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Investigating the Effects of Pharmacology Flashcards on Academic Achievement and Attitudes in Medical Students

Tıp Fakültesi Öğrencilerinde Farmakoloji Bilgi Kartlarının Akademik Başarı ve Tutum Üzerine Etkilerinin İncelenmesi

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Abstract

Aim: This study aimed to evaluate the impact of student-generated pharmacology flashcards on academic achievement and attitudes towards the pharmacology course among medical students. The study specifically investigated whether flashcard use improves pharmacology grades and fosters more positive perceptions of the subject.

Methods: This cross-sectional study involved 202 third-year medical students at a state university. Participation in the flashcard application was voluntary, with 66 students engaging in five collaborative sessions to create and review 100 flashcards based on pharmacology course material. The remaining 136 students attended standard lectures only. Academic performance was measured using semester 3 board 5 exam scores, final grades, and grade point average (GPA). Attitudes towards pharmacology were assessed using the Attitude Scale of Medical School Students Towards Pharmacology Course. The Mann-Whitney U test was used to compare academic and attitudinal outcomes between the two groups.

Results: Flashcard participants achieved higher scores in semester 3 board 5 exams ($p<.05$), final grades ($p<.05$), and GPA ($p<.05$), and demonstrated more positive attitudes towards pharmacology, scoring higher on the 'pharmacology as an indispensable course' subscale ($p<.05$) and lower on the 'useless course pharmacology' subscale ($p<.05$). Collaborative flashcard creation was associated with active engagement, improved knowledge retention, and more favorable perceptions of pharmacology. However, the general academic performance of participants before the intervention suggests potential self-

selection bias, as motivated and academically inclined students were more likely to participate.

Conclusions: Pharmacology flashcards were shown to enhance academic performance and foster positive attitudes towards the subject, indicating their potential as a valuable tool in medical education. The collaborative, student-driven approach promoted active learning and peer interaction, enhancing both knowledge retention and engagement. These findings support the integration of flashcard-based activities into medical curricula to improve learning outcomes and perceptions of pharmacology. Future research should address the limitations of self-selection bias and single-institution scope while exploring long-term effects and applications across diverse educational settings.

ÖZET

Amaç: Bu çalışma, tıp öğrencilerinin hazırladığı farmakoloji bilgi kartlarının akademik başarı ve farmakoloji dersine yönelik tutumlar üzerindeki etkisini değerlendirmeyi amaçlamıştır. Çalışmada, bilgi kartı kullanımının farmakoloji notlarını iyileştirip iyileştirmediği ve derse yönelik daha olumlu algılar oluşturup oluşturmadığı incelenmiştir.

Yöntem: Bu kesitsel çalışma, bir devlet üniversitesinde okuyan 202 üçüncü sınıf tıp öğrencisini kapsamaktadır. Bilgi kartı uygulamasına katılım gönüllülük esasına dayalıdır; 66 öğrenci, farmakoloji ders içeriğine dayalı olarak 100 bilgi kartı oluşturup gözden geçirmek için beş işbirlikçi oturuma katılmıştır. Geriye kalan 136 öğrenci yalnızca standart derslere katılmıştır. Akademik başarı, üçüncü dönem 5. kurul sınavı puanları, dönem sonu final notları ve genel başarı ortalamaları kullanılarak ölçülmüştür. Farmakolojiye yönelik tutumlar, Tıp Fakültesi Öğrencilerinin Farmakoloji Dersine Yönelik Tutum Ölçeği ile değerlendirilmiştir. İki grup arasındaki akademik ve tutumsal sonuçları karşılaştırmak için Mann-Whitney U testi kullanılmıştır.

