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Research Article

Exploration and Reflection on the Reform of the "Open Book Exam" in Organic Reactions for Drug Synthesis

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Abstract

Objective: In the era of big data, the traditional "memorization - repetition" learning method is inadequate for addressing the vast and ever - evolving knowledge in courses such as "Organic Reactions for Drug Synthesis". This article aims to explore how to shift students from "memorization - repetition" to "understanding - application" through educational reform and changes in assessment mechanisms, enabling them to adapt to a rapidly changing knowledge system.

Methods: The study analyzed examination data from 9 classes over three consecutive years to assess the impact of implementing "open - book exams" in the "Organic Reactions for Drug Synthesis" course. In the first and third years, a closed - book examination was employed, which is a traditional method that tests students' ability to recall and apply knowledge without external resources. The second year introduced an open - book examination, the exam allow students to consult materials, promoting a deeper understanding of concepts and the flexible application of knowledge to solve practical problems.

Results: The analysis revealed that open - book exams positively influenced students' ability to understand and apply concepts, fostering greater learning autonomy and creativity. However, issues such as over - reliance on materials and insufficient mastery of basic knowledge were also identified.

Conclusion: By examining the "successes" and "failures", this article offers valuable insights for reforming assessment methods in courses like "Organic Reactions for Drug Synthesis". Continuous exploration and practice can help educators develop teaching and assessment approaches better suited to the current era, ultimately enhancing students' comprehensive skills and innovative abilities.

Keywords: examination reform, organic reactions for drug synthesis, open book exam

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1 INTRODUCTION

"Organic Reactions for Drug Synthesis" is more than just a course; it is a cornerstone of pharmaceutical education, offering an in - depth exploration of the chemical reactions that underpin modern drug development. From the intricate processes of halogenation and hydrocarbonation to the complex transformations involved in acylation, condensation, rearrangement, oxidation, and reduction, this course delves into the core of pharmaceutical chemistry. It systematically imparts a deep understanding of the organic synthesis reactions essential to drug formulation, while instilling in students the principles of synthetic design that are crucial for innovation in this field[1].

The course is designed to move beyond traditional textbook learning, equipping students with the analytical and problem - solving skills needed to navigate the complexities of pharmaceutical synthesis. It aims to be a transformative experience, where students hone their scientific expertise to make meaningful contributions to the field of pharmaceutical sciences. However, the conventional didactic teaching methods, with their focus on theoretical content, often fail to engage students effectively[2]. The subject's inherent complexity, combined with the large volume of information, can overwhelm students, leading them to rely on rote memorization an approach that falls short in the dynamic and evolving field of pharmaceutical chemistry.

The digital revolution, with the rise of the Internet, has opened the door to a cornucopia of educational innovation. Models such as the "flipped classroom" and "Rain Classroom" are reshaping the educational landscape, advocating for a more interactive and participatory learning experience[3,4]. These approaches shift the pedagogical paradigm, encouraging students to move from passive recipients of knowledge to active participants in their educational journey. Despite the integration of these progressive educational models, courses like "Organic Reactions for Drug Synthesis" with their extensive knowledge base, continue to present formidable memorization challenges for students. The juxtaposition of vibrant classroom interactions with underwhelming exam results suggests that a deeper transformation in educational strategy is essential.

In the age of big data, where knowledge is continually refreshed and expanded, the conventional "recite and memorize" method is no longer sufficient. There is a pressing need to pivot towards an "understanding and application" approach[4]. It has become increasingly clear that a mere change in teaching methodology is not enough to meet the evolving demands of the discipline and the times. A more fundamental reform in course assessment methods is both necessary and urgent. Institutions have begun to experiment with innovative examination models, such as the "One - Page Reference" exam at the University of Bath, the "Semi - Open Book Exam" at the North China University of Science and Technology, and the "Open Book Exam" at Imperial College London, achieving promising outcomes[5,6].

While the impact of different assessment formats (closed book exam and open book exam) on learning outcomes varied, two significant findings emerged: (1) closed - book tests resulted in a reduced likelihood of forgetting; (2) students expressed a clear preference for open - book assessments[7]. For specialized fields such as medicine, closed book exams are definitely more reasonable. But for professionals in the field of new drug development or synthesis, who frequently consult the literature to guide their synthesis strategies, for high - end courses "Organic Reactions for Drug Synthesis", open book exams are obviously more suitable.

