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Enhancing Medical Students' Pharmacology Learning and Retention through a Spaced Repetition Flashcard Intervention: A Mixed-Methods Evaluation

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Abstract

Pharmacology forms a fundamental component of medical training, underpinning safe and effective prescribing. Nevertheless, medical students frequently report uncertainty regarding their confidence and competence in pharmacology. Despite growing efforts to enhance student performance, there is limited evaluation of how students approach learning, retaining, and applying pharmacological knowledge. A mixed-methods, student-centered strategy was implemented to design and assess targeted resources addressing gaps in pharmacology education. This approach included an anonymised scoping survey followed by semi-structured focus group interviews. Subsequently, a flashcard-based intervention was created to facilitate long-term revision for both academic and clinical success. The resource was distributed to a cohort of 100 graduate-entry preclinical medical students, who were invited to provide feedback through a follow-up anonymous survey at the end of the year. The scoping survey obtained 103 complete responses. Data from surveys and focus groups indicated that only 50% of students maintained ongoing revision practices. Within this cohort, the evidence-supported method of spaced repetition was highly valued. Consequently, we developed a tailored resource using Anki™, an open-source, spaced repetition flashcard platform. A total of 1,208 flashcards covering 156 distinct drug classes, accompanied by summary tables, diagrams, and explanatory videos, were produced. Evaluation demonstrated that students appreciated the "comprehensive" and "well-formatted" Anki™ resource, which complemented existing teaching, with an overall rating of 3.8/5.Customised and strategically designed resources for pharmacology education, supporting both in-semester revision and long-term retention, are highly valued by students for exam preparation and readiness for clinical practice. These findings reflect an innovative approach to identifying and addressing gaps in existing learning tools in a manner that is inclusive of student needs.

Keywords: Medical pharmacology, Spaced repetition, Flashcards, Medical education

Introduction

Mastery of medical pharmacology is essential for clinical competence, as it provides the foundation for rational prescribing and therapeutic decision-making. Students face substantial challenges in navigating the vast and evolving spectrum of medications, each with specific interactions and clinical considerations [1]. Unsurprisingly, many students express concern over their pharmacology competence, with only 39% of Australian medical graduates feeling adequately or well-prepared in this area [2, 3].

There is growing interest in educational reforms aimed at improving pharmacology learning outcomes. However, most interventions have been top-down, targeting curricular design, teaching approaches, or staffing structures [4]. Less is known about the specific strategies students use to study pharmacology, which could inform more targeted interventions to enhance learning [5-8].

Understanding how students manage rapid, integrated curricula is important, particularly in identifying support for more efficient study strategies [9]. Spaced repetition using digital flashcards, such as the cross-platform

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Anki™ program, has shown efficacy in improving student outcomes [10-13]. This method involves self-testing on flashcards, with difficulty ratings guiding the timing of subsequent reviews, thereby creating a personalised revision schedule.

Spaced repetition offers several advantages in medical education [14]. It engages learners in self-assessment with immediate feedback, leveraging the testing effect, where retrieval practice enhances learning more than passive review [15-17]. These resources complement traditional teaching by requiring free recall of knowledge, which is superior to passive methods like re-reading or multiple-choice formats [18-20]. The approach also optimises revision efficiency by prioritising items that are less well understood, while minimising time spent on mastered content **(Figure 1)** [20]. When curated and regularly reviewed by faculty, the resource centralises key information for easy student access.

