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ORIGINAL RESEARCH ARTICLE

Assessing the feasibility and outcomes of asynchronous and synchronous learning in nuclear medicine for medical students

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ABSTRACT

Introduction: Although both asynchronous and synchronous online learning have gained significant popularity in medical education, there have only been a few studies comparing the effectiveness of these two modalities.

Methods: We compared the exam scores, the proportions of students who scored below the minimal passing levels, and the satisfaction levels of medical students who attended asynchronous online nuclear medicine courses to those who attended synchronous ones.

Results: The asynchronous and the synchronous classes were attended by 241 and 268 students, respectively. The median score of the asynchronous class (Median=16, IQR=3) was not significantly different (p=0.859) from that of the synchronous class (Median=15, IQR=3). The percentage of students who scored below the minimum passing level in the asynchronous class (5.60%) was significantly higher (p=0.033) than that of the synchronous class (1.66%). Only 55 students from the asynchronous class (22.8%), and 12 students from the synchronous class (4.48%) returned the satisfaction questionnaires. From the available responses, we did not find significant difference between the satisfaction levels of the two classes.

Conclusion: We found no significant difference in exam scores and satisfaction levels between asynchronous and synchronous online nuclear medicine courses for medical students. However, the asynchronous class had a higher proportion of students scoring below passing levels, which could imply caution needed when implementing online asynchronous teaching methods.

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INTRODUCTION

Online learning is a mode of technology-enhanced learning that has been gaining an increasingly important role in radiology and nuclear medicine education in recent years [1]. This mode of learning provides students with convenient access to course materials through the internet. Within this realm, two primary approaches have been employed: asynchronous and synchronous. Asynchronous online learning offers students the flexibility to study at their own pace and create a personalized schedule that aligns with their learning style. Conversely, synchronous online learning allows students to cooperate with their peers, interact with their instructors, and fosters students' engagement in discussions.

The comparative effectiveness between asynchronous and synchronous online learning remains a matter of debate. Previous studies comparing asynchronous and synchronous online learning yielded inconsistent results. Some studies suggested that synchronous approaches resulted in better academic performance among medical students [2, 3], while others suggested that learners in asynchronous environments could obtain comparable knowledge, benefiting from the self-paced nature of the courses [4, 5]. Despite the exponential proliferation of these studies during the coronavirus disease 2019 (COVID-19) pandemic, there has yet to be conclusive evidence on this matter [6].

Almost all previous studies primarily compared asynchronous online experiences to synchronous in-person experiences. As a result, their findings may not be fully applicable to synchronous online learning, which has its own distinct characteristics and challenges. For example, synchronous online learning requires a reliable infrastructure, including a stable high-speed internet connection, compatible client devices, and an appropriate learning environment [7]. Furthermore, multiple studies have also reported that prolonged synchronous online learning can be psychologically draining, leading to a significant loss of focus and attention among students [8].

Unfortunately, some studies assessed the effectiveness of each learning experience using self-reported questionnaires. Those questionnaires asked whether the students felt they had acquired knowledge after their learning, which are not objective tools for assessment. In the Kirkpatrick model of evaluation, learners' perceptions obtained from questionnaire are considered within the reaction level. While learners' feedback is undoubtedly valuable, it cannot provide unbiased information on the knowledge acquired during the learning process.[9]

This study aimed to compare the examination scores of medical students who participated in an asynchronous online nuclear medicine course with those who enrolled in a synchronous online counterpart. We also seek to gather insights into students' experiences and perceptions through satisfaction questionnaires, which could provide a holistic evaluation of each educational approach and would be valuable in the context of online learning implementation.

METHODS

Study design and participants

This study was a retrospective causal-comparative study that was approved by the institutional review board (COA No. 052/2022). The analysis included scores from all students in each class, and a sample size calculation was performed to ensure statistical power. The sample size calculation was based on reported scores from a similar study, which suggested that the average percentage scores for the asynchronous class were approximately 90.2%, with a standard deviation (SD) of 5.03%, while the average percentage scores and SD for the synchronous class were approximately 77.5% and 10.2%, respectively [10]. The sample size was calculated with an α value of 0.05 and a desired power of 0.80, using an equation for estimating sample size and power when comparing two means [11]. The result indicated a minimum required sample size of 11 for generalization to the population.

