating educational games into the current CPK course can be time-consuming, the results can be tremendous, transforming the current pharmacy curriculum into something more innovative and fun. Further research related to the development and implementation of alternative learning materials based on these preferences can be conducted to assess its effectiveness in improving students' performance. Therefore, it is crucial to incorporate the insights of students when enhancing the current learning methodology in the future.

Keywords: Clinical pharmacokinetics, learning methodology, pharmacy student, suggestion, improvement
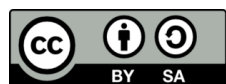
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1.0 Introduction

According to the American Pharmaceutical Association, pharmacokinetics (PK) is the study of how drugs are absorbed, distributed, metabolised and eliminated (ADME) in humans and animals, as well as their effects on health and disease. A drug attains therapeutic benefit when it reaches a specific therapeutic level range while staying below the toxicity threshold (1). Clinical pharmacokinetics (CPK) is the application of the above-mentioned principles to clinical practice and patient management with the intention of producing a safe, effective, and individualized pharmacotherapy plan (2). Clinical pharmacokinetics (CPK) encompasses a variety of practices, such as measuring bioavailability, assessing the effects of physiological and pathological conditions on drug disposition and absorption, and calculating dosage adjustments for certain diseases, when necessary, all of which are further correlated with the drug's pharmacological response. Furthermore, we can utilize this pharmacokinetic parameter information to individualize drug dosing regimens, evaluate drug interactions, and make clinical predictions, ensuring the most effective and safe drug therapy (1).

Higher learning institutions should introduce the basic concept and knowledge of CPK early due to its critical role in achieving positive patient therapeutic outcomes. The Accreditation Council for Pharmacy Education (ACPE) has constructed accreditation standards for professional degree programs in pharmacy that describe various elements required for continuous quality-assured professional education and improvement. The ACPE mandates the Pre-Advanced Pharmacy Practice Experience (Pre-APPE) Curriculum, a standard that integrates a didactic content element from multiple disciplines, including CPK, into individual or integrated courses (3). However, most students do not really favour these courses due to the complexity of the content, and due to its mathematically intensive nature, they deemed it a difficult subject to grasp (4).

Generally, teaching and learning methodologies play a key role in education by facilitating students' learning processes and encouraging them to learn more effectively (5). Moderate educational systems expect learners to demonstrate increasing autonomy and initiative in learning activities, such as evaluating learning materials and comprehending information (6). Students' ability to initiate, coordinate, and manage the information search as well as its subsequent processing and storage makes it possible for effective knowledge growth both within and beyond the school. Therefore, we need teaching methodologies to assist and guide students in enhancing their learning and comprehension. Each teaching methodology must be able to emphasize the skills required by students to learn new things independently and continuously on their own in order to keep their knowledge up-to-date (7).

Many universities teach pharmacokinetics using a multi-disciplinary and integrated approach, introducing first-year students to the basic concepts and theory of CPK within the realms of pharmacology, with a focus on basic concepts of ADME. In their second year, the curriculum will concentrate on formulating pharmaceutical dosage forms to enhance bioavailability using compartment and non-compartmental analysis equations. In the third and fourth years, students will apply their CPK knowledge to optimize medicines for their respective therapeutic goals through the use of therapeutic drug monitoring (TDM) computations. Nonetheless, the overall teaching processes are comprehended in a conventional manner between different streams, levels, and courses. The teaching of similar concepts from different perspectives in pharmacology, pharmaceutics,

and clinical pharmacy may cause a degree of confusion. Furthermore, research indicates that the traditional lecture-based learning approach in CPK results in inadequate comprehension, particularly when it comes to applying PK data to real-world scenarios, given that modern teaching methods no longer merely involve lecturing students and reciting brief notes (8).