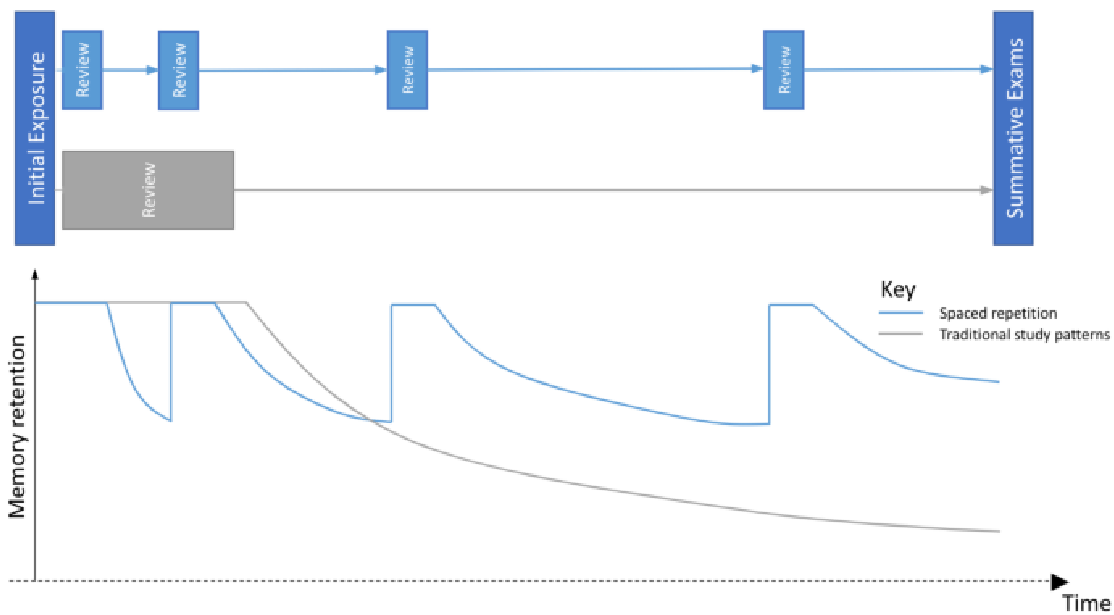

Figure 1. Comparison of knowledge exposure using spaced repetition versus traditional methods

The figure illustrates how conventional learning techniques initially focus on intensive practice, creating strong early memory formation that subsequently declines without continued review. In contrast, spaced repetition distributes meaningful practice over time, reinforcing knowledge and slowing memory decay to support long-term retention [20]. Individual flashcards are scheduled according to user-assessed difficulty: items rated as more challenging are reviewed at shorter intervals to enhance retention, while easier items are spaced further apart to optimise time efficiency and maintain appropriate cognitive challenge during revision. This study explores medical students' perceptions and strategies for learning pharmacology, aiming to identify weaknesses and inform the development of targeted educational resources. The goal is to improve understanding of student approaches while generating actionable interventions to enhance learning outcomes.

Materials and Methods

Participants in this study were enrolled in either direct entry (undergraduate) or graduate entry Doctor of Medicine (MD) pathways at an Australian university. The direct entry program spans five years, with students entering directly from secondary education, whereas the graduate entry course is four years, admitting students who have completed an appropriate bachelor's degree or higher. Each year has approximately 350 direct entry students and 100 graduate entry students. All current students across year levels were invited to participate via advertisements on student notice boards, yielding a total eligible population of 2,300 students.

The medical school's pharmacology curriculum is structured to progressively develop knowledge and skills. During the preclinical phase, students are introduced to core pharmacological principles within a strong clinical context, covering drug actions, adverse effects, and major clinical considerations for key therapeutic classes. In the first and second clinical years, the focus shifts to appropriate drug selection and adverse effect management in patient care. In the final clinical year, emphasis is placed on the development of prescribing competence.

Ethics approval was obtained from the university's human ethics committee prior to study commencement (MURHEC number: 2020–22814-44162), and all procedures complied with relevant guidelines and regulations. The estimated time for survey completion was under 20 minutes. Participation was voluntary and uncompensated; the Project Explanatory Statement noted that involvement could contribute to course improvement for both current and future students.