Participants

The participants were third-year medical students in a 6-year Doctor of Medicine program from Faculty of Medicine, Chulalongkorn University.

Setting

The study took place in the Faculty of Medicine, Chulalongkorn University. The nuclear medicine course is a mandatory course that was intended to provide medical students with a basic understanding of nuclear medicine imaging and radionuclide therapy. The course was one week long and consisted of 11 lecture-based teaching sessions taught by board-certified nuclear medicine physicians. Each session was approximately 45-60 minutes long. The 11 sessions were an introduction to nuclear medicine, dual energy x-ray absorptiometry, the thyroid gland, the skeletal system, the lymphovascular system, the gastrointestinal

system, the urinary system, the hepatobiliary system, nuclear cardiology, nuclear neurology, and nuclear oncology. All sessions were primarily assisted with a visual presentation software (PowerPoint, Microsoft Corporation, Washington, USA).

Two groups of students enrolled in nuclear medicine courses were included in this study. One group enrolled in early 2021, and the other in early 2022. Both groups have completed same mandatory courses during their first to third year of medical school. The 2021 cohort engaged in asynchronous online learning sessions, whereas the 2022 cohort participated in synchronous online sessions. The decision to assign asynchronous sessions to the 2021 cohort and synchronous sessions to the 2022 cohort was made by the course committee based on the COVID-19 situation and the government lockdown policies during each time period. The course committee was a panel of two nuclear medicine physicians and two radiation oncologists with years of teaching experience. The asynchronous class was structured so that each instructor provided prerecorded lectures that were available to students on the learning management system from the beginning of the course to the examination date. Students received a guidebook containing a recommended learning schedule (Figure 1A). The recommended schedule was also designed by the same course committee. However, students could adjust the schedule according to their own learning pace and preferences. The students were encouraged to participate in 2 channels of communication. The first channel was an anonymous chatroom on an instant messaging platform (OpenChat, LINE Corporation, Japan). Two of the 8 instructors were present in the chatroom and could answer students' questions directly. A teaching assistant was also present in the chatroom and could relay student questions to other instructors if necessary. The second communication channel was a one-hour teleconference session at the end of the course that was held on an online conferencing platform (Zoom, Zoom Corporation, USA). All students and all instructors joined the sessions, where students could ask their questions verbally and have discussions with instructors and their peers.

In the synchronous class, the instructors conducted lecture sessions on the Zoom online conferencing platform. Students and instructors could interact through the built-in messaging function (Figure 1B). Two of the instructors used the Mentimeter (Mentimeter Company, Sweden) audience response system to promote class participation. The system allowed two-way communication by the function of real-time polling and brainstorming. Recordings of the teaching sessions were available in the learning management system from one week after each session until the examination date. Students were encouraged to email the instructor or the teaching assistant if they needed clarification on any class content. The anonymous instant messaging platform and the teleconference session at the end of the course were not available to the synchronous class.

