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ORIGINAL RESEARCH

Participation and Interactivity in Synchronous E-Learning Pathology Course During the COVID-19 Pandemic

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Purpose of the Article: Due to the COVID-19 outbreak, educational institutions had to utilize online platform solutions to deliver their curriculum. We conducted this study to explore participation and interactivity in a synchronous e-learning non-mandatory participation course in pathology at a medical school in Greece. The knowledge acquired is expected to be instrumental in the development of educational practices.

Materials and Methods: The data for this study were gathered through the recorded video archives of the synchronous e-lessons. We observed online participation at seven time points during each of the assessed e-lessons. Moreover, we identified and categorized the professor's/students' interactivity patterns according to content.

Results: The maximum number of students participating in the first e-lesson was N = 196. We recorded a reduction of N = 91 students, approximately 46%, in maximum student participants from the second observed e-lesson, and an additional decrease of N = 28 students, approximately 27%, from the third observation. Participation numbers continued to lessen. Even though there was a statistically significant difference in the mean percentage of students participating between the seven time points of each e-lesson, the difference in the mean percentage of students' online participation between the seven e-lessons assessed was not statistically significant. This indicates a consistent e-audience. Evidence of interactivity was summarized in a table, and each professor–students interaction was classified according to its content. We found that the professor posed questions to his students every 2–5 minutes during every synchronous e-lesson and e-tutorial observed, and students wrote 3–6 answers in chat in response to each question. Students asked more questions as more synchronous e-learning classes took place, with limited exceptions.

Conclusion: From our perspective, our observations set the basis for further research to enhance our understanding of the aspects of the e-learning environment towards the formulation of policies for higher-quality education.

Plain Text: Our pathology department places high value on the quality of education that the medical students receive. Due to the COVID-19 pandemic, our department had to deploy e-learning modalities for curriculum delivery. Thus, we conducted this research to evaluate a pathology e-learning class in terms of students' participation and the interactivity dynamics between them and the professor. We used statistics to measure participation during each e-lesson and identified recurring patterns of interactivity. We avoided imposing our predetermined interpretations of the data in this study so as to present an accurate depiction of the aspects of the e-learning environment. We were very pleased to identify a steady e-audience despite the drop-out rate from one e-lesson to the next, as well as strong, increasing interactivity patterns between the students and the professor, as students posed more and more questions from one e-lesson to the next. We are looking forward to future studies that address the e-learning procedure's challenges and provide evidence of its effectiveness and quality.

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Introduction

The consequences of the COVID-19 pandemic have affected every aspect of social life, including the operation of educational institutions worldwide. New laws that were implemented (urgent measures employed to protect public health from the risk of further transmission of the coronavirus disease) forced universities to shift to online learning and suspend any kind of educational process involving physical presence regardless of the number of students. In Greece, the physical closure of higher education institutes has been legislated since the beginning of the academic year 2020–2021.[1] Under these circumstances, policy makers and educational institutes faced unprecedented challenges, such as how to mitigate learning losses and how to deploy remote learning. Curriculum delivery and assessment of students had to change; medical professors and students were suddenly forced to become more resilient and adapt to e-learning forms, utilizing online telecommunication platforms in order for academic studies to be normally continued at a consistent quality.

This research is focused on the synchronous online participation of undergraduate medical students on a pathology course at the School of Medicine, University of Athens during the autumn/winter semester 2020, during which students were invited to attend all their courses in virtual classrooms ("e-classes"). They did not have the choice to attend the class physically; they had to follow the implemented e-learning procedures throughout the semester. It has been mentioned[2] that a completely web-based approach faces challenges to online participation. Moreover, online participation is considered intertwined with interaction.[3] Our research focuses on both of these parameters of online lessons.