To investigate students' learning strategies in pharmacology, participants were invited to complete an anonymised scoping survey. At the end of the survey, students were offered the opportunity to participate in structured focus group interviews to further explore findings and refine educational resources. These resources were subsequently made available only to graduate entry preclinical students, who were invited to provide feedback through an anonymous follow-up survey at the end of the year **(Figure 2).**

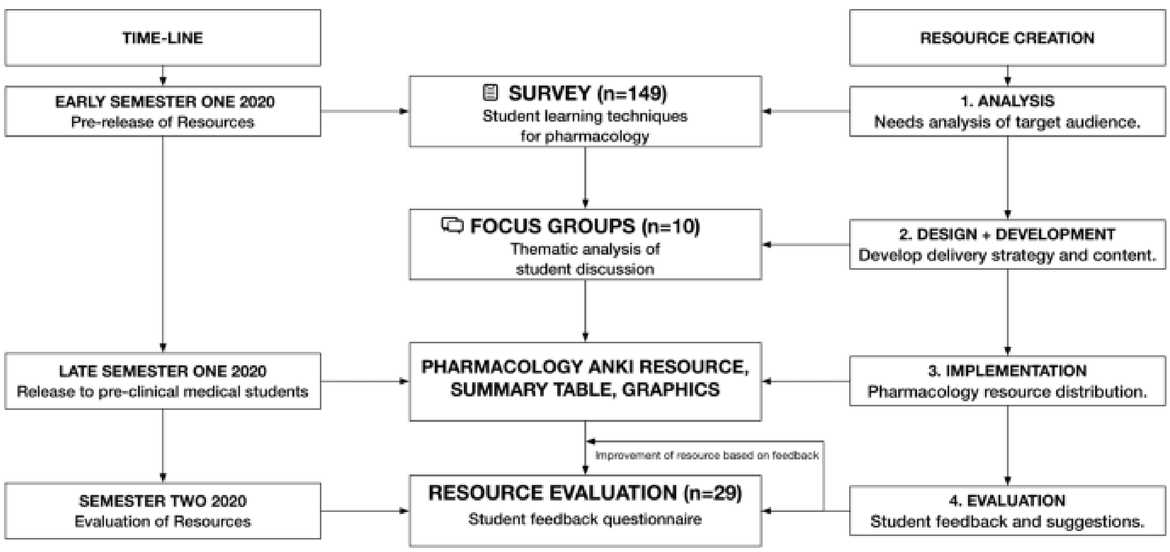

Figure 2. Flowchart of resource development and evaluation

This diagram presents the iterative, stepwise process of resource creation. The initial scoping survey informed the design, development, and deployment of bespoke pharmacology resources, with evaluation and feedback loops incorporated to ensure quality and continuous improvement.

Initial scoping survey design and analysis

To explore medical students' perspectives and learning strategies in pharmacology, an initial anonymised scoping survey was distributed to current MD students. The survey primarily employed 5-point Likert scales and open-text questions.

The survey contained two sections. The first captured demographic details, including age, sex, year of study, entry pathway, and domestic versus international status. The second focused on the study resources and techniques students employed for pharmacology learning, with Likert scales assessing usage frequency and open-text fields for additional methods. These strategies were evaluated across three learning stages: initial exposure to a topic, ongoing revision, and final review prior to summative assessments. Statistical analysis, including cross-tabulation and Student's t-test, was performed using MS Excel to identify significant associations.

Focus group design and data analysis

Survey participants were invited to take part in focus groups to gather deeper qualitative insights into the survey results and to assess several potential study aids.

Two rounds of focus group sessions were conducted, including a total of ten students.

Participant coding was as follows:

- **Focus Group A:** 4 students (A1, A2, A3, A4)
- **Focus Group B:** 6 students (B1, B2, B3, B4, B5, B6)

The study adopted a grounded theory framework, allowing conclusions to emerge directly from participants' shared experiences [21]. This methodology followed the procedures outlined by Watling & Lingard [22].

Design and implementation of spaced repetition flashcards

Analysis of the initial survey highlighted Anki™ flashcards, complemented with text summaries and diagrams, as an appropriate intervention for supporting pharmacology learning. Anki™ is a free, open-source tool accessible on PC, Mac, and Android (iOS is paid). The resources were first piloted in focus groups and later distributed to preclinical graduate-entry students for evaluation.