Bulgular: Bilgi kartı oturumlarına katılan öğrenciler, 3. dönem 5. kurul sınavı ($p<.05$), dönem sonu final notları ($p<.05$) ve genel başarı ortalamalarında ($p<.05$) bilgi kartı kullanmayan öğrencilere göre anlamlı olarak daha yüksek puanlar almıştır. Katılımcılar ayrıca daha olumlu tutumlar sergilemiş, "farmakoloji tıp eğitiminde vazgeçilmez bir derstir" alt boyutunda daha yüksek puan ($p<.05$) ve "farmakoloji gereksiz bir derstir" alt boyutunda daha düşük puan ($p<.05$) elde etmişlerdir. İşbirlikçi bilgi kartı hazırlama sürecinin aktif katılım, bilgi kalıcılığı ve farmakolojiye yönelik daha olumlu algılarla ilişkilendirildiği bulunmuştur. Ancak, katılımcıların müdahale öncesindeki genel akademik performansı, daha motive ve akademik açıdan yetkin öğrencilerin bu çalışmaya katılma olasılığının daha yüksek olduğunu göstererek potansiyel bir kendi kendine seçim yanlılığına işaret etmektedir.

Sonuç: Farmakoloji bilgi kartlarının akademik başarıyı artırdığı ve derse yönelik olumlu tutumları teşvik ettiği gösterilmiş, bu da onların tıp eğitiminde değerli bir araç olarak potansiyelini ortaya koymuştur. İşbirlikçi, öğrenci odaklı yaklaşım, hem bilgi kalıcılığını hem de katılımı artırarak aktif öğrenmeyi ve akran etkileşimini desteklemiştir. Bu bulgular, farmakoloji dersine yönelik öğrenme çıktıları ve algıları iyileştirmek için bilgi kartı tabanlı etkinliklerin tıp müfredatına entegre edilmesini desteklemektedir. Gelecekteki araştırmalar, kendi kendine seçim yanlılığı ve tek kurumla sınırlı olmanın getirdiği kısıtlamaları ele almalı ve uzun vadeli etkiler ile çeşitli eğitim ortamlarındaki uygulamalarını içermelidir.

INTRODUCTION

Pharmacology serves as a cornerstone of medical education by providing essential knowledge for safe and effective medication prescribing and patient care. A deep understanding of drug mechanisms, interactions, and therapeutic applications is crucial for future healthcare professionals to make informed clinical decisions and contribute to positive patient outcomes. However, traditional pharmacology education, often relying heavily on lectures and rote memorization (1), may not effectively foster the critical thinking and problem-solving skills essential for clinical practice (2). This passive learning approach can lead to superficial understanding and poor retention of complex pharmacological concepts. Furthermore, the sheer volume of information presented in pharmacology courses can overwhelm students, contributing to less favorable perceptions and decreased motivation. To address these challenges, educators are increasingly exploring active learning strategies