Our effort was to measure students' online participation in an attempt to assess whether there has been a statistically significant "drop-out" rate. The beneficial effects of online participation in terms of encouraging student involvement have been explored.[4,5] The learners' access rhythm was identified and measured as online participation in which online discussions occurred.[5–7] Online participation was measured by how many times students had logged on.[8,9] Some researchers aim to further study more complex dimensions of participation, such as whether participants feel they are taking part as they interact.[10]

Our challenge was to measure systematically and in detail online student attendance within the flexible context of synchronous e-learning, which was strictly implemented for the first time. As well as students' participation, our research focused on the interactivity between the professor and the students within the same pathology e-course during the autumn/winter semester 2020. Interaction is an important factor to consider in terms of e-learning medical courses,[11] and there are studies that have previously examined interactive modules in that field.[12–16] For the synchronous interaction activities, the instructor has to ask all students to be online at a certain time and must moderate large-scale conversations.[17] This is considered the practical difficulty that has led few studies to examine learners' synchronous interaction activities.[18] Additionally, there is a lack of studies on students' synchronous interaction behaviors in the context of distributed environments.[3] It is important to note that interactivity within education procedures has already been explored for previous pathology studies in our department, both in the conventional classroom and a laboratory based-setting, as well as in the asynchronous e-learning platform HIPON (HistoPathology Online) launched at the beginning of 2013. This interactive training platform deals with general and systemic pathology. It offers virtual slides, case studies, training videos, and image records, as well as self-assessment tests.[19–21]

The novelty of our research lies in its contribution to the gap in the body of knowledge of online participation and interactivity and in the investigation of the unprecedented implementation of synchronous e-learning due to the pandemic. Since it was the first time that e-learning totally replaced teaching in a traditional classroom-based setting from the beginning until the end of the semester, it is crucial to measure participation as a reflection of students' response to the mandatory e-learning process and to analyze the interactions between the professor and the students. This study is a systematic attempt to enhance our understanding of the new, innovative educational process, to develop new knowledge about the advantages and disadvantages of the current e-learning methods, and to apply the acquired knowledge for the improvement of educational practice.

Materials and Methods

Definitions of the Concepts

E-learning is a learning system that uses electronic resources, the internet, and electronic devices. We also use the terms "e-lessons", "e-tutorials", "e-course", and "live-streaming lessons". Synchronous e-learning mainly refers to live-streaming e-lessons. Usually, they take place on a web-based platform, so as to accommodate a large number of participants and provide opportunities for real-time communication. E-learning that is not occurring in real-time is called "asynchronous" and is the most popular form, as it does not require the discipline of a time schedule, and its content can be accessed regardless of location and time.[22]

For online participation, we use Hrastinski's definition:[10] "Online learner participation is a process of learning by taking part and maintaining relations with others". According to his interesting approach to the term, online learning participation acknowledges more complex dimensions such as doing, thinking, feeling, and belonging. In our study, we identify participation as the number of student attendees, as Davies and Graff did in their study,[2] where "students' access to the group area and communication areas were combined and used to represent the degree of participation".

Interactivity refers to the actions of individuals who interplay and communicate. It requires levels of messages that respond to previous messages, mutual or reciprocal actions or influence, according to the Merriam-Webster dictionary.[23] Moore[24] identified three types of interactivity in distance education: learner–instructor, learner–content, and learner–learner. Berge[25] states that interaction should not simply occur, but must be intentionally designed in the instructional program. This guides us to study interactivity in terms of modern synchronous e-learning. The term "interactivity" is described as the extent to which the e-learners perceive that their communication or interaction in the virtual environment is bi-directional, responsive to their actions and controllable.[26] In our research paper, our aim was to measure the learner–instructor interactivity via the exchanges between students and the professor. Thus, we measured interactivity patterns as the frequency of questions and answers between the students and the professor.

Educational Framework of the Research

The research was conducted in the three-hour, non-mandatory Pathology II course, which is offered weekly during the 5th semester (winter) of the undergraduate curriculum of the School of Medicine. The number of students enrolled in the pathology e-course was 257 in total. The virtual classroom software product that the Department of Pathology had chosen to use to provide access to the pathology synchronous e-course was Skype for Business. Cognitive load theory and Mayer's cognitive theory of multimedia[27] were applied in every e-lesson, as each lesson contained slide-text-photo presentations and microscopy histology images in high resolution, which accompanied the audio narration of the professor in favor of a student-centered "knowledge construction" model. Dialogue between the professor and students took place when the former posed questions orally, and students answered in the virtual classroom's chat. Typing in the chat box of the classroom's virtual environment was the only way they could communicate in the synchronous e-lesson; no other chat rooms were available.