Flashcards used cloze sentences, which are statements with missing words to test recall and comprehension **(Figure 3).** Students could review their answers and rate card difficulty, which guided the Anki™ algorithm to schedule future repetitions based on individual performance. The flashcards covered 15 core curriculum topics and 156 drug classes, generating a total of 1,208 cards. These cards spanned basic knowledge such as drug names, mechanisms, indications, and adverse effects, as well as advanced topics like clinical guidelines.

Decks were developed by the student author (DJ), reviewed for relevance by the pharmacology lecturer (SB), and validated by a graduate and junior doctor (JZ), previously a qualified pharmacist. On average, each deck represents approximately one hour of lecture material and requires three hours to produce.

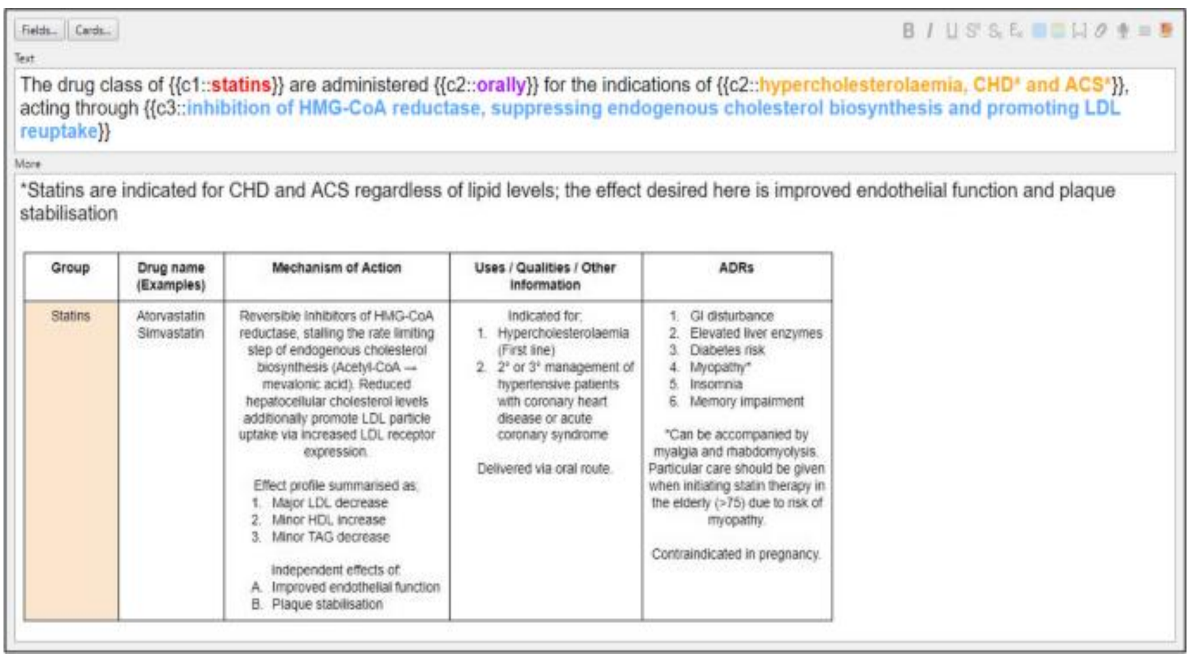

Figure 3. Example Anki™ flashcard structure

This figure shows Anki™'s back-end editor, demonstrating three differently coloured clozes within a single note, producing three individual flashcards. During review, students see one cloze blank and attempt free recall. After submission, the card displays the correct answer along with additional explanatory content.

Supplementary text and diagram summaries were also produced to complement Anki™, providing a broader context for drug classes and clinical pharmacology topics, usable inside and outside the software.

