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The impact of interactive clinically-based learning on the performance of medical students in radiology

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ABSTRACT

Objectives: The purpose of this study is to evaluate the effectiveness of changing the teaching method in the radiology course at a medical school from lecture-based learning to clinically case-based learning using interactive methods, with the aim to improve undergraduate radiology education and students' diagnostic abilities.
Methods: During the 2018–2019 academic year, we compared the achievements of medical students in the radiology course. Teaching in the first year was primarily conducted through conventional lectures (traditional course; TC), while in the following year, a case-based teaching approach along with an interactive web application called "Nearpod" (clinically-oriented course; COC) was employed to motivate student participation. The student knowledge assessments were composed of identical post-test questions, which included five images of common diagnoses. The results were compared using Pearson's Chi-Square test or Fisher Exact Test.
Results: There were 72 students who answered the post-test in the first year and 55 students responded in the second year. Post-test student achievements following the methodological changes were significantly higher as compared with the control group in the total grade (65.1 ± 21.5 vs. 40.8 ± 19.1, $p < 0.001$). An improvement in the identification rates of all assessed cases was noticed, with the most prominent improvement in pneumothorax recognition (4.2% vs. 61.8%, $p < 0.001$).
Conclusion: Teaching radiology using clinical case-based teaching methods combined with web-based interactive applications like Nearpod results in significant improvements in identifying key imaging pathologies when compared to traditional teaching methods. This approach has the potential to enhance radiology learning and better prepare students for their future roles as clinicians.

1. Introduction

In recent decades, a significant transformation has taken place in the approach to medical education, where the traditional method of passive learning through lectures has been replaced with student-centered, active learning methodologies that utilize a variety of innovative teaching methods [1–3]. Rather than memorizing information and taking notes solely for the purpose of preparing for tests, this approach encourages students to engage in critical thinking, analysis, and integration of knowledge. Numerous studies have demonstrated the efficacy of such active learning techniques in enhancing students' academic performance [4–9].

Radiology education has been part of the general trend with numerous studies addressing this important issue. To further advance radiology education, the Radiology Research Alliance Task Force on Noninterpretive Skills, a sub-group of the Association of University Radiologists, conducted a comprehensive review of several innovative teaching methodologies with the objective of enhancing the traditional radiology lecture format [10]. However, this review, while informative and providing practical suggestions, lacks an empirical study that directly compares these methodologies.

The advantages of these and other methodologies remain a subject of debate and yield inconclusive results in the literature. In their review, Zafar et al. [11] conducted a comprehensive literature analysis with the goal of assessing the outcomes presented in the literature, while also examining the characteristics and elements of e-Learning interventions employed in undergraduate radiology education. They determined that no specific research illustrated a performance change in clinical practice or patient outcome. Nevertheless, other studies [12,13], primarily focused on the flipped classroom model, demonstrated its association

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with enhanced academic achievement, increased task value, and more positive achievement emotions.

At our institution, undergraduate radiology education has conventionally been conducted through traditional didactic education, primarily consisting of presentations and frontal lectures on introductory radiology topics, approaches, and selected clinical cases. In recent years, student course satisfaction questionnaires have consistently indicated dissatisfaction with this approach, with concerns that the course material was insufficient and difficult to integrate into clinical rounds. In line with the prevailing trend in medical education, we have restructured the traditional didactic education employed in the course by incorporating interactive clinical and case-based methodologies, alongside with basic introductory lectures. Additionally, we integrated a web application (NEARPOD) that allows presenting an image and prompting students to mark the lesion on their personal screen, simulating a "real-life" radiologist's clinical work. This encourages students to diagnose based on presented images, thereby fostering student engagement, and facilitating active learning. To the best of our knowledge, only Huang et al. [14] employed a similar methodology, and while innovative, their study solely assessed student responses without evaluating academic achievements.

