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Quantitative Courses in Higher Education: A Comparison Between Asynchronous and Synchronous Distance Learning

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Abstract

Quantitative courses in higher education have always been difficult and demanding because they involve complex principles and procedures and students are required to deal with complicated problems. With the outbreak of the COVID-19 crisis and the need to move immediately to distance learning, the challenge involved in undertaking such courses has become even more significant.

Recent studies point to different findings regarding the effect of asynchronous and synchronous learning on student performance so it is not entirely clear which method is preferable. The present study addresses the above ambiguity with a focus on quantitative courses, known for their special complexity. The study examined which method is preferable and why, based on the learners' point of view. Two main issues were examined: the contribution of each method to the learning process and whether one of them is significantly superior to the other and can even replace it exclusively.

The research was based on two samples of students ($n_1 = 84$, $n_2 = 56$) who enrolled in eight quantitative courses at two colleges. The courses were given during the year 2020–2021 using combined teaching formats: Asynchronous and synchronous distance learning. Learners were asked to answer an online questionnaire that assessed the characteristics and advantages/disadvantages of both methods.

The findings show that students distinctly prefer asynchronous learning over synchronous. The main reasons for this are the ability to repeat lessons indefinitely, time savings, flexible learning anywhere, anytime and at the appropriate pace as well as the ability to better understand the material.

Keywords: distance learning, online learning, higher education, asynchronous learning, synchronous learning

1. Introduction

1.1 General Background

Over the past two years, there has suddenly been an urgent need to move from traditional classroom learning to online learning. This was done quickly and without the ability to invest adequate time resources for early preparation. As a result of the COVID-19 pandemic crisis, it has become apparent that the digital readiness of teachers and students is insufficient (Crawford et al., 2020; Demuyakor, 2020). The immediate transition to an emergency period resulted in improvised moves rather than initiating planned and orderly online distance learning processes. This immediate transition has been called ERT: Emergency Remote Teaching (Hodges et al., 2020; Rapanta et al., 2020).

Lecturers with different backgrounds, were forced to prepare and deliver the lectures from home, with all the practical and technical challenges involved, and often without adequate support (Hodges et al., 2020). Another challenge for higher education lecturers was the lack of Pedagogical Content Knowledge (PCK) required for online teaching. PCK includes the technical and administrative aspects of online teaching as well as the pedagogical foundations and knowledge needed to create meaningful online learning (Baldwin, Ching, & Friesen, 2018; Shulman, 1987).

In ERT, almost all face-to-face instruction has been replaced by online instructional formats. Although there was an awareness that pedagogy needs to be adapted to the new medium, in practice, existing pedagogy has simply been transferred from one medium (face-to-face learning) to another (online learning) without maintaining quality studying. Practically, many academic staff members were looking for video conferencing technologies

(such as Zoom) to replicate traditional classrooms. They referred to these technologies as an easier and more immediate substitute for face-to-face teaching. Unfortunately, a pedagogical transition from one medium to another is not necessarily smooth. Due to the constraints of the pandemic, it was required to create urgent transitions without providing appropriate opportunities for the redesign of learning processes required for the new medium (Cicha et al., 2021; Henriksen et al., 2020).

There are two major alternatives for online distance learning, asynchronous and synchronous. They differ in terms of time and place constraints regarding the conduct of learning: in asynchronous learning there is no time limit so that one can progress at a personal pace and without significant dependence on the guide (Bernard et al., 2004; Xie et al., 2018). Although asynchronous learning may allow students to work at their own pace and regardless of time and place (Van der Keylen et al., 2020), not all learners are equipped with the right strategies to enjoy this potential benefit. Learning at home, especially in asynchronous contexts, requires more self-learning skills to stay on track, including adequate motivation and a desire to achieve learning goals (Hartnett, 2015). Students should also be equipped with strong digital skills to perform academic work and successfully complete learning activities (Kim et al., 2019). On the other hand, synchronous learning environments should be less natural and less "rich" than face-to-face synchronous learning environments. Thus, this leads to higher cognitive load, greater communication ambiguity, and lower activation. In contrast, the main strengths of synchronous online learning are real-time interpersonal communication, use of natural language and immediate feedback (Blau et al., 2017; Lim, 2017).

Research findings regarding the effect of synchronous and asynchronous learning on student performance are not without ambiguity. Nieuwoudt (2020) found that it does not necessarily matter whether students learned remotely in a synchronous or asynchronous format. However, a significant linkage was found between academic success and the number of hours students participated and interacted with the online learning system. It has also been found that active participation in both synchronous and asynchronous online learning opportunities results in higher engagement and better academic outcomes than participation in face-to-face classes only (Northey et al., 2015). Fabriz et al. (2021) claim that synchronous and asynchronous learning environments are different in terms of their potential to facilitate social interaction. Synchronous environments enable learning management through group work or video discussions, which by nature support students' social interaction as well as student-teacher or student-student interaction. In contrast, asynchronous environments are more content-oriented and focus on facilitating students' interaction with learning materials (Alqurashi, 2019; Fabriz et al., 2021).

Another difference between synchronous and asynchronous settings has to do with the choice of tools used and their pedagogical goals. Xie et al. (2018) defined five variables to differentiate between the two types of learning: communication tools, types of feedback, input methods, collaboration modes, and the skills to be acquired. They argue that there are aspects about which students are more satisfied with asynchronous communication, such as discussion forums and email communication. On the other hand, as for other features, they prefer the synchronous alternative, such as, receiving direct feedback from the instructor.