This paper presents an in - depth analysis of the examination effectiveness over three academic years, encompassing nine cohorts. Compared to other studies, this article has a larger sample size and spans over three years. Each year has a data volume of three grades, ensuring the reliability of the data. Importantly, we adopted a research strategy of alternating between "closed book exam", "open book exam", and "closed book exam" to avoid the impact of time on teachers' teaching abilities. It evaluates the impact of the "open book exam" reform in the "Organic Reactions for Drug Synthesis" exam, reflecting on its successes and identifying areas for improvement. By emulating the practical approach of drug synthesis, the "open book exam" serves not only as an evaluative instrument but also as a conduit linking theoretical knowledge with practical pharmaceutical synthesis operations.

This study is a testament to the belief that through ongoing exploration and implementation, educators can uncover teaching and assessment methodologies that resonate with the characteristics of our time. It is a call to action for the academic community to continuously refine and innovate, with the ultimate goal of nurturing students' comprehensive qualities and fostering an environment that encourages innovation and creativity. By aligning our educational practices with the realities of the pharmaceutical industry and the demands of the big data era, we can better prepare our students to meet the challenges of tomorrow with confidence and competence.

2 METHODOLOGY

2.1 Research Design

2.1.1 Research Methods

The "Organic Reactions for Drug Synthesis" course, integral to the pharmacy undergraduate curriculum, is meticulously structured around a comprehensive training program that is designed to align with the examination outline and to effectively utilize the allocated class hours. The knowledge points are strategically distributed to ensure a progressive and coherent learning experience that builds upon foundational concepts and gradually introduces more complex ideas and techniques.

2.1.2 Teaching Methods and Process

The consistency of the main instructor over the three years provides a stable educational environment, which is crucial for the continuity and depth of the course material. The primary mode of instruction has been multimedia lectures, leveraging the visual and auditory elements to enhance student engagement and comprehension. These lectures are not static; they evolve to incorporate a variety of teaching methods to cater to different learning styles and to keep the content fresh and relevant.

During the three years, the course has integrated innovative teaching approaches such as "Rain Classroom", which utilizes digital platforms for interactive and immediate feedback, "Online - Offline Integration", blending the traditional classroom experience with online resources and activities, and "Online Teaching", which offers flexibility and accessibility to students. Despite these additions, the traditional teaching approach remains the backbone of the course, providing a solid foundation upon which the supplementary methods build.

The traditional teaching approach, with its emphasis on in - person interaction, direct communication, and real - time clarification of concepts, is complemented by the multimedia aspect, which can include video demonstrations, interactive simulations, and digital slides. This fusion of traditional and modern pedagogical tools aims to create a rich learning environment that is both informative and engaging.

2.1.3 Assessment Methods

The evolution of assessment methods over the three years reflects a deliberate strategy to explore different forms of evaluation and to determine the most effective means of gauging student understanding and application of the course material.

In the first year, a closed - book examination was employed, which is a traditional method that tests students' ability to recall and apply knowledge without external resources. This approach sets a baseline for understanding the foundational concepts and principles of "Organic Reactions for Drug Synthesis".

The second year introduced an open - book examination, a significant departure from the first year's method. This reformative step aimed to assess higher - order thinking skills, such as analysis, synthesis, and evaluation, rather than mere memorization. The open - book format encourages students to demonstrate their ability to navigate and utilize resources effectively, mirroring real - world scenarios where chemists consult literature and databases to solve complex problems. The third year returned to a closed - book examination.

The cyclical nature of the assessment methods over the three years is not a regression but a reflection of the educational philosophy that values a balanced approach to learning and assessment. It acknowledges the importance of foundational knowledge while also recognizing the need for adaptability, critical thinking, and independent problem - solving skills.

In summary, the "Organic Reactions for Drug Synthesis" course, through its thoughtful distribution of knowledge points and its varied teaching and assessment methods, seeks to prepare pharmacy students for the dynamic and challenging field of pharmaceutical chemistry. It is a course designed to evolve with the students, gradually equipping them with the necessary tools to excel in their professional lives and to contribute to the advancement of pharmaceutical sciences.

2.1.4 Question Types and Weighting

All exam questions are meticulously crafted to align with the training program for undergraduate students in Pharmacy and the examination outline of the "Organic Reactions for Drug Synthesis" course. This ensures that the assessment is directly relevant to the course objectives and provides a clear roadmap for students to navigate their learning journey.

Definition Explanations: This section tests the foundational knowledge of key terms and concepts within pharmaceutical synthesis. Students are expected to demonstrate not only their retention of definitions but also their ability to articulate the significance of these terms within the broader context of the subject matter.