Follow-up survey design and analysis

To measure the intervention's effectiveness among preclinical graduate-entry students, a follow-up survey was advertised on student forums and noticeboards. Students provided feedback using 5-point Likert scales and free-text responses. Data were analysed using MS Excel to identify trends and patterns.

Results and Discussion

Initial scoping survey findings

The scoping survey collected 103 complete responses from an eligible population of roughly 2,300 medical students across all years, yielding a response rate of 4.5%. Respondents had a median age of 22 years, with 69% identifying as female. Fifty-six percent were enrolled in the direct-entry pathway, and 81% were domestic students. In terms of year level, 26% were in preclinical years, 44% in the first clinical year, 11% in the second clinical year, and 20% in their final year.

Student learning preferences and approaches

Participants reported engagement across three learning stages: initial exposure, in-semester revision, and pre-assessment review. Most students indicated active study when first learning new material (95%) and before exams (80%), while only 50% reported consistent pharmacology revision throughout the teaching year.

When asked about the usage of specific study techniques **(Table 1)**, students preferred class-based activities (63%), text-based notes (84%), and faculty-provided question banks (60%). Overall, students tended to revisit and repeat the methods used during initial learning for both in-semester and exam-focused revision.

Table 1. Relative popularity of medical pharmacology study methods among students

Learning Technique	First Exposure Learning (%)	In-Semester Revision (%)	Exam Revision (%)
Class activities or resources	63	41	56
Personal text-based notes	84	40	78
Concept maps	23	18	26
Flow charts	29	18	27
Diagrams	46	23	42
Faculty question banks	60	30	58
Flashcards	35	30	63

Assessment based on a 5-point Likert scale; reported percentages reflect strong or very strong engagement.

An exception was seen with flashcards, which showed increased use during semester review (30%) and exam preparation (63%), compared to first exposure (35%), despite lower overall engagement at these later stages. Digital flashcards employing spaced repetition scheduling (e.g., Anki™) were consistently the preferred flashcard study method.

Focus group findings

Focus group participants were 70% female, 70% direct-entry students, and 50% preclinical. Two primary domains emerged from discussions: "Medical pharmacology learning" and "Use of flashcards in revision."

Category 1: medical pharmacology learning

Two clear themes arose: student experience and learning barriers. Overall, students responded positively to pharmacology teaching, particularly valuing clinically integrated, case-based approaches.

"We get a fair number of clinical cases, which makes it easier to connect what we learn with real patients." Student B4 (preclinical, direct entry)

Students also identified barriers to learning, with time management and difficulty retaining knowledge long-term being most frequently mentioned.

"There should be a system to keep students accountable so we don't cram everything at the end of the year." Student B3 (preclinical, direct entry)

"More focus is needed on how to study effectively… you can put in hours but still not learn efficiently." Student B5 (preclinical, direct entry)

"During exams, I knew the pharmacology well, but now I can't recall anything—it hasn't stuck in long-term memory." Student B5 (preclinical, direct entry)

Category 2: flashcards as revision tools

Two main themes emerged: engagement with flashcards and their limitations. Overall, students viewed flashcards positively, citing time efficiency and an active learning approach.

"Flashcards are a more interactive way to study, letting you learn and retain content faster, which is exactly what we need." Student A3 (preclinical, graduate entry)

"I liked using Anki™ in my biomed degree; it's a structured and active way to manage revision." Student A3 (preclinical, graduate entry)

Some students highlighted flashcards' role in promoting long-term retention:

"For long-term knowledge, Anki™ is ideal… the way it's structured suits this purpose perfectly." Student A1 (clinical, graduate entry)

Concise, well-structured resources are important for engagement and comprehension. Anki™ flashcards deliver only key points, making them appealing and accessible.

"Flashcards would be excellent because they're concise and include real-world examples—it makes learning much clearer." Student B2 (clinical, direct entry)

An identified limitation of the Anki™ resource was that some students found it "intimidating," particularly those who had not previously used flashcards as a study strategy.