We hypothesized that by changing undergraduate radiology education into active and clinically oriented learning, in addition to placing students in the "radiologist's chair," would simulate the radiologist's role in image interpretation and diagnostic decision-making. This change would ultimately result in enhanced student satisfaction and improved diagnostic performance in imaging.

2. Methods

2.1. Teaching methodology and classes

At our institution, the medical school is a six-year program accredited by the Israeli Council for Higher Education. Traditionally, the radiology course is taught during the fourth year and consists of lectures delivered via presentations, covering topics such as introduction to radiology, neuroradiology, chest, abdominal, and musculoskeletal imaging. These lectures are conducted by attending radiologists and last between two and three academic hours. The lecture content primarily focuses on an introduction and approach to the topic, accompanied by examples of images and pathologies.

The current study was carried out during the radiology course for two cohorts (class of 2018 and class of 2019) at our institution, following the approval of the institution's ethics committee.

Beginning with the class of 2019, the radiology course underwent restructuring. In the redesigned course, attending radiologists delivered introductory lectures on the same topics (neuro-, chest-, abdomen-, and MSK-radiology), which were then followed by case-based active learning sessions facilitated by residents. To accommodate scheduling constraints, the introductory lectures were shortened to one to two hours, while the case-based practice sessions lasted one to two hours. The residents who led these practice sessions were in their third year of residency or beyond. The practice sessions incorporated real-life cases from each topic selected from daily work. Cases were presented with clinical details, followed by imaging.

Images were displayed using an interactive online platform called Nearpod, which enables educators to create and deliver engaging multimedia presentations, lessons, and assessments to their students. Students could access Nearpod lessons through any internet-connected device, such as a computer, tablet, or smartphone. For the current study, Nearpod provides the unique capability of presenting an image to the student and asking them to identify and mark the lesion on their personal screen, thereby simulating the work of a radiologist in real-life situations. Moreover, during the lessons, other interactive features were used, including polls, quizzes, and open-ended questions to further enrich the students' learning experiences. After completing tasks, discussions took place concerning the description of the lesion, differential diagnosis, and subsequent management options (Fig. 1).

2.2. Post-course examination

Following the completion of each course, a post-test was administered. This voluntary and anonymous test remained consistent for both classes. Five diagnoses were selected that were deemed fundamental and should be familiar to all medical students (pneumonia, pneumothorax, normal CXR, and CT images of ischemic stroke and subdural hematoma). Students were presented with the cases on a screen and asked to choose the correct diagnosis from a list of provided options.

2.3. Statistical analysis and considerations

The results obtained from the post-course tests were compared using Person's Chi Square test. In the specific case of pneumonia detection, we used Fisher Exact Test for group comparison given the high successful detection rates in both courses which left the expected count of 50% of the cells under the value of 5.

In order to minimize possible confounding effects due to interclass variations, medical school admission scores were compared between the classes, as well as each student's performance during the three years prior to the current course using repeated-measure ANOVA with class as the between subject factor and year as the within subject factor.

To ascertain the source of the difference between the classes, we compared the distributions of the average grades of the two classes using a two sample Kolmogorov-Smirnov test.

3. Results

In the class of 2018 (traditional course, TC), 72 students participated in the post-course test, compared to 55 students in the class of 2019 (clinically-oriented course, COC).

The results of both tests are summarized in Table 1. As demonstrated, the total grade for the COC class was significantly higher compared to the TC class (65.1 ± 21.5 vs. 40.8 ± 19.1, $p < 0.001$). An improvement in the identification rates of all assessed cases was observed between the TC and COC classes, favoring the COC. While this improvement was minimal in the case of pneumonia (93.1% in the TC class vs. 94.5% in the COC class, $p = 1$), it was considerably more pronounced in the rates of pneumothorax recognition (4.2% in the TC class vs. 61.8% in the COC class, $p < 0.001$).