Completion of Reaction Equations: This component represents the bulk of the exam score, underscoring the importance of understanding and applying the chemical reactions central to pharmaceutical synthesis. Students must correctly complete reaction equations, demonstrating their grasp of reaction mechanisms, reactants, products, and conditions.

Writing the Best Equivalent Reagent or Intermediate: This section assesses the student's ability to select or

propose the most effective reagents or intermediates in a synthesis pathway. It requires a deeper understanding of the strategic aspects of chemical synthesis, including the selection of reagents that can improve yield, and specificity, or simplify the synthesis process.

Synthesis Problems: The synthesis problems are designed to evaluate the student's capacity for creative and logical thinking in a practical context. Students must devise a synthesis route for a given target molecule, taking into account the availability of starting materials, the most efficient sequence of reactions, and the overall synthetic strategy.

2.2 Participants

Since the course "Organic Reactions for Drug Synthesis" is scheduled for students in their third year, students majoring in Pharmacy who have taken this course for three consecutive years at our university are selected as the research subjects. During the research process, due to changes in the number of classes in the major, to ensure comparability, 1-3 classes of the major are selected as research subjects, totaling 396 participants. This study is an analysis of the examination reform over three years (2018, 2019, 2020), with groups divided into the first, second, and third years. In the first year, the traditional closed book exam was used in three classes (N=122), in the second year, the open book exam was used in three classes (N=162), and the traditional closed book exam was reused in three classes in the third year (N=112).

2.3 Data Collection

Throughout the research, to preserve comparability despite variations in the number of classes available, the study specifically targets classes numbered one to three for in - depth analysis. To ensure the consistency of grading, each student's examination paper is evaluated by a minimum of four teachers. The final scores are extracted directly from the institution's academic records system, thereby guaranteeing the integrity and authenticity of the data. Following a thorough analysis, any dubious data points have been meticulously excluded to safeguard the credibility and reliability of the educational outcomes.

2.4 Data Analysis

The exam in the "Organic Reactions for Drug Synthesis" course serves as a pivotal educational assessment tool, providing a comprehensive and objective measure of students' grasp of the theoretical concepts covered in the initial part of the semester. The exam is meticulously designed to reflect the depth and breadth of the course content, ensuring a fair and accurate representation of each student's understanding and analytical capabilities.

The theoretical course exam is scored on a hundred - point scale, a universal academic standard that allows for a detailed and nuanced evaluation of student performance. This scale provides ample granularity to distinguish between varying levels of mastery and to offer targeted feedback for improvement. All data are expressed as mean±SD and obtained from three independent classes. The results are compared using t - tests. All data are statistically analyzed using Origin 2019 b.

3 RESULTS

The "open - book exam" is a common and not a novel examination method. Often, subjects that adopt this examination method tend to see an improvement in students' scores. However, the average scores of the three - year paper exam for "Organic Reactions for Drug Synthesis" were 64.65±4.68, 65.62±3.06, and 66.68±1.48, with a P - value greater than 0.05, indicating no significant difference in the average scores over the three years (Figure 1). This means that the continuous three - year switch in the examination mode from "closed - book" to "open - book" and back to "closed - book" did not significantly affect the students' average scores, nor did it lead to the expected improvement in scores with the "open - book exam". Analyzing this aspect, the reform is considered a "failure". We speculate that this is due to the "open - book" exam, which led some students to allocate less time and energy to this course during their review. Unlike the "open - book" exams for other subjects, "Organic Reactions for Drug Synthesis" involves a large number of structural formulas and reaction schemes, and without serious review, even with an open - book, students would be at a loss on where to start.

The average score is only a part of the parameters reflecting the assessment results; the distribution of exam scores can also reflect the assessment outcomes. The score distribution for the first year is as follows: 100-90 points: 4.33±2.52 people (10.66%); 89-80 points: 4.33±1.53 people (10.66%); 79-70 points: 4.33±2.52 people (10.66%); 69-60 points: 20.67±4.51 people (50.82%); Below 59 points: 7±6.08 people (17.21%) (Figure 2). The score distribution for the second year is as follows: 100-90 points: 2±2 people (3.70%); 89-80 points: 4.67±2.89 people (8.64%); 79-70 points: 13±2.65 people (24.07%); 69-60 points: 20±4.58 people (37.04%); Below 59 points: 14.33±4.93 people (26.54%) (Figure 3). The score distribution for the third year is as follows: 100-90 points: 0.67±1.15 people (1.70%); 89-80 points: 4.67±1.15 people (11.87%); 79-70 points: 8±1.73 people (20.34%); 69-60 points: 17±1.73 people (43.22%); Below 59 points: 9±2.65 people (22.88%) (Figure 4). By comparing the score distribution between the first and second years, the second year has lower scores in the high range (80-100 points) and in the 69-60 point range compared to the first year, seemingly indicating that the "open - book exam" resulted in lower scores. However, by comparing the scores over three consecutive years, it can be seen that the normal distribution of scores in the second year is more uniform compared to the first year (Figure 5).