According to Swanson et al. (2014) (9), the use of graphical representations, mathematical calculations, and problem sets can considerably improve the student's knowledge of pharmacokinetics and pharmacodynamics, correspondingly making them highly applicable to active-learning exercises (9). Thus, many innovations or initiatives have been taken to facilitate students' better understanding in a clinical sense and assist them in having fun and interactive learning in difficult courses, such as CPK. Therefore, the aim of this study is to gather suggestions from students regarding potential enhancements to the current learning methodology of the CPK courses. The findings of this study will provide a new insight into preferred alternative learning materials for the students in the CPK course. It has the potential to enhance their learning experiences, enhance their memorization skills, and deepen their understanding of basic concepts and applications, all while encouraging students to remain engaged in this challenging course. Additionally, it can serve as a guide to create more engaging learning tools, enabling students to apply their knowledge and confidently confront real-life clinical settings without compromising patient safety.

2.0 Materials and methods

2.1 Design of the study

This is a prospective cohort study conducted among fourth-year undergraduate pharmacy students (intake 2019) who failed their mid-semester test in the CPK course. Bloom's Taxonomy (10-13) classifies the mid-semester test into two categories: remembering (C1) and understanding (C2). We categorize students as passed if they obtained 10 marks or above in the test, and as failed if their marks fell below 10. We chose those who failed their midterm test because this study aimed to improve students' understanding by building strong foundational knowledge and enhancing their ability to apply the facts and formulas in the CPK course. Therefore, the researcher could gain a deeper understanding of what is lacking in the current learning methodology and offer their opinions on how to improve it.

2.2 Sampling and sample size

The Raosoft® Sample Size Calculator calculates the required sample size for this study, which is at least 36 respondents from a population of 39 students who failed their mid-semester test in the CPK course. This calculator helps determine the optimal sample size for the online survey based on margin of error, confidence level, population size, and response distribution. We implemented a 95% confidence level, a 5% margin of error, and a 50% response distribution for this study. We identified these students using the UiTM e-Result Exam System (e-RES). Out of these 39 students, two declined to participate in the study and did not consent and do not complete the questionnaires. The final respondents of this study are 37 students.

2.3 Study instrument and procedure

The investigators used a self-developed, validated online questionnaire to gather data on students' opinions about potential improvements to the current learning methodology in the CPK course (Appendix

1). Five academicians involved in teaching CPK validated the questionnaire. This questionnaire consists of two parts. Part A is the beginning of the questionnaire, which focused on the consent of students to participate in this research project. Once we obtain the students' consent, they can move on to Part B of the questionnaire, which comprises 3 open-ended and 5 multiple-choice questions. Initially, the study procedure identified and screened a total of 173 fourth-year undergraduate pharmacy students for eligibility. Out of these, approximately 39 students met the inclusion criteria, having failed the mid-semester test of the CPK course. The Google Form platform then distributes the questionnaire to them, which they must complete. During this process, they have the option to select multiple answers in Part B, with the exception of questions 2 and 3. Figure 1 summarizes and presents the complete procedure.

2.4 Ethical considerations

The Faculty Ethics Review Committee (FREC) at Universiti Teknologi MARA (UiTM) granted ethics approval with reference number REC (PH)/UG/042/2023.