that promote student engagement and integrate theoretical knowledge with practical application (2,3). Among these strategies, flashcards have emerged as a promising tool for enhancing learning outcomes and fostering a more positive learning experience. Given the critical role of pharmacology in shaping clinical competencies, identifying and implementing effective teaching tools like flashcards is essential for equipping future healthcare professionals with the knowledge and skills necessary to provide optimal patient care. This study investigates the impact of student-created pharmacology flashcards on academic performance and student attitudes towards the subject. While flashcards offer promise as an active learning tool, their effectiveness can be influenced by multiple factors, including self-selection bias (4,5). Students who voluntarily engage in such interventions are often more motivated and academically inclined, potentially skewing outcomes in favor of the intervention. Addressing this limitation is crucial to accurately assess the impact of flashcards on both academic performance and student attitudes. Flashcards are educational tools consisting of cards displaying information, such as terms, concepts, or questions on one side, and corresponding answers or explanations on the other. They facilitate memorization through active recall and spaced repetition, where learners review material at increasing intervals to strengthen memory retention (4). This active learning approach contrasts with passive methods like traditional lectures, potentially leading to deeper understanding and improved knowledge retention. The use of flashcards is common in medical education, particularly for memorization-intensive subjects like pharmacology. While students often perceive flashcards as helpful for visual learning and knowledge retention, their impact on academic outcomes, especially in pharmacology, remains unclear. This ambiguity stems from the complex interplay of factors influencing academic performance, including learning styles, assessment methods, and prior academic achievement (6–9). Despite their widespread use, research on flashcard effectiveness in pharmacology has shown inconsistent results. Some studies report no significant impact on exam performance in pharmacology courses (10,11), while others demonstrate positive associations with knowledge retention and conceptual understanding (4,12). Kruidering-Hall & Tuan (10) found that while flashcards did not significantly improve pharmacology exam scores, they helped reduce stress and fostered conceptual learning. Similarly, Lampe et al. (11) reported that flashcards failed to produce measurable improvements in exam outcomes for pharmacology topics. In contrast, Santos-Ferreira et al. (4) highlighted that digital flashcards, when used consistently, significantly improved knowledge retention in physiology, a discipline closely linked to pharmacology. Furthermore, Byers et al. (5) emphasized that the effectiveness of flashcards and other innovative learning tools is enhanced when integrated into interactive and supportive learning environments. These findings suggest that variations in study designs, implementation methods, and the specific educational context likely contribute to the discrepancies observed in literature. The mixed findings regarding flashcard efficacy in pharmacology underline the need for a focused investigation into their impact within this domain. Furthermore, understanding how flashcards influence student attitudes towards pharmacology is crucial, as favorable attitudes can enhance motivation and engagement with the subject. By addressing both academic performance and attitudinal changes, this study aims to provide a nuanced understanding of the role of flashcards in pharmacology education. Furthermore, the impact of flashcards on student attitudes towards pharmacology is also ambiguous. While Sun et al. (12) report positive student perceptions of flashcards as a helpful and stress-reducing revision tool, Lampe et al. (11) suggest that practical experiences like clinical attachments and clerkships may have a more profound influence on student attitudes. This difference in impact may be attributed to the immersive nature of clinical experiences, which provide real-world context and direct patient interaction, potentially fostering deeper engagement with the subject matter. This raises the question of whether flashcards primarily affect how students study or also influence their overall engagement and interest in the subject matter. Specifically, it remains unclear whether the perceived benefits of flashcards translate into genuine enthusiasm for pharmacology or simply represent a preference for a particular study method.

Despite their popularity, the effects of flashcards on academic performance and student attitudes in challenging subjects like pharmacology remain underexplored. This knowledge gap is significant because understanding the effectiveness of learning tools is crucial for optimizing medical education. This study aims to address these gaps by investigating the relationship between pharmacology flashcard use, academic performance in pharmacology courses, and student attitudes towards pharmacology. We hypothesize that consistent use of pharmacology flashcards will correlate with both improved pharmacology grades and more favorable student attitudes towards the subject. By examining both performance and attitudinal outcomes, this study seeks to provide a comprehensive assessment of the role of flashcards in pharmacology education. This research contributes to discussions on effective learning strategies in medical education and provides insights into the potential of flashcards to enhance academic outcomes and student engagement in pharmacology.

METHODS

This study is a cross-sectional study to compare the attitudes towards pharmacology course and academic achievement of students who participated and did not participate in flash card application among semester 3 students studying at a state university medical faculty.

Participants

There are a total of 202 students in semester 3. It was announced to the students that the pharmacology courses within the scope of the semester 3 board 5 course would be taught with flash cards as an extracurricular activity and that participation would be voluntary. 66 students voluntarily participated in the flash card application as an extracurricular activity. The remaining 136 students only attended the courses within the scope of the training program. Therefore, 66 students participated in the flash card application of the study and 136 students were included in the group that did not participate in the flash card application. The voluntary nature of participation may introduce self-selection bias. This potential bias is addressed as a limitation of the study.

Data Collection Tool

Within the scope of this study, data were obtained from two sources. The first one is the pharmacology attitude scale, and the other one is the exams used by the faculty to determine semester and board success.