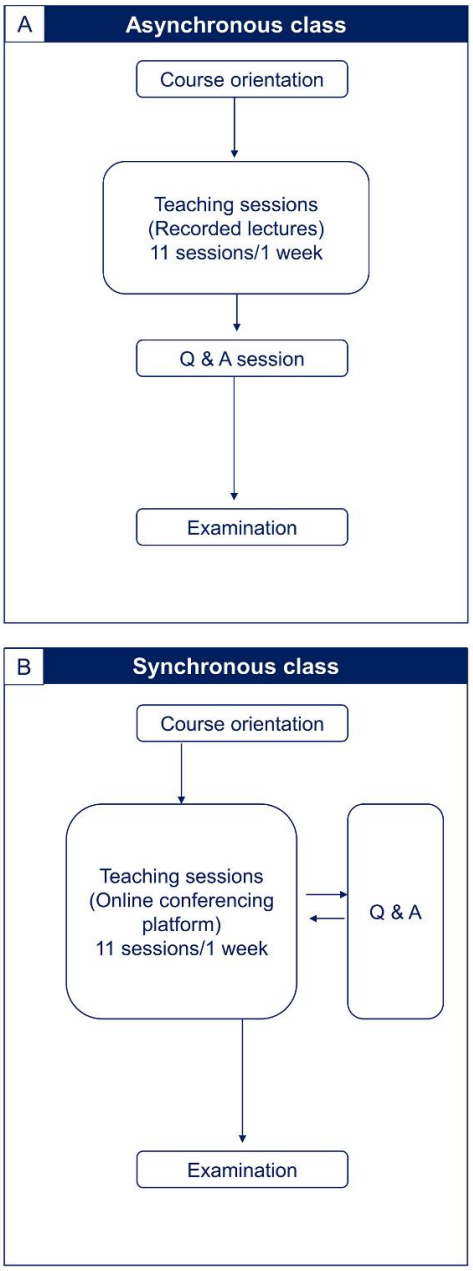

Figure 1. Diagram illustrating the learning experiences of the asynchronous (A) and the synchronous (B) class

Measurement of outcomes

The scores of summative exams represent the outcome at the learning level. The students took the exam approximately eight weeks after their respective teaching sessions. The exam consisted of 20 multiple choice questions with a single best answer for each question, equating to a total score of 20. The table of specification and the item analyses result can be found in the Supplementary materials. For the purposes of this investigation, we defined a minimum passing level as 60% of the score achieved by the 95th percentile student in each class, which are sometimes referred to as the modified Cohen method, which should be able to accounts for the minor differences on the occult heterogeneity in students' baseline knowledge and item difficulty between the two cohorts [12].

The responses from the satisfaction questionnaires represent the outcome at the reaction level. The teaching assistant distributed anonymous questionnaires to the students at the end of each class using an online survey platform (Google Forms, Alphabet Inc, California, USA). The questionnaires addressed the satisfaction levels and the perceptions of the students based on five Likert items and a free text comment.

Statistical analysis

All statistical analyses were performed using R statistical software packages. Formal comparisons of categorical variables between groups were made with Chi-square or Fisher's exact test, as appropriate. Continuous data were described as either mean with standard deviation or median with interquartile range (IQ) and formal comparisons were made with Student's t test or Mann–Whitney U test, as appropriate. A p-value of <0.05 was considered statistically significant.

RESULTS

Participants

There were 241 students in the asynchronous class and 268 students in the synchronous class, all of whom were third-year medical students in a six-year Doctor of Medicine program and had completed all the same mandatory courses for their first and second years. All students in both classes took the summative exam, with 55 students (22.8%) from the asynchronous class and 12 students (4.48%) from the synchronous class responding to the questionnaires.

Eight instructors participated in the asynchronous class and seven instructors participated in the synchronous class. Five of the 11 teaching sessions were taught by the same five instructors (Table 1).

In the asynchronous class, instructors and the teaching assistant noticed that students posted quite a few questions in the anonymous instant messaging chatroom. Questions about learning content appeared on approximately every other learning topic, and approximately 5-6 misunderstandings were clarified during the end-of-course teleconference. In the synchronous class, students asked 2-3 questions per topic. They asked questions verbally or through the text messaging function of the teleconference software. The teaching assistant noticed that some specific attendees dominated the verbal questions. No emails were sent to the instructors or the teaching assistant.