All synchronous e-learning lessons were recorded and then uploaded on the YouTube channel created for the e-course by the department, named "PATHAN", the following day. These videos were mainly searched, viewed, and reviewed by the medical students interested in pathology with the purpose of keeping up with the lectures (in case they missed the synchronous e-lesson) or for revising and enhancing their understanding of the course's content.

Research Design

The process of collecting personal data in this research complies with the data protection principles, as outlined in the EU General Data Protection Regulation, and is in accordance with the Declaration of Helsinki. Via the faculty, students were informed of the research purpose and consented to the recording of the online synchronous lessons as educational video archives, which would be used for this research and its publication. To assure the confidentiality of the students in the data, all names were replaced with pseudonyms. Moreover, the attendees' cameras and microphones were disabled at all times during the e-lessons.

The first step of our research was the practice of observation. One important lesson from psychometrics is that people are not always in the position to accurately report what they do.[28] Naturalistic observation methods are well suited to addressing some of the limitations inherent to momentary self-reports.[28] Therefore, we conducted a naturalistic observation of the classroom as

detached observers, being cautious to minimize our influence on the students' behavior, as they would know that they were being constantly observed. The observations were conducted in the three-hour theoretical pathology e-lessons and clinical pathology e-tutorials during the autumn/winter semester by watching the asynchronous e-lessons (recorded synchronous e-lessons uploaded on the YouTube channel "PATHAN"). The population of the study comprised all the enrolled undergraduate students in the pathology course (257 in total).

From our perspective, we concentrated on the participants' attendance in the synchronous e-learning class. Our goal was to count the number of participants from the beginning of each e-lesson and observe its change over time. The number of student attendees was always visible on the platform during every e-lesson. Within the 180 minutes of the e-course, we noted the number of students attending each of the seven stable time points we defined (15 min, 30 min, 60 min, 90 min, 120 min, 150 min, and 180 min after the start) and created a separate column for the maximum number of student attendees during the whole lesson. We decided that the first number of student attendees would be recorded at the 15th minute for two main reasons: a) the time frame we observed to have the highest log-in rate to the e-lesson was 0–15 minutes; and b) during the earlier minutes, there were regards, technical questions, and a description of the content of the day's e-lesson. The teaching procedure started, on average, by the 15th minute, and student participation had almost come close to reaching its peak by this time in every observation. We observed videos of the first, the last, and the in-between e-lessons on a 15-day frequency. Each pathology e-lesson was a weekly three-hour synchronous e-learning session. As a result, our observation was conducted over seven e-lessons, which spanned the whole of the semester. We had the opportunity to update and verify our findings as each video became available on the YouTube channel.

The gathered data on online participation from our seven observations permitted us to adopt quantitative, statistical methods for the analysis and depiction of the results in numerical form using SPSS software. We measured the correlation and the degree of association between the percentages of online students' participating in the synchronous e-lessons at specific time points.

To address the research question of interactivity, we counted the number of questions and answers contributed by the professor and his students in each e-lesson. Based on this data, we calculated descriptive statistics of interactivity and visually presented the results in a scatter plot diagram. Moreover, we identified recurring themes of interactive behavior and categorized them according to their content.

Research Questions

Participation: Did attendance (participation) during the time of each synchronous e-learning course differ? Did the distribution of attendance (participation) during the semester differ?

Interactivity: If interaction occurs between the professor and the students, what are its patterns?

Results

Descriptive Statistics on Participation

Results from Table 1 show that in each e-lesson, both the maximum number of students attending and the starting point of the drop-outs occurred within the first 30 minutes. In each e-lesson, we noticed a significant reduction in the number of students attending from the e-lesson's beginning to its end (Figure 1).

One other interesting finding from the collected data was the extremely high maximum participation rate seen in the first e-lesson, which was 76.26% (N = 196 of the total 257 students), in comparison with the maximum participation rates seen in the following e-lessons. Two weeks after the first e-lesson, we conducted our second observation and calculated a reduction of N = 91 students, approximately 46% of the maximum student participation rate. By the end of the second month of the semester, we noticed an additional decrease of N = 28 students, approximately 27%. Rate numbers continued to lessen until the second half of the semester (Table 1, Figure 1), at which point they seemed to stabilize, especially 60 min after the beginning of each e-lesson (Table 1, Figure 2).