Attitude Scale of Medical School Students Towards Pharmacology Course

Within the scope of the study, in order to examine the attitudes of medical faculty students towards pharmacology course, the Attitude Scale of Medical Faculty Students towards Pharmacology Course developed by Tekes (13) was used. There are 12 items in the scale. The scale is a 5-point Likert-type scale. The scale consists of two factors. These are: “Pharmacology is an indispensable course in medical education” and “Pharmacology is a useless course”. The Cronbach Alpfa coefficient to determine the internal consistency of the total and subscales of the scale was calculated as 0.80 for the total scale, 0.90 for the first subscale and 0.90 for the second subscale. The McDonald’s Omega reliability value of the first factor is 0.90, while the reliability value of the second factor is 0.91. The McDonald’s Omega reliability value of the whole scale was calculated as 0.82. The confirmatory factor analysis fit indices of the scale were calculated as RMSEA=0.073, CFI=0.941, TLI=0.924.

Measuring Academic Success

The academic achievement of the students was measured using (1) semester 3 board 5 exam scores, (2) semester 3 final exam scores, and (3) overall average achievement over the three years until the end of semester 3. The measurements were obtained through the official exam grades used by the faculty.

Procedure

- The fifth board of semester three of the medical faculty of a state university was selected to implement the flashcard application.
- In the current curriculum, 5 pharmacology course topics are covered in the board for 10 hours. The number of hours and sessions required to convert these topics into flashcards was determined. As a result, it was decided to conduct five sessions and create 100 flashcards.
- The permission of the Scientific Research and

Ethics Committee of Çanakkale Onsekiz Mart University dated 08.02.2024 and numbered 02/44 was obtained for the conduct of the research. - Following the approval of the ethics committee, an information meeting was held for all semester three students about the research. In this meeting, it was informed that the pharmacology courses in semester three board five would continue in accordance with the program and that the flashcard application would be carried out as an extracurricular activity during non-class hours. It was informed that participation in the applications was voluntary, that in the flashcards application, the pharmacology courses in semester three board five would be transformed into flashcards together with the students, and that at the end of the applications, the attitudes towards the pharmacology course and the academic achievement of the students who participated and did not participate in these applications would be compared. - Applications were carried out in five sessions with 66 students who gave consent for voluntary participation in the applications. - At each session, the flashcards were prepared by the students collaboratively. This collaborative approach was chosen to promote active learning, peer teaching, and knowledge sharing among students (14). The students were divided into small groups of 5-8 members to work as a team. They created their flashcards using textbooks, lecture notes, and other resources. On the front side of the flashcards, the drug name (e.g., Sertraline) was written, and the back side contained its explanation. Students were encouraged to include "therapeutic drug group (e.g., selective serotonin reuptake inhibitor, antidepressant)," indications, and side effects. However, adding more details was left to their discretion to allow them to develop their own style. The flashcards were designed to align with both the educational objectives outlined by the medical faculty and the national core curriculum for medical education (UÇEP). The content covered essential pharmacology topics, including drug mechanisms, therapeutic indications, contraindications, and adverse effects, directly addressing key competencies such as understanding the pharmacokinetics and pharmacodynamics of medications, as well as patient safety considerations. For example, flashcards related to selective serotonin reuptake inhibitors (SSRIs) included information on pharmacokinetics, therapeutic use, and contraindications, thereby supporting students in developing the ability to individualize treatments and ensure patient safety-key learning objectives emphasized in the medical faculty's curriculum. - At the end of the application, students' attitudes towards the pharmacology course were measured. At the end of the year, the students' fifth board course grades, semester three final/completion grades, and the general achievement scores at the end of the third year were obtained from the faculty student affairs with the permission of the faculty dean. - The attitudes towards pharmacology course and academic achievement of the students who participated and did not participate in the practices were compared and reported.