"I spoke with a few peers who began using it; they seemed to struggle unless they had reviewed slides or done some pre-learning first." Student A3 (preclinical, graduate entry)

"There are so many cards, it can be overwhelming to tackle them all." Student B4 (clinical, direct entry)

Students suggested that providing a guide and positioning flashcards as a post-lecture revision tool could help learners fully engage with the Anki™ system.

"A manual explaining each step… something written down that students can consult anytime." Student A2 (preclinical, graduate entry)

Intervention follow-up survey findings

The follow-up survey targeting preclinical graduate-entry students who had access to the Anki™ resource achieved a 29% response rate. Reported usage of the resource was high at 83%, with 52% of respondents indicating that they completed all scheduled revisions, and 31% using Anki™ more like a conventional question bank for occasional review. Overall satisfaction was strong, with an average rating of 3.8 out of 5. In addition, 66% of students valued the automatic scheduling of reviews in Anki™, and 76% endorsed its long-term usefulness as a study method. Notably, 83% recognized the benefits of using Anki™ for other subjects beyond pharmacology. The accompanying summary tables and diagrams were also well received, with 79% and 83% positive ratings, respectively **(Figure 4).**

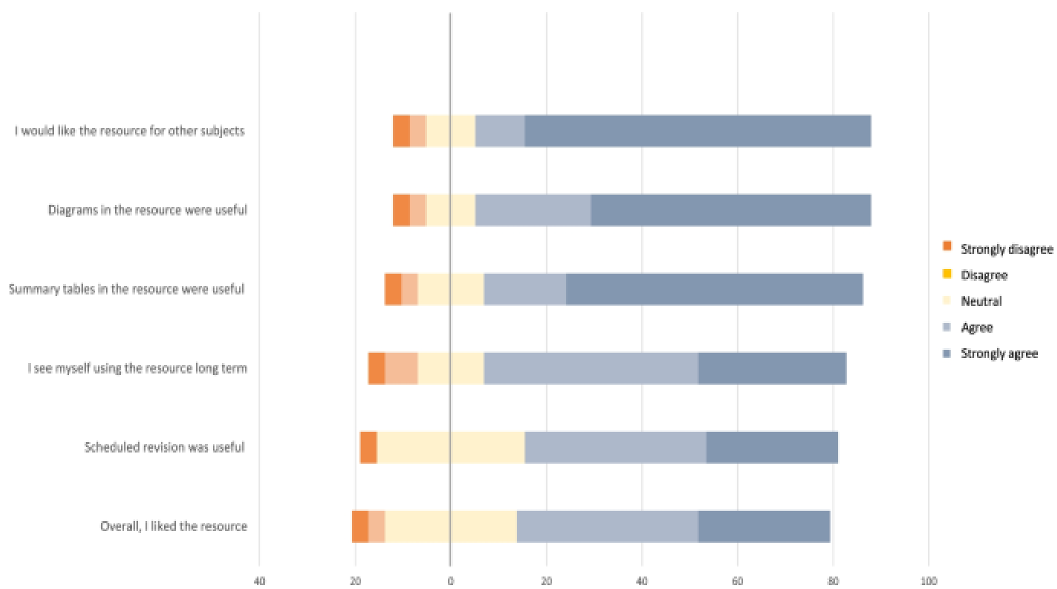

Figure 4. Likert scale assessment of student-guided learning interventions

This figure illustrates the proportion of student responses on a 5-point Likert scale evaluating the Anki™ resource developed based on primary survey insights.

When asked about strengths and potential improvements, participants reflected themes similar to focus group discussions, describing the resource as a "great" and "comprehensive" "study system" suitable for "continuous revision" of key pharmacology concepts. Students emphasized its dual utility: supporting immediate exam preparation while also serving as a reliable reference for long-term knowledge retention during clinical years.

"It's not just useful for current exams, but a resource to revisit later, highlighting essential concepts we need to know for future years."