Applied Statistical Analysis on Participation

The variables under investigation were the mean percentages of the students participating in the synchronous e-lessons at the defined time points (15 min, 30 min, 60 min, 90 min, 120 min, 150 min, and 180 min after the beginning of the e-lesson). These percentages were calculated for all seven e-lessons assessed.

Table 1 Number of Students Attending Synchronous e-Learning Pathology

	15 Minutes After the Beginning	30 Minutes After the Beginning	60 Minutes After the Beginning	90 Minutes After the Beginning	120 Minutes After the Beginning	150 Minutes After the Beginning	180 Minutes After the Beginning
Observation 1 (first e-lesson)	192	196	187	173	157	138	103
Observation 2	96	105	97	86	75	63	59
Observation 3	74	77	73	64	58	48	37
Observation 4	52	61	56	48	47	39	35
Observation 5	49	52	50	51	49	43	34
Observation 6	47	50	54	50	50	50	34
Observation 7 (last e-lesson)	55	54	50	49	50	47	47

Participation During the Time of Each E-Lesson

We tested the null hypothesis that the maximum percentage of students attending one e-lesson would not change with time during this lesson. In order to accept or reject this null hypothesis, we used the Kendall rank correlation coefficient nonparametric hypothesis test[29] to measure the strength and direction of association that existed between the variables, ie, the correlation between the mean percentage of the attending students and the consecutive time points (N = 6, Kendall's W= 0.809, Chi-Square = 29.132, df = 6, Asymp. Sig = 0.000).

The Asymptomatic Sig p-value is less than 0.05, which provides strong evidence against the null hypothesis. Therefore, we reject the null hypothesis and conclude that there was a statistically significant difference in the mean percentage of students attending the class between the seven time points of each e-lesson (Figure 3).

Participation During E-Lessons Throughout the Semester

We tested the null hypothesis that the average percentage of students attending with respect to the maximum participation in each e-lesson would not change from one e-lesson to another. As in the previous analysis, we used the Kendall rank correlation coefficient nonparametric hypothesis test[29] (N = 6, Kendall's W= 0.186, Chi-Square = 6.689, df = 6, Asymp. Sig.= 0.351).

The Asymptomatic Sig p-value for this test is greater than 0.05, which provides evidence in favor of the null hypothesis. Therefore, we accept the null hypothesis and conclude that the mean difference in the percentage of students attending the seven e-lessons was not statistically significant. This indicates that, from the start of the e-course, there was a consistent e-audience of student

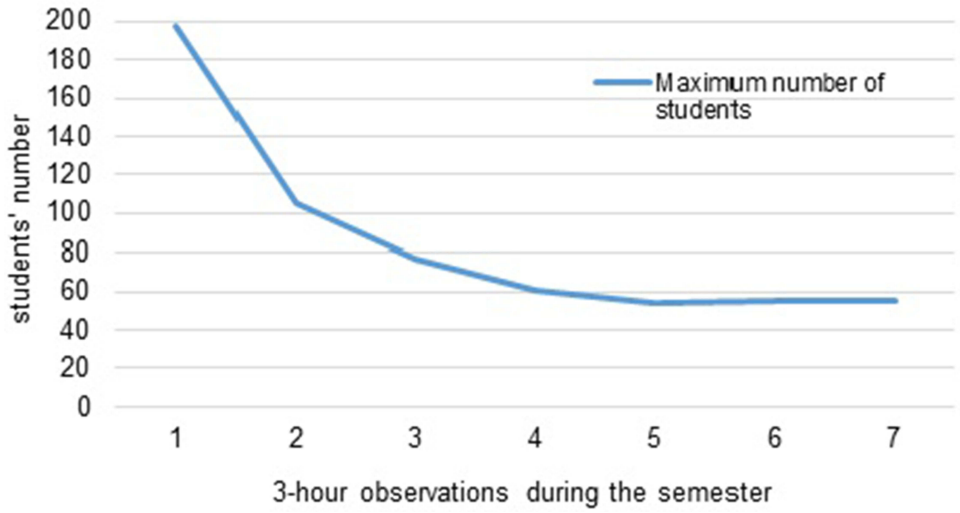

Figure 1 Maximum number of attendees throughout all synchronous e-lessons observed.