Data Analysis

The data obtained were transferred to JAMOVI software. The reason for choosing this statistical software is that it is a free software. The attitude scores towards the pharmacology course, semester three board five grades, semester three final/completion grades and general achievement scores until the end of semester three were examined with the normal distribution test. It was determined that the data were not normally distributed ($p<.05$). The attitudes towards pharmacology course and academic achievement of the groups who participated and did not participate in the flashcard application were compared with the nonparametric Mann Whitney U Test. In comparison, $p<.05$ level was used as significance level.

RESULTS

The scores obtained from the two sub-factors of the attitude towards pharmacology course scale, semester three board five grades, semester three final grades, semester three general academic achievement average, and the average of the general academic achievement scores until the end of semester three were compared between 66 students who participated in the flashcard application and 136 students who did not participate in the applications. Comparisons were made with the nonparametric Mann Whitney U Test because the data were not normally distributed. The results are shown in Table 1.

Table 1.

Comparison of attitudes towards pharmacology course and achievement status of students who participated and did not participate in flashcard application (Mann Whitney U Test)

Measurement	Group	N	Mean (Std. dev.)	Median (Min-Max)	U	p
Pharmacology as an indispensable course in medical education	Did not participate	136	24,63(1,42)	25(21-27)	62,50	0,001
	Participated	66	27,91(0,94)	28(27-31)		
Useless course pharmacology	Did not participate	136	13,29(1,22)	13(11-17)	205,00	0,001
	Participated	66	10,59(0,89)	11(7-12)		
Semester 3 Board 5 Grades	Did not participate	136	64,60(13,59)	68(17-91)	2055,00	0,001
	Participated	66	75,58(7,41)	75(60-91)		
Semester 3 Final Grades	Did not participate	136	61,46(15,53)	65(0-83)	2800,50	0,001
	Participated	66	69,27(6,50)	69(55-82)		
Semester 3 General Academic Achievement Average	Did not participate	136	61,00(13,15)	64(0-83)	2326,50	0,001
	Participated	66	68,68(5,36)	68(58-83)		
Semester 1, 2, and 3 General Academic Achievement Average	Did not participate	136	68,70(6,54)	69,44(39,68-82,49	2820,00	0,001
	Participated	66	72,27(4,01)	72,19(62,62-86,39)		

Analyses showed that the scores of those who participated in the flashcard application were significantly higher than those who did not participate in the sub-factor of “pharmacology as an indispensable course in medical education”, which is an indicator of a constructive attitude towards pharmacology course ($p<.05$). On the other hand, in the “useless course pharmacology” sub-factor, which is an indicator of less favorable attitudes towards pharmacology course, the scores of those who participated in the flashcard application were appreciably lower than those who did not participate ($p<.05$). This indicates that flashcard applications created a substantial improvement in attitude towards the course. The scores of those who participated in the flashcard applications in terms of semester three board five grades, semester three final/completion grades, semester three general academic achievement and general academic achievement until the end of semester three were markedly higher than those who did not participate in the flashcard applications ($p<.05$). Students who participated in the flashcard sessions had notable academic gains and more favorable attitudes towards pharmacology. However, this finding should be interpreted with caution, as the general academic achievement scores prior to the intervention suggest that students who were already academically successful were more likely to participate in the flashcard sessions. This suggests that flashcard practices made a positive difference in academic achievement. However, it is necessary to be careful in this interpretation. Because students who are already interested in the lessons and have high GPAs tend to participate in flashcard applications, as reflected in their general success average until the end of semester three. Further research is needed to better understand the contribution of flashcard applications to success, and the findings should be compared with this study’s results.