2.5 Data statistical analysis

We used IBM® Statistical Package for Social Sciences version 29 to perform all statistical analysis in this study. We further evaluated the collected responses using descriptive analysis to understand students' perspectives on current methodologies. We calculated descriptive statistics to summarise the data. We interpreted, quantified, presented, and tabulated the frequency of all-choice survey items as numbers and percentages in their respective tables.
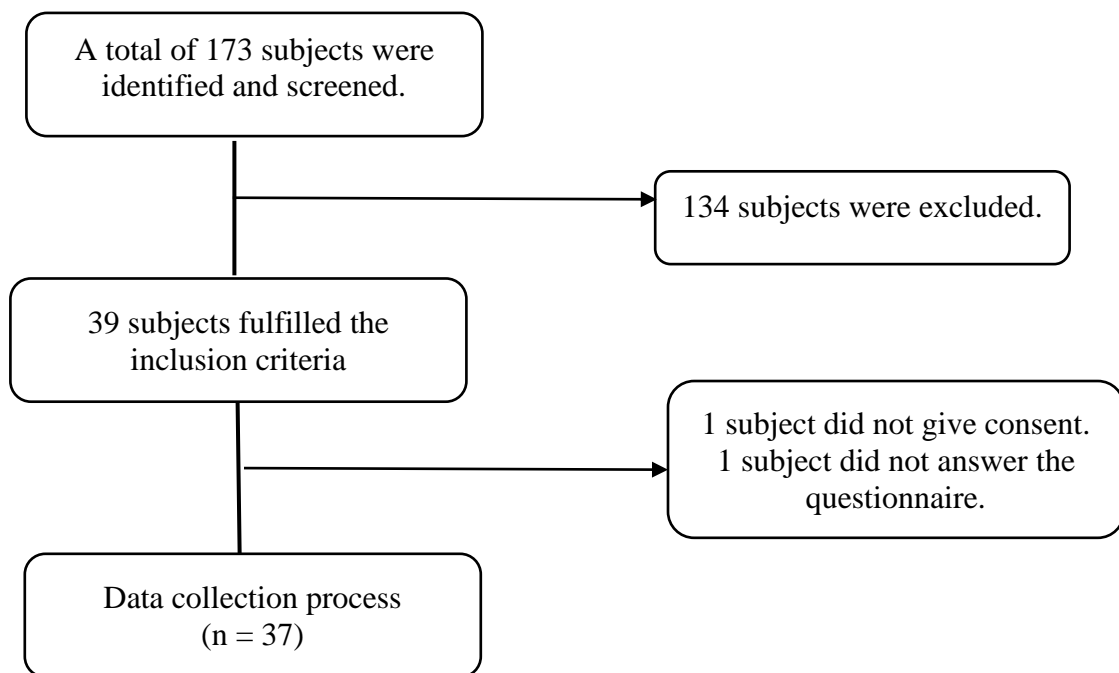

Figure 1: Study Flow Diagram

3.0 Results

In this study, the final respondents are 37 out of 39 selected fourth-year students who answered the questionnaire, with a response rate of 94.87%. Two students declined to participate in this study and did not respond to the questions. Table 1 tabulated the survey results, revealing that the majority of students (91.9%) selected online quizzes like Quizzizz, Kahoot!, and ProProfs as the most engaging interactive tools for learning CPK, followed by flashcards (56.8%), board games (29.7%), and case studies (2.7%). 89.2% of them preferred to include both feedback and marks for answers in the new learning materials, if applicable, while only 8.1% preferred to include marks for answers or feedback on their performances. Additionally, 32 students (86.5%) expressed their preference for the content in the preferred learning methodologies to encompass both basic and application-based concepts, whereas the remaining students (8.1% and 2.7%, respectively) preferred the content to focus primarily on either application-based or basic concepts.

Students also had the option to select the preferred interface type for the learning materials. The majority of them chose to include more colourful pictures and diagrams in the new learning materials (70.3%), followed by listing the references used in the materials (56.8%) and supplementing more notes or words on the topic (51.4%). One student chose to include tutorial questions and discussions in the new learning materials (2.7%). Finally, 83.8% of the students believed that the ideal characteristic of learning materials was easy access, without any restrictions on time or location. Many students believe that the ideal new learning material should provide a clear description and information on the topic (78.4%), allow for reference with complete notes (75.7%), and simplify all important information (67.6%). Thus, it can be concluded that online quizzes, getting feedback and marks, colourful pictures and diagrams, and easy access to the materials were the most preferred by the students to be included in the new learning materials.

In the open-response questions aimed at improving the students' learning experience in the CPK course, the majority of students suggested adding more tutorials, exercises, and examples to enhance their learning experience. Table 2 summarizes additional examples of responses. The researcher also delved into the potential challenges that could hinder the students' performance in their mid-semester exam for the CPK course. Their comments included, lack of understanding towards the theories and basic concepts, calculations and their applications, limited time to revise and study topics, confusion to apply formulas for particular drugs in specific cases, and many more.

Table 1: Students' choices in designing new learning materials for the CPK course.