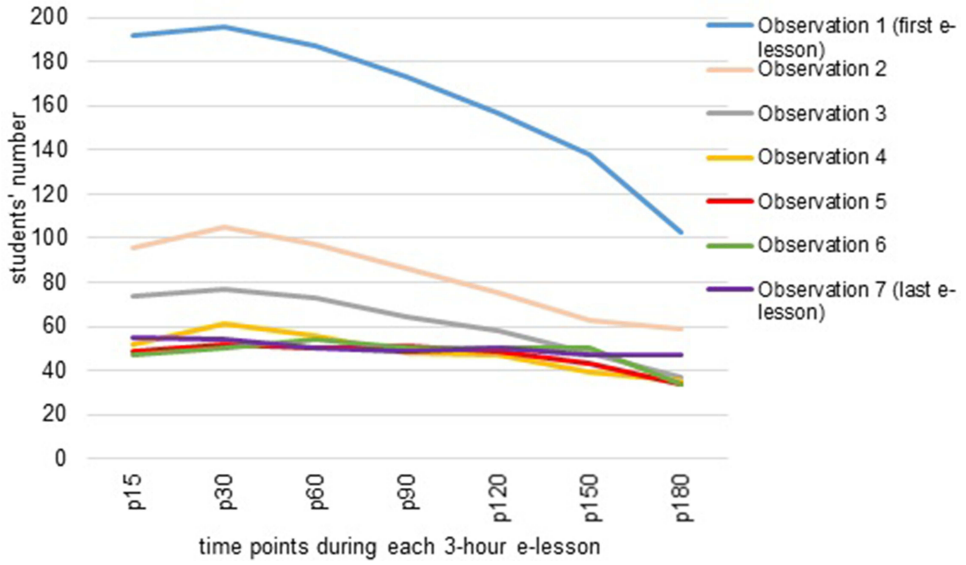

Figure 2 Maximum number of attendees with regard to specific time points in all e-lessons observed.

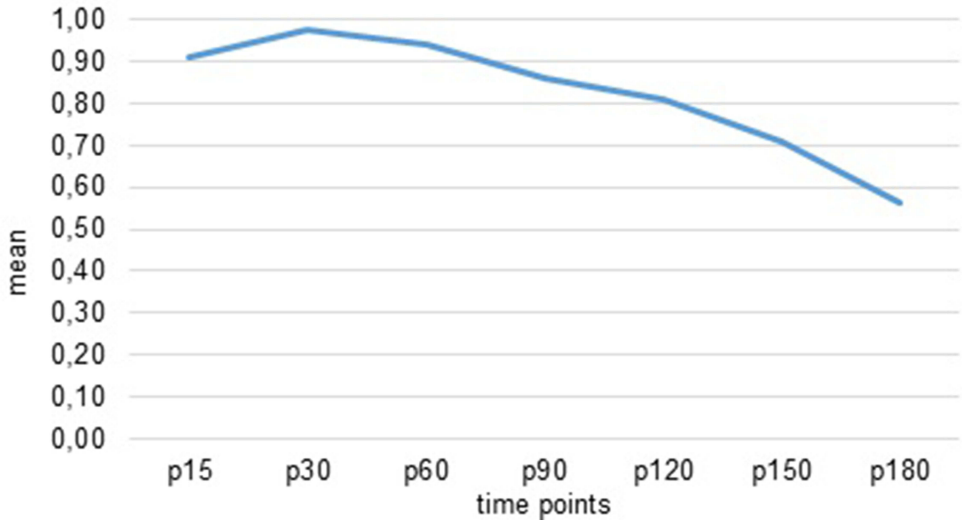

Figure 3 Average percent of participation per time point during each three-hour e-lesson.

attendees, regardless of the overall number of participants and continuation of the drop-out rate (Figure 4).