DISCUSSION

Our findings reveal a remarkable association between pharmacology flashcard use and both academic performance and student attitudes

towards the course. This suggests that active engagement with flashcards can enhance learning and foster more favorable perceptions of pharmacology. Students using flashcards demonstrated superior performance across multiple assessments ($p<.05$), including semester grades and GPA. This suggests that active engagement with pharmacological concepts through flashcard creation and review enhances knowledge retention and application, as supported by studies emphasizing the role of active recall and spaced repetition in improving academic outcomes (4,15). Additionally, participants in the flashcard activities scored higher on the "pharmacology as an indispensable course in medical education" sub-factor, indicating a more positive outlook towards the course, and lower on the "useless course pharmacology" sub-factor, reflecting a diminished negativity, compared to non-participants. The collaborative activities may have fostered a sense of community and peer learning (16), contributing to increased confidence and a more positive perception of pharmacology. While our findings strongly support the benefits of flashcards in this specific context, it is important to acknowledge that broader literature presents mixed results, highlighting the importance of nuanced implementation and design. Mixed literature on flashcard usage highlights the importance of context and implementation. The mixed findings in the literature may be attributed to variations in flashcard design (e.g., conceptual vs. detailed flashcards) (17), implementation strategies (e.g., consistent use vs. sporadic use) (4,15), and the specific context of their use (e.g., pre-clerkship vs. clerkship settings). A dose-dependent positive effect of flashcards has been demonstrated on medical physiology performance (4). Furthermore, flashcard design (e.g., detailed versus conceptual) plays a crucial role in their effectiveness (17). For example, detailed flashcards might focus on specific drug mechanisms, while conceptual flashcards could emphasize broader therapeutic categories or clinical applications. These variations in design can significantly influence learning outcomes. Our results contribute to the growing body of evidence supporting the judicious use of flashcards as a valuable learning tool in pharmacology education. Future research should explore how the effectiveness of flashcards varies across different educational contexts, such as pre-clerkship versus clerkship settings. Our study's findings align with the broader literature underscoring the benefits of flashcards on academic performance. For example, the utility of spaced-repetition flashcards has been shown to enhance satisfaction with self-study among medical students, particularly in content-heavy disciplines such as psychiatry (12). Similarly, medical students using Anki, a digital flashcard application, scored significantly higher across standardized exams, highlighting the role of spaced repetition and active recall in improving retention and exam performance (18). Furthermore, the efficacy of spaced-repetition flashcards in pharmacology has been demonstrated, with consistent flashcard use fostering long-term retention and improved comprehension of key concepts (15). These findings resonate with our structured approach, which involved collaborative flashcard development within small groups, thereby promoting active recall and consistent study habits. This structured, collaborative approach in our study likely contributed to the observed positive impact on both academic performance and student attitudes. However, the literature reveals mixed results. For instance, while Kruidering - Hall & Tuan (10) reported that pharmacology flashcards did not significantly improve exam performance, they noted that flashcards helped reduce stress and support conceptual learning. In contrast, Sun et al. (12) found that spaced repetition flashcards significantly improved students' retention of key concepts in psychiatry, indicating the importance of implementation strategies. Byers et al. (5) emphasized the importance of learning environments in determining the effectiveness of innovative tools like flashcards. Additionally, Gilbert et al. (18) demonstrated that digital flashcards, when used consistently as part of a spaced-repetition system, contributed to better academic performance across multiple standardized exams. These varying findings suggest that context, implementation strategies, and the discipline in which flashcards are used are critical factors influencing their effectiveness in medical education. These findings highlight the importance of tailoring flashcard use to specific learning environments and contexts, which was a key consideration in our study's design. Byers et al. (5) emphasized the importance of learning environments in determining the effectiveness of innovative tools like flashcards.