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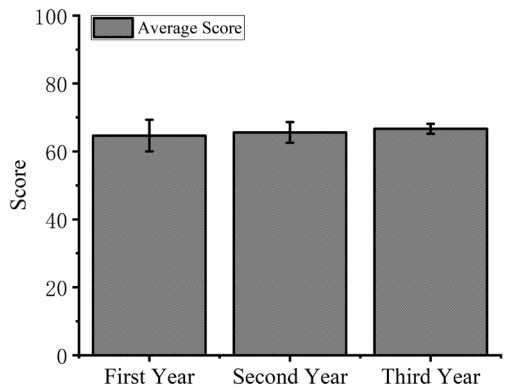

Figure 1. Average exam scores over three consecutive years, with the first year being a closed - book exam, the second year an open - book exam, and the third year a closed - book exam.

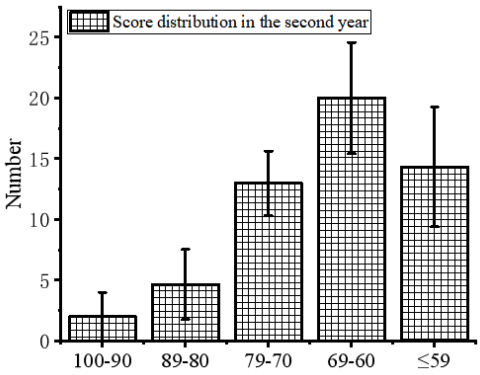

Figure 3. Distribution of exam scores across various score ranges for the second year.

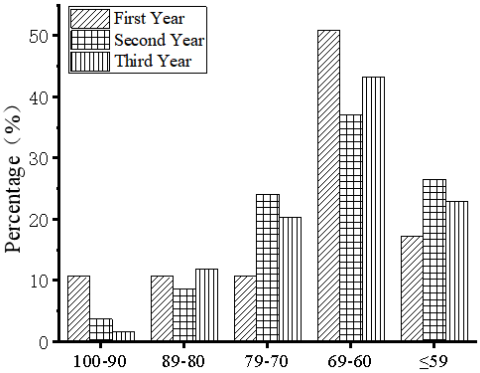

Figure 5. Comparison of score distributions over the three years.

From this perspective, the "open - book exam" appears to be a success.

However, a three - year tracking of the grades in this subject found that although the average scores were similar over the three years and the distribution of the "open - book exam" scores more closely matched the normal distribution, the exam reform did not achieve the desired results, mainly for three reasons[6,7]. First: The difficulty level of the questions over the three years was the same, yet the open - book exam scores were similar, indicating that students

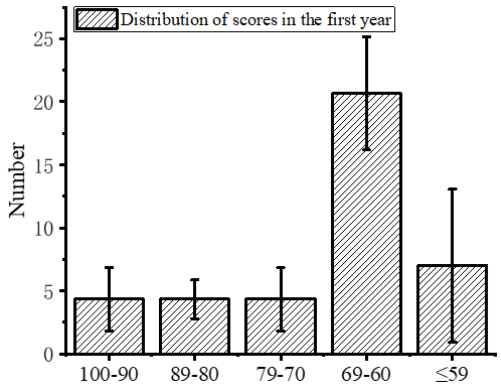

Figure 2. Distribution of exam scores across various score ranges for the first year.

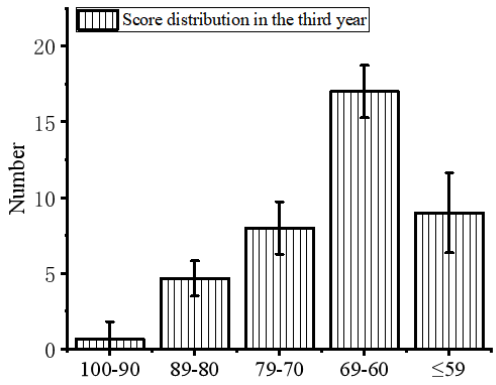

Figure 4. Distribution of exam scores across various score ranges for the third year.

participating in the "open - book exam" had a lower level of knowledge mastery; Second: The number of students with failing grades (below 59 points) was relatively high, indicating that some students underestimated the difficulty of the "open - book exam"; Third: The number of students in the high score range (80-100 points) was relatively low, indicating that some outstanding students also relaxed their review of the subject due to the "open - book exam".