To account for the possibility that the 2019 class performed better in the radiology post-test due to higher overall grades, we compared the

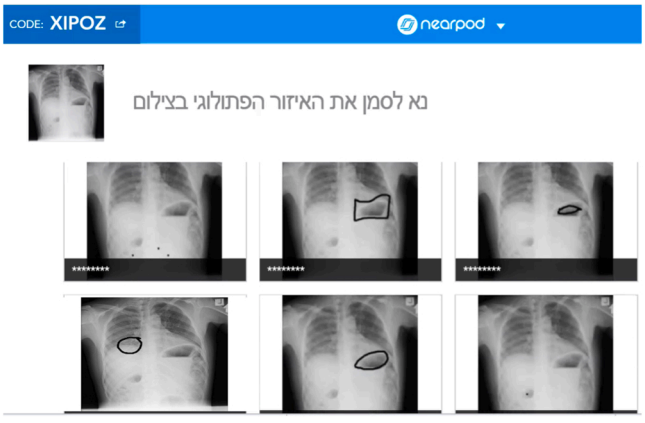

Fig. 1. A screenshot from the Nearpod app during chest case-based practice. Students are instructed to mark the lesion on the image (Hebrew text at the top, original image at the top left). The six images below display the markings made by students on their personal screens as they attempt to identify the lesion.

Table 1
Comparison of the results obtained in each year from the post-course tests.

Variable	Clinically-oriented course (n = 55)	Traditional course (n = 72)	P-value
Pneumothorax, n (%)	34 (61.8%)	3 (4.2%)	**< 0.001**
Normal, n (%)	30 (54.5%)	24 (33.3%)	**0.02**
Pneumonia, n (%)	52 (94.5%)	67 (93.1%)	1
Subdural hemorrhage, n (%)	32 (58.2%)	31 (43.1%)	0.09
Stroke, n (%)	31 (56.4%)	22 (30.6%)	**0.003**
Total grade, mean (SD)	65.1 (21.5)	40.8 (19.1)	**< 0.001**

students' achievements in the previous years. An analysis of each class's prior achievements revealed a significant yet minor difference in the average grade between the classes (83.52 ± 0.02 for TC vs. 84.7 ± 0.02 for COC, p = 0.001). Furthermore, a comparison of the average grade distribution over the three years preceding the course showed only minor differences between the two classes, as illustrated in Fig. 2.

4. Discussion

The results of our study showed a significant improvement in the total grade for the COC compared to the TC. An improvement in the identification rates of all assessed cases was observed between the TC and COC classes, favoring the COC. These results support our hypothesis, suggesting that the incorporation of active and clinically oriented learning methods in undergraduate radiology education can lead to improved students' learning outcomes.

A number of studies have investigated the benefits of utilizing innovative teaching methods instead of traditional lectures for undergraduate students in medical education and other fields [4–9]. Many of these studies have focused on measuring student satisfaction rather than assessing their academic or clinical performance. Within the realm of radiology education, the Radiology Research Alliance Task Force on Noninterpretive Skills conducted a comprehensive review of various innovative teaching methods. These included the use of audience response technology, remote teaching, the flipped classroom model, and active learning strategies [10]. The task force concluded that integrating these methods could potentially yield more interactive, engaging, and effective educational experiences. However, similar to the limitations found in previous studies, this review offered practical implementation advice but did not measure the impact of these methodologies on student academic performance or clinical competency.

Despite the potential advantages of these and other methodologies, literature findings are inconclusive. Some research has found no significant improvement in academic achievements [11], while other studies have reported positive results [12,13]. Our approach to radiology education is unique in that we employed the NEARPOD app to simulate the experience of a "real-life" radiologist, fostering a more engaging learning environment. While Huang et al. [14] utilized a similar methodology, their study primarily evaluated student satisfaction rather than diagnostic performance in imaging, which is the focus of our research. This distinction highlights the potential value of our study in demonstrating the impact of innovative teaching methods on students' diagnostic abilities in radiology education.