Despite the resource's comprehensiveness and inclusion of clinically applied pharmacology, 45% of students felt "the sheer volume of some decks was overwhelming" and that certain decks included material "beyond the preclinical pharmacology syllabus." Suggestions for enhancing the resource included integrating case-based examples, adding links to supplementary materials and videos for specific drugs, and incorporating "more visual schematics" into flashcards—reinforcing feedback collected from the initial survey and focus groups.

Revision and self-testing are essential components of learning, supporting knowledge consolidation and enhancing student confidence in clinical practice [10]. The demanding nature of modern medical curricula places students under substantial time pressures, which can hinder regular revision. In our study, 95% of participants reported actively studying pharmacology to learn new material, and 80% engaged in pre-exam review, yet only 50% performed consistent revision during the semester. Qualitative data indicated that such revision was often motivated by imminent assessments rather than a focus on long-term mastery. These findings align with previous research suggesting that students frequently rely on shallow learning strategies such as rereading, highlighting, and last-minute cramming [23, 24]. Therefore, strategies that promote consistent, active learning and revision can provide clear benefits to educational outcomes [25].

Examining students' approaches to learning revealed further insights. Many students were aware of the heavy learning demands and time constraints early in their medical studies and therefore valued methods that were efficient and evidence-based. While some students understood techniques like spaced repetition, they often encountered barriers to implementing these methods, including the time needed to learn the software and create personal flashcards. This situation meant that students struggling with time management were less able to adopt efficient study strategies.

Given these findings, we hypothesised that the creation and deployment of a comprehensive Anki™ pharmacology resource aligned with the curriculum could offer multiple advantages. As an open-source, freely available tool, such a resource reduces entry barriers for students, enabling efficient, curriculum-specific revision [26]. It also encourages effective revision strategies, including retrieval practice and free recall [24], while the spaced repetition functionality prioritises challenging content to maximise learning outcomes [13, 27]. The digital format allows for ease of editing, collaborative input, and accessibility, ensuring the resource remains sustainable over time [14].

The extensive Anki™ deck was integrated into the medical pharmacology program, with completed sets released to students following traditional classes as a form of ongoing revision in line with Bloom's Taxonomy **(Figure 5)** [28]. Embedding Anki™ within the curriculum allows instructors to be confident that students are regularly self-testing, reinforcing foundational knowledge, and assessing comprehension. A significant advantage of this approach is the feedback students receive during self-testing: difficult concepts are highlighted, and explanatory text and diagrams provide opportunities for review, better preparing students for clinical application [29]. Flashcards have previously been used as simple prescribing aids and have been shown to increase confidence in prescribing [30]. Early familiarisation with Anki™ may also encourage students to adopt the tool for other subjects, including creating their own flashcards during clinical years to consolidate applied knowledge.