Table 1: Summary of comments and suggestions from the satisfaction questionnaires

Asynchronous class	Synchronous class
- The recommended schedule is too crowded.	- Prolonged sitting in front of a screen can be overwhelming. Synchronous live sessions should not last more than 4 hours per day, as spending more time can lead to a decrease in motivation, sadness, and hopelessness.
- Some sessions are more suitable for live sessions than recorded.	- Breaks between teaching sessions should alleviate stress.
- The time needed for learning is usually longer than the length of the recording, and with very little time to digest, it becomes difficult to catch up with the class or come up with questions for the live teleconferencing sessions.	- Questions from some classmates disrupted the flow of class content.
- The anonymous instant messaging chatroom is very helpful and confidential.	- The absence of an anonymous communication channel for questions discourages students from asking questions.
- The lack of self-discipline is a major barrier to learning in this mode.	

Examination scores

The median score of the asynchronous class was 16 (IQR=3). The median score of the synchronous class was 15 (IQR=3). The difference in scores between the two classes was not statistically significant (U=30532, p=0.859) (Figure 2).

The subgroup analyses of scores from the teaching sessions taught by the same instructors showed heterogeneous results. In sessions such as the thyroid gland (U=37230, p<0.001) and nuclear oncology (U=36918, p<0.001), the examination scores of the asynchronous class were higher. In other sessions, including the skeletal system (U=28191, p=0.001) and the lymphovascular system (U=10088, p<0.001), the examination scores of the synchronous class were higher. The examination scores of the two classes from the introduction to nuclear medicine session (U=31810, p=0.500) were not significantly different (Figure 3).

The minimum passing level of the asynchronous class was 11.4 and the minimum passing level of the synchronous class was 10.8. Fifteen students (5.60%) in the asynchronous class had examination scores below the minimum passing level, and 4 students (1.66%) in the synchronous class had examination scores below the minimum passing level. The proportion of students who had examination score below the minimum passing level was larger in the asynchronous class (X^2 (1, N=509)=4.43, p=0.033).

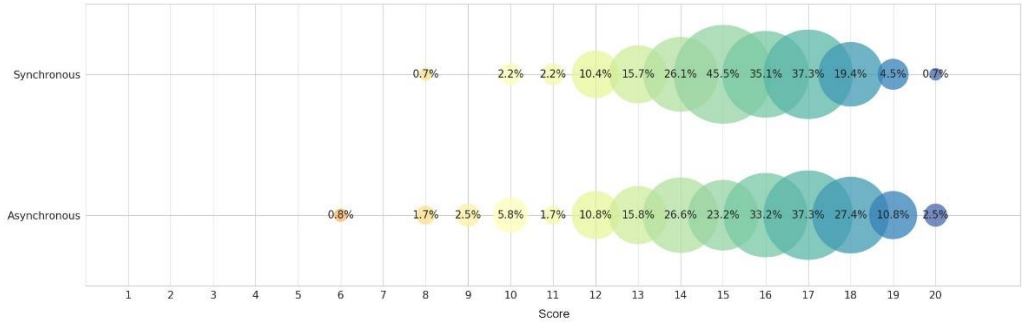

Figure 2. A balloon plot showing the score distribution of students in the asynchronous and the synchronous class