Choice Survey Items	n (%) [a]
1. Which interactive tools do you think is the most interesting method to learn CPK?	
Online quizzes (e.g. Google Form, Kahoot!, ProProfs, Quizizz)	34 (91.9)
Flashcards	21 (56.8)
Board Games (e.g. Monopoly, snake ladder, Saidina)	11 (29.7)
Case Study	1 (2.7)

2. Which methods do you prefer to be included in the learning material if applicable?	
Both feedback and marks for answers	33 (89.2)
Marks for your answers	3 (8.1)
Feedback on your performance	1 (2.7)
3. Which content do you prefer to be included in the development of new learning material?	
Covers both basic concept and application-based in new material	33 (89.2)
More application-based instead of basic theory	3 (8.1)
Focuses on the basic concept of CPK only	1 (2.7)
4. Which interface do you prefer to be included in the development of the new learning material?	
More colourful pictures and diagrams	26 (70.3)
Include the reference so that you can refer to it later on	21 (56.8)
More notes/words on the topic	19 (51.4)
Others (Tutorial Qs with discussion)	1 (2.7)
5. What do you think is the ideal characteristics for learning material?	
Easy to access anytime and anywhere	31 (83.8)
Has a clear description and information on the topic	29 (78.4)
Can be referred with complete notes on the topic	28 (75.7)
All important information is compiled in a simplified form	25 (67.6)

[a] Participants can provide more than one response and therefore responses do not add up to 100%.

Table 2: Summary of students' suggestions on improving learning material and the challenges that they faced during the mid-semester test of the CPK course.

Questions	Exemplar Comments
1. What is your suggestion(s) to improve learning experience in CPK course?	• Modification of case-based learning. • More tutorials, exercises, simplified notes, examples of cases and discussions to familiarize with the clinical applications of the topic. • The use of interactive tool (e.g., Kahoot!). • Doing tutorials in a small group. • Providing the answer scheme for the tutorials. • Early access to the tutorial questions (e.g., at least 2 days before the class).

2. What is the challenge(s) that you faced during the mid-semester test that may have caused you to fail it?	• Lack of understanding towards the theories and basic concept, calculations and its applications. • Feeling overwhelmed as there are many things to catch up with (e.g., busy with Final Year Project and classes). • Limited time to revise and study the topics. • Access to past year questions is restricted to the students. • Confusion on applying formulas for drugs in specific cases. • Pace of the discussion conducted in class is too fast. Forgetfulness (e.g. forget the formula, took more time to memorise compared to other students). • Lack of time management skills (e.g. last-minute study for the test). • Lack of exercises based on topics taught in the course. • Lack of engagement with friends and lecturer because of ODL. • Lack of formulas that are being provided in the appendix during the test.

4.0 Discussion

Various innovations, such as simulations and gamified quizzes, have facilitated students' learning processes in higher education (9, 14-29). The intent of this research study was to identify students' suggestions for improving the current learning methodology in the CPK course. A recent study revealed that students frequently struggled to sustain their focus on the presented material, whether in a physical or online learning environment (30). Overflowing content in the provided materials can exhaust students, leading them to divert their attention to other distractions like social applications or the Internet, in an attempt to alleviate the boredom or stress they experience in the classroom (30, 31). Hence, fun and interactive game-based materials can improve students' engagement, commitment, and motivation, as well as their knowledge and skills (25-27, 31-33). Souza and Kasseboehmer (2021) (26) supported this statement, as they agreed that educational games are considered ways to promote an active and cooperative learning approach, increasing motivation and maintaining students' attention. Despite numerous promising claims about educational games,

their effectiveness may not be uniform across all educational settings or student populations. There is a lack of empirical evidence, leading to a discrepancy between theoretical assertions and empirical demonstrations (34).

The questionnaire results revealed that students primarily selected online quizzes, feedback and marks, colourful pictures and diagrams, and easy access to materials for inclusion in their new learning materials. The previous study conducted a similar survey among students to evaluate their perceptions of learning via gamified online quizzes (27). Students who participated in their study reported high agreement on statements similar to those in this study's survey (27). The students agreed that the online quizzes were more enjoyable than the traditional method and suggesting that the online quizzes were more effective in enhancing their learning (27).