Context and implementation strategy, therefore, appear pivotal to maximizing the effectiveness of flashcards. Our flashcard activities were embedded within a supportive learning environment, including structured workshops on creating effective flashcards and facilitated small group discussions where students shared strategies and provided peer support. These workshops, for example, covered topics such as identifying key concepts, formulating effective statements, and integrating diverse learning resources. The small group discussions, in turn, allowed students to collaboratively develop flashcard sets, share diverse perspectives on the material, and learn from each other's insights. This collaborative approach aligns with Byers et al. (5) findings regarding how supportive and interactive learning environments enhance both student engagement and academic outcomes. The structured workshops and peer-led activities fostered a sense of community and equipped students to effectively utilize the flashcards. Our study's emphasis on a supportive learning environment and interactive activities may explain the positive results observed, despite the mixed findings in broader literature. The mixed results in literature might also stem from individual learning styles and preferences. For instance, student satisfaction with instructional tools has been shown to vary significantly, implying that flashcards may be more suitable for students with specific learning preferences (7). Flashcards, being inherently visual, cater well to visual learners who benefit from seeing information presented in a concise, image-rich format. Research suggests that visual aids can significantly enhance learning and memory (19). The ability to create custom flashcards with diagrams, charts, and other visual aids further enhances their effectiveness for this learning style. While traditional flashcards primarily cater to visual learners, adaptations can be made for auditory and kinesthetic learners. Auditory learners could incorporate recorded audio alongside their flashcards, leveraging the benefits of auditory learning (20). Kinesthetic learners might benefit from creating physical flashcards or using interactive digital platforms that incorporate drag-and-drop or other interactive elements, aligning with their preference for hands-on learning experiences (21). It is important to note that learning styles and preferences are complex and extend beyond the traditional VARK (Visual-Auditory-Read/Write-Kinesthetic) model. Factors such as cognitive style, learning strategies, and motivational factors also play a significant role in how students learn and interact with educational resources. Furthermore, it has been shown that conceptual flashcards often benefit less able learners more than detailed flashcards, highlighting the need for adaptive design tailored to diverse student needs (17). The development of adaptive flashcard platforms aligns with the growing trend towards personalized learning, where educational resources are tailored to individual student needs and preferences (22). Such platforms could dynamically adjust the content, format, and presentation of flashcards based on individual learning styles, prior knowledge, and learning progress. Future research could investigate the effectiveness of algorithms that personalize flashcard delivery based on student performance data. Exploring the integration of adaptive flashcards with other personalized learning technologies would also be a valuable area of inquiry. As with any personalized learning technology, ethical considerations regarding data privacy, algorithmic bias, and equitable access must be carefully addressed in the development and implementation of adaptive flashcard platforms. Our study considered these diverse learning styles by encouraging students to create flashcards in a variety of formats, with a particular emphasis on visual elements, potentially contributing to the positive outcomes observed. The positive shifts in attitudes observed in our study reflect broader trends reported in the literature. The importance of fostering positive attitudes in education has been emphasized, noting their direct correlation with increased motivation and academic success (23). Our finding that flashcard participants perceived pharmacology as indispensable aligns with these insights. However, not all studies show such positive outcomes. For example, practical experiences, such as clinical attachments, might have a more profound impact on attitudes than self-study tools like flashcards (24). Similarly, it has been observed that hands-on learning opportunities, such as psychiatry clinical rotations, were more influential in shaping student attitudes than isolated study aids (11). These findings highlight the complementary nature of flashcards and experiential learning, suggesting that integrating both strategies could