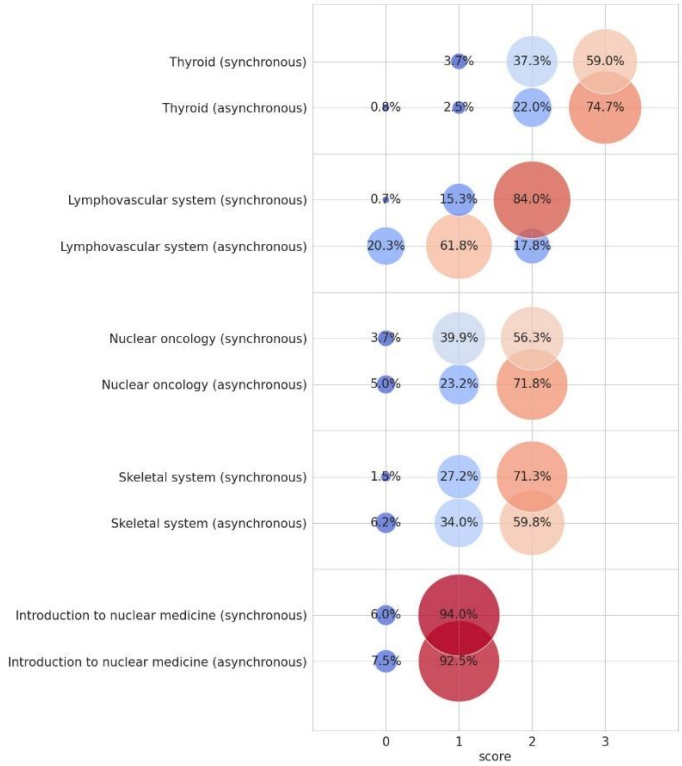

Figure 3. A balloon plot detailing the score of examination items by topics that were taught by the same instructors, including an introduction to nuclear medicine, (1 item), the skeletal system (2 items), nuclear oncology (2 items), the lymphovascular system (2 items) and the thyroid gland (3 items)

Satisfaction level

We found no significant differences between the satisfaction levels in the objectives of the course (p=0.389), the instructors (p=0.342), the knowledge gained (p=0.786), the learning materials (p=0.622) or the duration of the session (p=0.696) (Figure 4). Some of the notable free-text comments are summarized in Table 1.

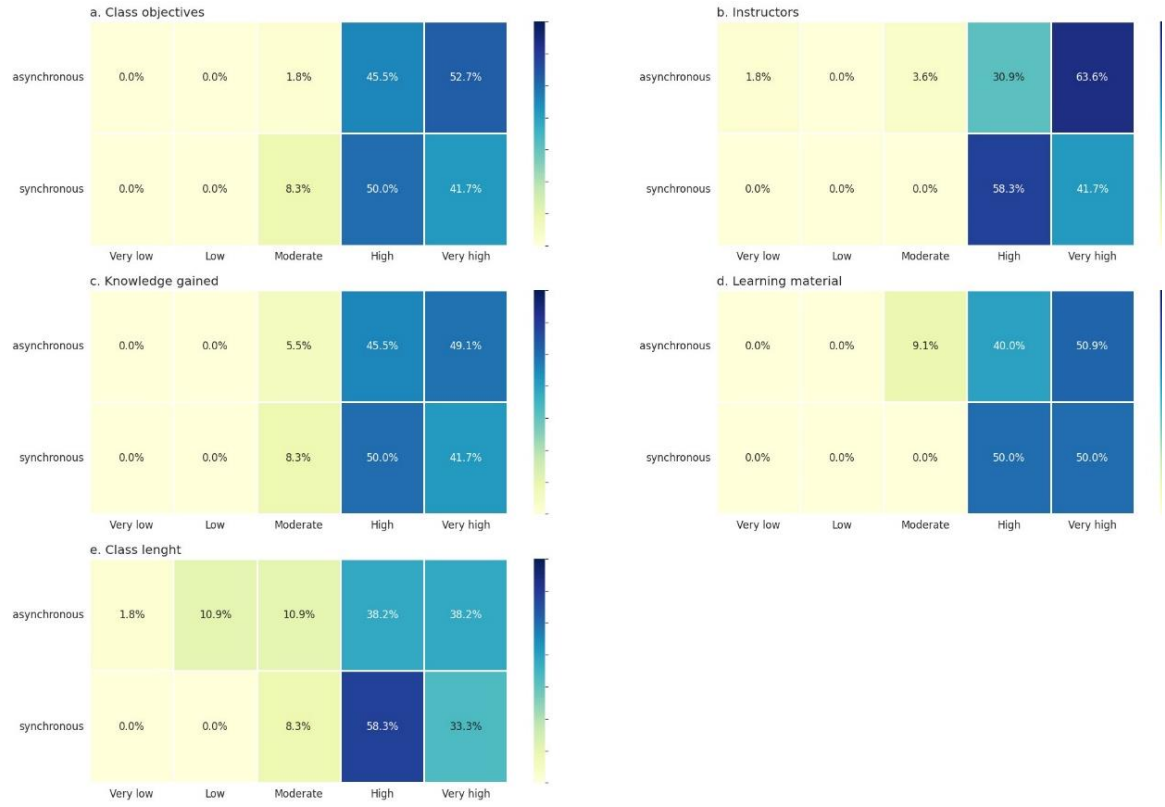

Figure 4. Responses from satisfaction questionnaires. The Likert items in the questionnaires were presented as "Please rate your satisfaction regarding the following areas in this course: class objectives, instructors, knowledge gained, learning materials, and class length". Each column represents 5 satisfaction levels by the respondents in percentages