Furthermore, they agreed that the speed and accuracy reward system in the quiz may have enhanced their learning process (27). Conversely, our interactive quiz lacks a reward system that allows students to view their scores and rankings based on speed and accuracy. However, it provides students with immediate feedback on whether they

answered the questions correctly or incorrectly, which is essentially comparable. Both studies provided immediate feedback on the students' answers. Therefore, they can improve their understanding further of the topics and revise much faster compared to waiting for feedback from their lecturers on their answers, which is time-consuming. In addition, they concurred that the flexibility of online quizzes was beneficial for their learning process (27), which aligns with the high preference of students in this study for easy access to new learning materials. As for the colorful pictures and diagrams, Martinez *et al*. (2021) (35) reported higher engagement and grades from students who used colors to design their mind maps compared to those who did not use them. These findings suggest that students prefer colourful pictures and diagrams, as they enhance their engagement. Furthermore, it can aid students in recalling older memories more effectively than traditional methods (36).

In terms of the interactive quiz, it can be a valuable tool that allows students to recall information more effectively, as the recalling process plays a fundamental part of teaching and learning in medical and health courses (37). Castillo-Cuesta (2022) (38) attempted a similar approach in a different course, using Genially to improve students' English for Foreign Language (EFL) reading and writing skills. His findings showed that the implementation of Genially Games increased the post-test scores of the experimental group compared to the control group. Wilkinson et al. (37) conducted another research study to investigate the benefits of smartphone quiz games as 'last-minute' revision tools for students' achievement. They obtained the same results after repeating the study over two different academic years, which might indicate the effectiveness of the gameplay in improving students' performance (37). The students can benefit from the repetitive formative testing through gamification elements, which contribute to higher engagement in the topic (37). From their interviews with the participants, they discovered that most students have positive perceptions of using quiz games for learning, citing their high level of interaction, accuracy in recall, ease of memorization, fun, and enjoyment (37). It was also consistent with studies by Delfino (2019) (39) and Lei *et al*. (2018) (40), where they found a positive correlation between all dimensions of engagement (behavioural, emotional, and cognitive) with academic performance, where the more engaged the students are, the higher their academic performance (40).

Medical fields widely use mind maps because they require students to memorise extensive information (35). Martinez *et al*. (2021) (35) mandated weekly assignments involving mind maps for students who participated in their study, which in turn contributed to their final grade. They actually found no significant difference between the mean scores of the control and intervention groups (35). However, they noticed a shift in the peak of the grade distribution histogram towards higher scores, indicating that the mind map positively impacts students' learning in a more uniform and harmonious manner (35). Moreover, this concept proves to be highly effective in organizing large volumes of information. By connecting various knowledge points together and branching from the main point, this concept may help students enhance their memory recall and improve their thinking divergence (36). Thus, students can present more progressive and sequential relationships between knowledge points more clearly and recall older memories more efficiently compared to conventional methods (36). Guo *et al*. (2021) (41) also support this, stating that effective use of mind maps can diversify the way of thinking, cultivate creative thinking, make the thinking process more active, and

improve the ability to analyse and solve problems.

Pharmacy students still need critical thinking skills in their professional activities, despite the emphasis on memorisation in their courses. Therefore, during medical training, mind maps can enhance both critical and memorisation skills. However, researchers noted that there is no significant evidence to support the long-term influence of this intervention on the learning process (35). Shete *et al.* (2017) (42) reported similar findings, observing no significant difference in the examination scores between the mind map and usual study technique groups. Thus, they concluded that mind mapping was not superior compared to other conventional study methods as a short-term learning tool for a newly trained population, though it still had potential as an educational tool (42). Nevertheless, most of the students in the mind-mapping group perceived the methods as a useful way to summarize the information they inquired about and memorize it in an organized manner (42).

5.0 Conclusion

This study aimed to identify student suggestions for improving the current learning methodology in the CPK course. We found that the new learning methodology should incorporate online quizzes, provide feedback and marks, cover both basic and clinical-based concepts, use colourful pictures and diagrams, and facilitate easy access to the materials. When evaluating the effectiveness of the current learning methodology, it is crucial to consider the students' suggestions and perspectives, as they play a significant role in enhancing the effectiveness of the learning processes.

Authorship contribution statement

NWZ: supervision, main idea, methodology. **NNIN**: methodology, formal analysis, writing – draft corrections. **NST**: writing – review & editing, formal analysis. **NEAH**: supervision, writing – review and editing, methodology.

Acknowledgment

Conflict of Interest

The authors declare no conflict of interest

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