Descriptive Statistics on Interactivity

The data in Table 2 show that the students posed questions more frequently in the second half of the semester, showing an increase in interactivity during e-learning. Additionally, in terms of the correlation between the professors' question frequency and the students' question frequency, we find N = −41%. No linear relationship was found, as made clear in the following scatter plot.

Beyond Descriptive Statistics

The collected data gave a straightforward answer to our research question; there was a strong pattern of interactivity. Apart from question frequency and average answers per question, which were summarized in Table 2 and visualized in Figure 5, we identified interaction patterns.

The discussions were initiated by the professor posing questions and were developed by the students' responses. The professor's questions were put into the following categories: a) technical questions; b) questions naming a specific pathologic lesion or disease based on the

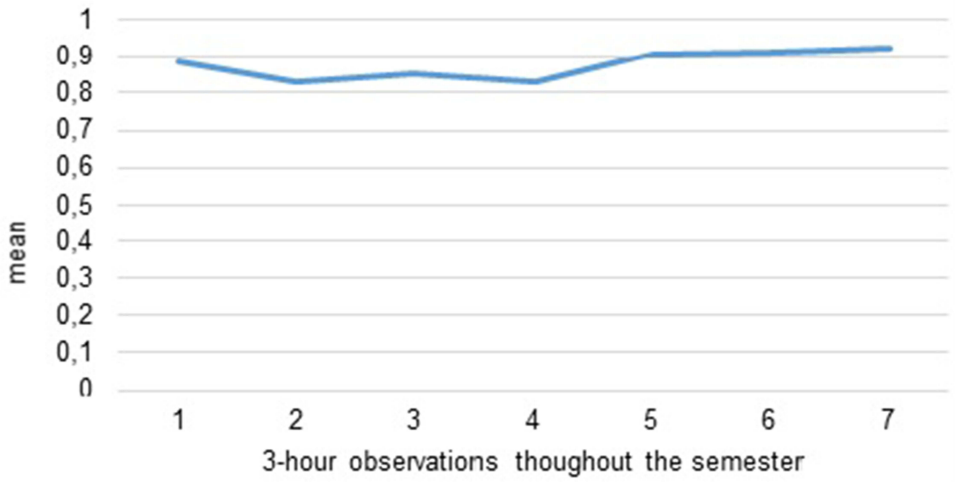

Figure 4 Average percent of participation for all e-lessons observed throughout the semester.

information provided; c) questions to establish a diagnosis; and d) questions aimed to remind students of previous pathology knowledge. Two types of students' responses were noted: answers or questions. Their answers were divided into two specific types: brief and descriptive. Their questions to the professor were also divided into two specific types: explanatory and clarifying. The professor's feedback consisted of either positive reinforcement or answers to questions.

Questions Posed by the Professor

Few technical questions were posed in each e-learning lesson. The professor would ask if students could see and hear him, if the screen sharing was correct, if he should zoom more on virtual microscopy findings, etc. When the professor posed pathology questions, he mostly asked his students to recognize specific types of lesions, eg, "necrosis, type of inflammation, tumor grade". Questions establishing a diagnosis were asked after viewing a detailed patient profile, which included clinical data and respective microscopy findings. Additionally, there were questions that tested prior pathology knowledge, taught in either previous e-lessons or previous courses during the current semester. All questions posed by the professor shared common features; none of them were seeking a "yes" or "no" answer and none of the questions lacked answers. Questions, apart from those in the technical category, were a consistent way for the professor to determine the level and depth of knowledge the students already possessed. He was able to identify the gap between theoretical knowledge and practical understanding, engage students' interest, and motivate students; all in favor of an interactive teaching procedure.