4 DISCUSSION

In the current era of big data, the sheer volume and velocity of information necessitate a fundamental reevaluation of educational paradigms. The "rote memorization" approach to learning and examination is no longer a viable strategy for students who must navigate a sea of constantly updating knowledge points[8]. Instead, the emphasis is shifting towards a "search - application" methodology, which prioritizes the ability to efficiently search for information, critically assess its relevance, and apply it effectively to address real - world challenges.

The emergence of innovative educational models such as the "flipped classroom", "Rain Classroom", and "micro - courses" represents an important step towards fostering a more interactive and student - centered learning environment[9]. These models not only enhance students'

engagement but also equip them with the skills to learn autonomously and collaboratively. The "flipped classroom" model, for instance, allows students to delve into course content at their own pace, while class time is dedicated to discussions, debates, and practical applications, thereby deepening their understanding and retention of the material[3]. However, the mere adoption of these teaching methods is not sufficient to fully address the evolving demands of the digital age. A more profound transformation is required in the domain of course assessment methods. The traditional exam - oriented learning model, which often rewards superficial knowledge and rote memorization, must be restructured to encourage deep learning and the cultivation of applied competencies.

The "open - book exam" in courses like "Organic Reactions for Drug Synthesis" is a case in point. This approach, by allowing students to access resources during the exam, is designed to alleviate the burden of memorization and to promote a more profound engagement with the subject matter. However, an analysis of exam scores over three consecutive years has revealed several areas where the reform has not met expectations.

Firstly, the "open - book exam" requires a different approach to question setting. Questions should be fewer in number but more refined, designed to assess students' analytical skills, their ability to find and synthesize information, and their problem - solving capabilities. The current exam reform has not fully achieved this goal, often resulting in questions that do not effectively measure these higher - order skills.

Secondly, the "open - book exam" may inadvertently lead to a decrease in the rigor of students' preparation. To counteract this, educational institutions must employ strategic communication and pedagogical techniques that underscore the importance of the subject and instill a proper understanding of the "open - book exam" among students. This includes emphasizing the value of deep understanding over superficial knowledge and the importance of developing research and analytical skills.

Thirdly, the teaching model itself must undergo a corresponding reform. Transitioning from a traditional "infusion" model, where knowledge is passively received, to a "guidance" model, where students are actively engaged and guided in their learning, is essential. This shift empowers students to take ownership of their education, fostering a sense of curiosity and a proactive approach to learning.

The university experience is a critical juncture, marking the transition from school to society, from passive to active learning, and from rigid memorization to practical application and innovation. Universities play a pivotal role in cultivating students' logical thinking, creativity, and the ability to apply knowledge in innovative ways, which aligns with the ultimate aim of the exam model reform in subjects like "Organic Reactions for Drug Synthesis". Reform is imperative, yet it is fraught with challenges and resistance. It is a process that cannot be achieved overnight and requires ongoing refinement and commitment. The goal is to identify an examination method that is congruent with the institution's context, the discipline's requirements, and the educational objectives of producing well - rounded professionals.

5 CONCLUSION

In summation, this research stands as a pivotal juncture in the evolving narrative of educational innovation, with a particular emphasis on specialized domains such as "Organic Reactions for Drug Synthesis". It compellingly argues for a departure from the antiquated pedagogical models that have historically hinged on the rote memorization of facts, and instead, it presents a vision for an educational paradigm that is vibrant, interactive, and fundamentally centered on the learner.

The findings of this study shed light on the transformative potential of progressive assessment strategies, suggesting that by incorporating the "search - application" methodology and harnessing the technological advancements of our digital era, we can construct a curriculum that resonates with the learning preferences of today's students and effectively cultivates the sophisticated skill set required by the contemporary labor market.

The implications of this work transcend the boundaries of a single academic course or field of study. It resonates with the wider educational sphere, championing a transformative shift in perspective that regards assessment not as a simple gauge of learning outcomes but as a critical catalyst for the development of critical thinking, problem - solving abilities, and innovative prowess. This approach is essential for the creation of a curriculum that is attuned to the diverse and evolving needs of learners and the dynamic demands of the global economy.

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Conflicts of Interest

The authors declared no conflict of interest.

Author Contribution

Ma J was in charge of Statistical analysis, paper writing

and funding support. Hu J and Jia H were in charge of data organization, statistical analysis and funding support. Liu D and Feng K were in charge of research guidance and data organization.

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