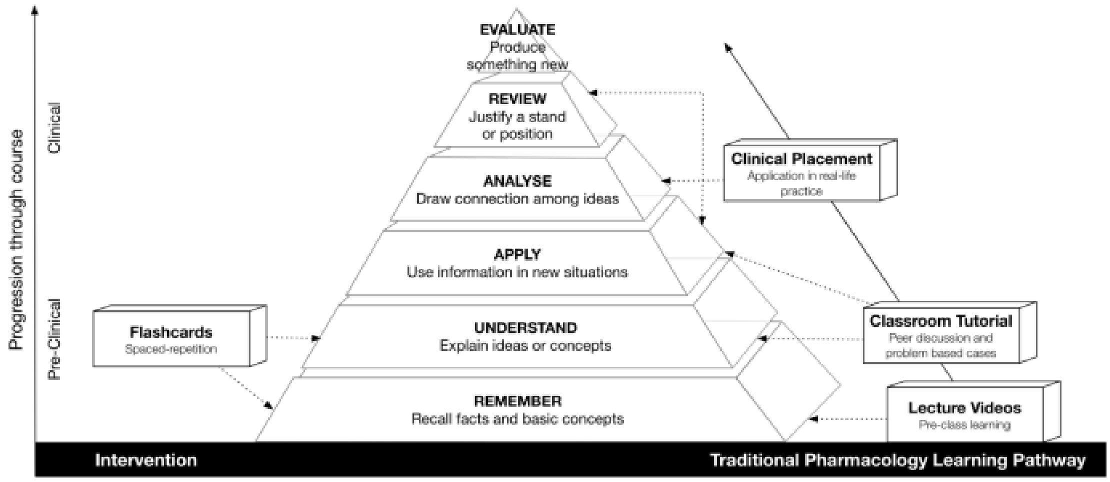

Figure 5. Integration of Anki™ spaced repetition flashcards into pharmacology teaching aligned with Bloom's Taxonomy

This figure illustrates how the flashcard intervention supports understanding and recall of materials, complementing traditional teaching methods, and promoting further learning as students progress through the course.

Feedback from the preclinical student cohort was largely positive, with the majority using spaced repetition scheduling as their primary study method. Students acknowledged the resource's comprehensiveness and its alignment with the medical pharmacology curriculum. Importantly, students indicated intentions to engage with the resource over the long term and expressed interest in similar resources for other areas of the medical curriculum. The potential for sustained use is notable, as the inherent nature of Anki™ ensures repeated exposure to curriculum content, supporting long-term retention [24, 31].

Based on these findings, the optimal approach for integrating flashcards into medical education is to introduce them during preclinical years as a supplement to lectures and tutorials. This strategy not only supports memorisation and conceptual understanding required for higher-order learning but also establishes a structure for ongoing revision throughout the course.

A key concern raised by students was the perceived extensive scope and detail of the material, which aligns with observations in pharmacology education research [3]. This challenge may be amplified for students who struggle to keep up with scheduled revision, leading to backlog accumulation, stress, and reduced motivation. From our perspective, resources of this nature should aim to be comprehensive to ensure utility throughout multiple years of study. To mitigate this challenge, additional guidance could be offered to help students customise their Anki™ usage. Potential strategies include adding metadata to flashcards to classify content by academic priority or providing instructional guidance on personalising settings, such as limiting daily review volumes or excluding specific cards from scheduled repetitions [32, 33]. Although the present study did not track the number of times students reviewed individual flashcards, Anki™ includes built-in analytics recording review counts, durations, intervals, and correctness percentages, which could inform future research.

The next phase of this initiative involves making these Anki™ resources openly accessible to other medical schools, particularly in regions with students from lower socioeconomic backgrounds. Supplementary materials, including user guides and tutorials, would accompany the resources, alongside research on best practices for broader implementation.

This study has several limitations. Low response rates in the initial survey and focus groups may have introduced bias. Furthermore, focus group participants were a subset of survey respondents, reducing overall participation. Recruitment through noticeboard advertisements, a passive approach, may have introduced selection bias in both the survey and focus groups. Additionally, the involvement of students from a single medical school may limit the generalisability of findings. Nonetheless, the results are largely consistent with existing evidence on medical student learning and the effectiveness of spaced repetition for improving outcomes [13, 27].

Replication in other university cohorts is warranted to validate these findings.

Conclusion

This study outlined an approach to enhancing medical pharmacology education within an Australian medical school by exploring student learning strategies and developing an Anki™ spaced repetition flashcard resource accordingly. The resource was well received, particularly for addressing a clear need for time-efficient methods to support ongoing pharmacology revision. We propose that this approach has potential for broader application across medical curricula to enhance student learning outcomes.

Practice points

- Medical students appear to engage minimally with ongoing in-semester revision as a result of fast-paced integrated curricula.
- Evaluations of student cohort learning can lead to significant insight to guide interventions.
- Spaced repetition flashcard resources are well regarded, well received and attract long term engagement when designed as a curriculum specific, prepared resource on open source and freely available software.
- Spaced repetition flashcard resources are best implemented during the preclinical phase of the medical curriculum to support knowledge acquisition and retention through structured revision.

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Ethics Statement: None

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