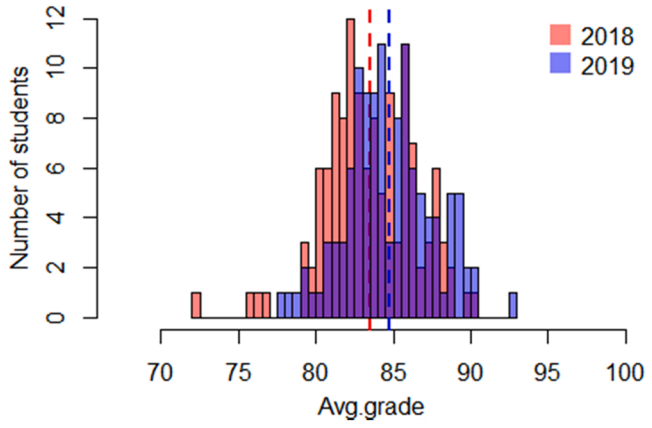

Fig. 2. The distribution of the average grade (over 3 years) of students of class 2018 and 2019. Dashed lines represent the mean grade of each class.

Several factors within the revised course may have contributed to the observed improvements in our study. Firstly, in line with the positive outcomes reported in existing literature [4–9, 12–13], the transition from traditional lecture-based learning to integrated, clinically-oriented, case-based learning promotes active engagement among students, encouraging them to think and analyze the material rather than passively listening and memorizing information. This approach is likely to result in better knowledge retention and understanding. The successful implementation of these innovative teaching methods in our study further supports the broader trend in medical education towards more interactive and engaging learning experiences.

In addition to the shift towards clinically-oriented, case-based learning, our study incorporated the innovative use of the NEARPOD app for interactive learning, which allowed students to simulate the work of a radiologist by presenting images and asking them to identify and mark lesions without relying on multiple-choice questions. This unique approach, specifically tailored to radiology education, further engages, and motivates students, ultimately enhancing their diagnostic skills. The contrasting performance of students in recognizing pneumonia and pneumothorax, with marked improvement observed in pneumothorax identification and minimal change in pneumonia detection, may be attributed to the inherent difficulty in discerning subtle pneumothorax cases. The hands-on experience provided by our revised course proved particularly valuable in such instances, compared to the more easily detectable pneumonia cases. This highlights the potential benefits of incorporating practical, interactive learning experiences in radiology education.

Another possible factor contributing to the improved outcomes observed in the COC is that the case-based learning approach places radiology at the heart of patient management, rather than simply being viewed as a service provider. This perspective shift motivates students to actively participate in the learning process and fosters a deeper understanding of the integral role radiology plays in patient care, which in turn may lead to better academic achievements.

It is important to recognize the limitations of the present study and consider their potential impact on the results. First, our findings are based on data from a single institution and a relatively small sample size. Additionally, we did not evaluate long-term retention of the learned material or its impact on clinical practice. Future studies should address these limitations by involving multiple institutions, larger sample sizes, and assessing long-term retention and effects on clinical practice. Another limitation of the current study is the possibility that the overall academic performance may differ between the two classes, which could act as a confounding factor for the observed superiority of the COC students. To minimize the impact of this limitation, we analyzed the students' performance in previous years of medical school, which revealed a marginally higher general grade average among the class of 2019. Although this might have contributed to the improved radiology performance observed, we believe that the statistically significant difference between the classes, albeit minimal (half a point), is unlikely to be the primary factor explaining the disparity in achievements between the two classes in the context of the radiology course.

5. Conclusion

In conclusion, our study demonstrates that incorporating a clinical case-based approach and web-based interactive applications in

undergraduate radiology education leads to significant improvements in learning, particularly in the identification of key imaging pathologies. Our findings suggest that educators should consider adopting innovative teaching methodologies in radiology education to enrich the learning experience and better prepare students for their future roles as clinicians.

CRediT authorship contribution statement

Shelef Ilan: Supervision, Methodology, Conceptualization. **Lior Yotam:** Formal analysis. **wachsman uriel:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Ben-Arie Gal:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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