DISCUSSION

Regarding the examination scores, we did not find significant difference in overall examination scores between the asynchronous and the synchronous class. However, a higher proportion of asynchronous students scored below their minimal passing level. There were also varying outcomes in different teaching sessions, with students in the synchronous class demonstrating superior performance in specific sessions, with students in the synchronous class scored better in some and students in the asynchronous class scored better in others.

Our findings suggested that while the two learning modes might lead to similar overall learning outcomes, the asynchronous learning environment could present certain challenges for some students, evidenced by the higher proportion of students in the asynchronous class who scored below the minimal passing level.

The fact that some teaching sessions witnessed superior examination scores from students in the synchronous class, while in other sessions, students in the asynchronous class scored better may highlight that the possible effects of individual instructors or the content covered in specific teaching sessions on the effectiveness of each learning mode.

In contrast to several prior studies, our investigation reveals no significant disparities in examination scores between the asynchronous and synchronous classes. For example, a study in 2022 compared 3 radiology rotations of clerkship medical students, including an asynchronous online rotation, a synchronous in-person rotation, and a rotation with a combination of asynchronous online and synchronous in-person learning. That study concluded that students who enrolled in the asynchronous online rotation had

examination scores lower than the two other rotations [5].

Other studies likewise reported that medical students in synchronous learning environment scored better in cardiovascular physiology and emergency medicine [2,3]. This discordance in results may be attributed to the differences between synchronous in-person and synchronous online learning because synchronous online learning possessed unique challenges that are not present in in-person learning environments [7].

The higher proportion of students in the asynchronous class who scored below the minimal passing level is concordant with the challenges of asynchronous online learning that have been reported in several prior studies such self-discipline, time management skills, and the ability to effectively utilize self-regulated learning [13, 14].

A few limitations should be considered for the applications of this study's result. First, more than half of the teaching sessions were taught by different instructors, which could confound the examination scores due to the effects of individual instructors and teaching styles [15]. Secondly, the synchronous class could experience asynchronous learning mode by accessing recorded lectures available in the learning management system. Because our learning management system lacked viewing record logs, we could not estimate the frequency of such occurrences and to what extent it affected the examination score of the students. Thirdly, although all students had completed the mandatory and the pre-requisite courses in accordance with the curriculum in our center, there could be the difference in baseline knowledge and competency that could affect the learning outcomes of this course. Finally, because the response rate of the questionnaires was very low in this study, the information on the satisfaction level should be interpreted with substantial caution.

As the role of online learning in radiology and nuclear medicine education has become increasingly significant [1, 4, 16], the findings of this study can provide useful information contributing to the ongoing discourse on the effectiveness of asynchronous and synchronous online learning. There remain some challenges to improve the effectiveness of online learning, both asynchronous and synchronous. Additional studies are also needed to clarify the exact reason why some students in the asynchronous class scored below the minimal passing levels and to determine the effect of different instructors on the effectiveness of online learning.

CONCLUSION

This study compared the examination scores of medical students participating in asynchronous and synchronous nuclear medicine classes. The results did not reveal significant difference in median scores between the two groups. However, a higher percentage of students in the asynchronous class scored below the minimal passing level, suggesting potential challenges in that learning environment. Therefore, both asynchronous and synchronous online learning can be used to deliver nuclear medicine course for medical students, but special caution should be paid to students, particularly in an asynchronous environment to ensure they achieve sufficient proficiency.

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