optimize student engagement and perceptions of challenging subjects. Moreover, the versatility of flashcards was emphasized in studies like one which noted their preference among students for visually intensive tasks, such as histological image identification (25). This adaptability aligns with our results, where collaborative flashcard creation allowed for the contextualization of pharmacological concepts, fostering deeper engagement with the material. Flashcards, when paired with strategies like spaced repetition and active recall, have shown significant promise across disciplines. For instance, the effectiveness of flashcard-style educational games in improving confidence and knowledge retention in diabetes management among medical students has been demonstrated (26). Such creative implementations underscore the potential for flashcards to serve as versatile tools in medical education, extending beyond traditional study methods. Additionally, the correlation between learning environments and educational tools highlights the role of student perceptions in mediating academic outcomes (27). Their findings resonate with our observations, suggesting that the perceived utility of flashcards may be influenced by the broader educational context. Taken together, these findings suggest that flashcards are effective for enhancing both academic performance and student attitudes when thoughtfully implemented. Our study's focus on collaborative flashcard creation within a supportive learning environment likely contributed to the positive attitudinal shifts observed, demonstrating the potential of flashcards to enhance engagement and foster positive perceptions of pharmacology. The observed benefits of pharmacology flashcards suggest their potential as a valuable learning tool in medical education. Incorporating flashcard creation and review into the pharmacology curriculum could provide students with a structured yet flexible approach to reinforce core concepts, improve knowledge retention, and foster more positive attitudes towards the subject. Rather than prescribing rigid protocols, educators could provide clear guidelines for flashcard development, encourage collaborative creation within small groups, and integrate flashcard-based activities into both classroom settings and online learning platforms. This approach aligns with broader trends in medical education emphasizing active learning strategies and student-centered pedagogies. The positive outcomes of this study suggest that integrating flashcard-based learning into the pharmacology curriculum could enhance both academic performance and student engagement. Future research could explore the feasibility of embedding flashcard activities within regular coursework as a structured learning tool to reinforce key concepts, particularly in competency-based medical education frameworks. This study has several limitations. Although the sample size was substantial, it may not fully represent the broader medical student population, particularly in diverse educational or cultural contexts. The study's duration, focusing primarily on Semester 3 performance, limits its ability to assess the long-term impact of flashcard use on knowledge retention and academic success. Furthermore, the self-selection bias presents a challenge in isolating the specific effects of flashcard intervention. The observed improvements may be partially attributable to pre-existing differences between participants and non-participants, such as motivation levels or academic standing. Lastly, the study's focus on a single institution and specific pharmacology curriculum restricts the generalizability of the findings to other settings or disciplines. Future research should address these limitations by employing larger and more diverse samples, including students from different institutions and varying levels of academic proficiency. Extending the study duration would allow for an exploration of the long-term effects of flashcard use on knowledge retention, academic success, and professional competency. Implementing randomized controlled trial designs could mitigate self-selection bias, ensuring a more equitable distribution of participant characteristics. Additionally, exploring the effectiveness of student-generated flashcards in other medical disciplines, as well as comparing different implementation strategies (e.g., individual vs. collaborative, paper-based vs. digital flashcards), would provide a more comprehensive understanding of their utility. Investigating the specific cognitive mechanisms underlying the benefits of flashcard use, such as active recall and spaced repetition, could also yield valuable insights, enabling educators to optimize their application in medical curricula. Future research should explore the alignment of student-generated flashcards with

core educational goals, such as those outlined in national medical education standards like UÇEP. Investigating how well flashcards support competency-based learning outcomes, including explaining pharmacokinetic and pharmacodynamic principles or identifying contraindications in specific patient groups, would provide valuable insights into their role in medical curricula.

CONCLUSIONS

This study demonstrates the potential of pharmacology flashcards to enhance both academic achievement and attitudes towards the pharmacology course among medical students. The findings suggest that flashcard-based learning activities, when thoughtfully integrated into medical curricula, can serve as a powerful tool for promoting active learning, improving knowledge retention, and fostering more positive perceptions of challenging subjects like pharmacology. Specifically, our results indicate that students who actively engaged with flashcards demonstrated a statistically significant improvement in exam scores and reported a more favorable view of the subject matter. While further research is needed to address the limitations and explore long-term effects, this approach aligns with the ongoing shift towards student-centered learning in medical education and holds promise for enhancing the overall educational experience. By empowering students with effective and engaging learning tools, pharmacology educators can better equip future healthcare professionals to succeed in both academic and clinical settings. Future investigations should explore the optimal integration of flashcard-based learning within diverse educational contexts and assess their impact on long-term knowledge retention and clinical performance.

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