Students' Responses

Students' answers were written into a "chat box". Most of them used medical terms, eg, prostate gland epithelium, nephrosclerosis, cancerous invasion of the renal vein, and

Table 2 Data on Interactivity During the Three-Hour e-Lessons of Pathology

	Total Number of Oral Questions Asked by the Teacher	Total Number of Answers Written in Chat by the Students	Total Number of Questions Written in Chat by the Students	Frequency of the Professor's Questions	Average Number of Student Answers Per Question	Frequency of Students' Questions Frequency
Observation 1 (first e-lesson)	80	390	9	2m 3sec	4,9	20m
Observation 2	86	377	4	2m 1sec	4,4	45m
Observation 3	33	110	8	5m 5sec	3,3	22m 5sec
Observation 4	55	298	19	3m 3sec	5,42	9m 5sec
Observation 5	54	316	28	3m 3sec	5,85	6m 4sec
Observation 6	43	212	33	4m 2sec	6,42	5m 5sec
Observation 7 (last e-lesson)	31	111	14	5m 8sec	3,58	12m 9sec

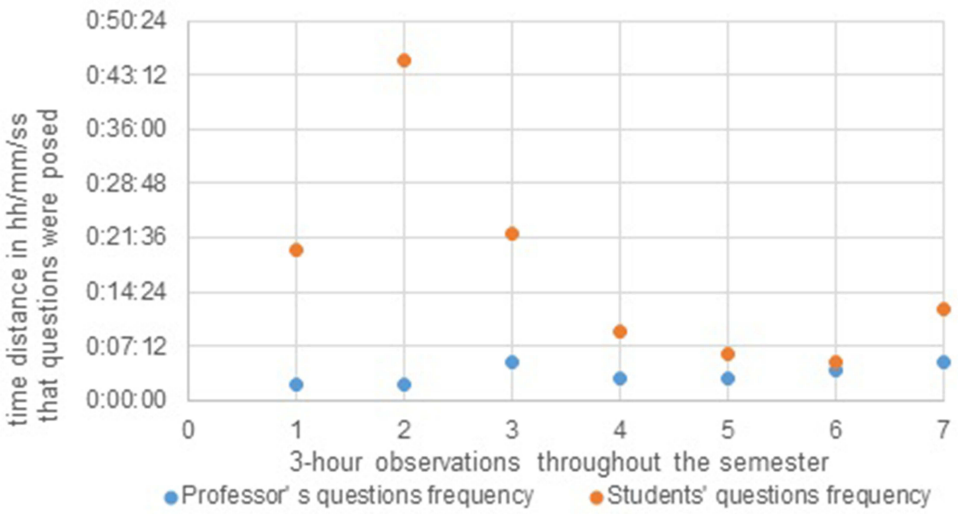

Figure 5 Scatter plot on question frequency.

hyperplasia. Some were explanations of their thoughts that led them to specific answers. In the example below, we see how a question regarding establishing a diagnosis was answered briefly:

Professor: - A 60-year-old man treated with long-term IV gentamicin suddenly becomes nauseous and oliguric. When his lab values come back, they indicate hyperkalemia, hyperphosphatemia, azotemia, and elevated urine sodium. Muddy brown casts appear in his urine sample (see image). The best decision is to stop the gentamicin and evaluate the possibility of placing the patient on dialysis. Name the underlying pathological lesion based on the shown microscopic images.

Students' answers in chat: - "Acute tubular necrosis" (correct answer), "acute drug-induced interstitial nephritis", etc.

Students asked two types of questions: explanatory and clarifying. For example: "What is a stereotactic biopsy?", "Which is the most aggressive type of kidney cancer: clear cell, renal cell carcinoma or collecting duct carcinoma?".

Feedback from the Professor

The professor waited to read the students' responses in the virtual classroom's chat. He did not proceed with the teaching of new information unless the correct answer was given and clearly justified. He regularly used positive reinforcement in the form of praising his students for their answers, from simply "yes!" to '"this is correct", "great", "congratulations", "excellent", "astonishing answer", "excellent way of thinking", "how brilliant of a mind do you have?", "you are impressive", "you are great colleagues", and "you are better students than me when I was a student".

Discussion

The impressive number of participants in the first e-lesson was not seen again in any other e-lesson. The observed drop-out rate could be the result of a variety of factors, such as the non-mandatory participation in the e-course, the general lack of motivation for learning, or the stress factors and the "burn-out" associated with prolonged telecommunication and e-learning. Furthermore, the unexpected length and severity of the COVID-19 pandemic has drastically increased the levels of stress, depression, and anxiety among the public, including university students, resulting in difficulties in focusing on or prioritizing academic work.[30]

In trying to explore the possible reasons that lie behind the students' reluctance to stay connected and attend the e-course from its beginning to the end, we take into consideration the asynchronous e-learning opportunity offered to them, which gives access to the uploaded videos of the same recorded e-lessons and e-tutorials. It is possible that students are inclined to follow asynchronous educational e-lessons at any time they like since they do not seem to value the benefits of synchronous participation and interrelations with the professor.

Active learning methodologies can be described simply as teaching where students are actively involved in and contribute to the learning process. The key element here is that learning activities are designed to enable students to

activate their existing ideas and perceptions, and through collaboration and social participation, they move on to attain higher levels of conceptual knowledge and understanding.[31] The focus of active learning is not on the acquisition of information but on the journey and method by which the students acquire information and values. It is a comprehensive term for a group of teaching methods that focus on placing the responsibility of learning on the student.

Acquiring an active role in learning develops the students' abilities to think critically, solve problems, and make informed judgments useful to their future everyday practice as professionals. The applied pedagogical approach in the pathology course through the synchronous e-lessons was very effective in targeting the steady e-audience's creativity and talent since it required active involvement for them to proceed. There have been numerous studies on students' perspective on the benefits of active learning, and these strategies are shown to enrich their engagement and comprehension of content, as well as to boost critical thinking skills.[32–34] Moreover, it increases comprehension and retention of material, promotes student learning, incorporates theory into practice, and increases ownership of learning. Synchronous e-learning, when conducted appropriately, motivates students as they are provided with opportunities for practice and feedback.[35,36]

When students choose to attend the synchronous e-lessons, they are basically taking advantage of the opportunity to actively participate in their education, since we observed high professor–student interactivity levels in this specific study. Park and Bonk[37] describe the major benefits of using a synchronous virtual classroom. These include being able to provide immediate feedback, encourage the exchange of multiple perspectives, enhance dynamic interactions among participants, strengthen social presence, foster the exchange of emotional support, and supply verbal elements. We encountered most of these benefits while observing e-courses in pathology. Unlike the decreasing numbers of online student participants, interactivity between the professor and the students who continued to attend the e-courses gradually increased. The steady e-audience showed considerable progress in their ability to interact with the professor and, thus, in developing their communicative and social skills.

From the perspective of self-criticism, we recognize that we did not take into consideration the specific content of each e-lesson or the amount of online slide-text-photograph presentations. Our analysis would be different, and possibly deeper, if other relations could have appeared and if other dynamics of the class could have been illuminated. Additionally, we could have also noted and counted the minutes that the dialogues took place in order to determine the strength and direction of interactivity patterns during each e-lesson.

Conclusion

The findings of this research inform us of the significant drop-out rate of students in the virtual classroom environment and indicate possible student preferences in terms of asynchronous e-learning. Interactivity levels, though, actually increased from one e-lesson to the next. To summarize, some of the key-points of this research are:

- The highest number of participants was seen in the first e-lesson.
- The drop-out rate of participants during each e-lesson was statistically significant.
- Not statistically significant drop-out of the participants during the semester.
- There were interactivity teaching patterns in the synchronous e-learning pathology course.
- A stable e-audience gets involved interactively.

We believe our conclusions regarding the drop-out rates in synchronous e-learning during each e-course throughout the semester lay a foundation for further research, which should purposefully and systematically include interviews, questionnaires, and surveys with students in the target population. Further investigation should be focused on exploring the reasons why students skip the e-classes, what motivates them to attend, and their preferences between synchronous and asynchronous e-learning. However, it should also focus on evaluating the methodology that was applied for the setting of the virtual classroom of synchronous e-learning pathology in terms of organization, innovation, and education quality. Educational research findings illuminate the aspects of the e-learning environment and play a vital role in the improvement of the learning programs and practices, the provision of solutions, and the formulation of policies towards higher-quality education.

Ethics Approval and Informed Consent

Ethical clearance and approval was obtained from the Ethics Committee of the National and Kapodistrian

University of Athens, protocol number 429, and conducted following the guidelines of the Declaration of Helsinki. Students were informed about the purpose of the study and consent was obtained from them. Confidentiality and privacy were secured during the whole period of the study.

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Disclosure

The authors declare that they have no conflicts of interest in this work.

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