Studies also indicate that especially in asynchronous learning, the following factors have a strong effect on learning satisfaction and the perceived quality of studying (Nandi et al., 2015; Alqurashi, 2019):

- The quality of the content-learner interaction, that is, reading interactive texts, watching videos and completing assignments.

- The learner-teacher interaction, i.e., feedback, summative and formative assessments and documentation of student progress.

On the other hand, learners evaluate participation in online synchronous discussions as more focused, have a stronger sense of contribution, improve motivation and support course performance better compared to asynchronous discussions (Hrastinski, 2010; Malkin et al., 2018).

Since both settings have advantages and disadvantages, Xie et al. (2018) claim that a combination of synchronous and asynchronous modes is more desirable for online learning than any of them separately.

1.2 The Conceptual Framework of the Study

The study compares the learning effectiveness of quantitative courses in higher education taught in two ways: asynchronous and synchronous. Part of each course studied was conducted in an asynchronous format and the other one, in a synchronous setting. The percentage of each component (asynchronous and synchronous) in each course is detailed below. All courses were given by the same lecturer who has extensive knowledge of the various types of online learning. The lecturer acquired the knowledge through intensive personal instruction given to him by an online learning expert for several months. The training took place before the start of the

courses and was based on the TMOC (Training for the Management of Online Courses) model (Ghilay, 2017). Since the two methods were applied by the same lecturer with respect to the same courses and students, it was possible to compare them.

The synchronous part of each course was given through Zoom, whereas the asynchronous component was based on videos that were pre-produced in laboratory conditions using professional video capture software (Camtasia Studio). The videos, were a substitute for the lectures and they underwent rigorous control and editing processes, as required by the VBL (Video Based Learning) model (Ghilay, 2018a). Video clips were divided into small portions and shared with the students via YouTube, including the creation of playlists for a series of videos covering an entire topic.

Beyond that, based on the OTLA (Online Teaching Learning and Assessment) and ODL (Online Distance Learning) models for asynchronous learning in higher education (Ghilay & Ghilay, 2013; Ghilay, 2017a; Ghilay, 2017b), the lecturer allowed students to ask questions during the asynchronous learning, while providing real-time answers. Communication took place through a variety of channels such as LMS (Learning Management System) chats, Email, SMS, instant messaging software (such as WhatsApp) or phone calls.

Eight quantitative undergraduate courses in the departments of architecture were examined, including the following topics:

College A—the NB Haifa School of Design and Education

First year:

1) Mathematics for architects (30% of the course topics were given in asynchronous learning while 70%, in synchronous learning):
    - Introduction, motivation and the connection between mathematics and planning, design, architecture and engineering, proportions, important ratio constants, mathematical principles of design.
    - Lines and parabolas, algebraic tools.
    - Solving a system of equations, quadratic equations and above and graphical meaning.
    - Vectors, trigonometry and vector operations.
    - Forces and torques, equivalent system.
    - Deployment of forces, calculation of areas using integrals.
    - Geometric center of gravity.
2) Structure Theory A (asynchronous: 25%, synchronous: 75%):
    - Introduction, purpose of design, basic structural elements.
    - Structural behavior, forms of failure.
    - Power definitions, units, Newton’s laws.
    - Equilibrium at the junction, transfer of forces in simple elements—tensing and pressing.
    - Equilibrium at the junction, passage of forces and reactions at anchor points.
    - Height stabilization model—sticks and cables.
    - Equilibrium and reactions.
    - Elastic lines and the connections between linear schemes and surfaces and elastic lines in surfaces.
    - Elastic lines and the efficiency of the supports of linear and surface elements.
    - Calculations of reactions in a particular static beam - calculated compared to experiment-based.
    - Sorting of loads and devices.

Second year:

3) Structure Theory B (asynchronous: 40%, synchronous: 60%):
    - Structural systems—column, beam frame, lateral stability.
    - Structural systems—reinforced ceiling lateral stability.
    - Center of mass and center of hardness—basic principles.

- Flow of forces in spatial elements—lengths of influence and forces.
- Spatial structure model—torques equilibrium.
- Trusses—tensing and pressing on the components of the structure.
- Elasticity, stresses in beam sections and axial stresses.
- Familiarity with concrete structures, reinforced concrete properties and reinforcement types.
- Principles of design according to standard, borderline state of service and destruction.

4) Statics (asynchronous: 50%, synchronous: 50%):
   - Vectors, torques and a simple equivalent system.
   - Equilibrium equations and calculations of reactions in buildings.
   - Internal force moves—shear axes and bending torques.
   - Reactions in trusses and the node method.
   - Complete truss solution—the node method and the Ritter method of sections in trusses.
   - Calculating and finding a center of gravity in a section consisting of steel profiles.

Third year:

5) Structure Theory C (asynchronous: 30%, synchronous: 70%):
   - Introduction to surface elements.
   - Reinforced concrete ceilings—calculation principles, with and without beams.
   - Reinforced concrete ceilings—principles of calculation, thickness, decline and types of reinforcement.
   - Finding typical design loads according to standards.
   - Concrete ceilings—design and principles.
   - Earthquakes—mechanics, factors and structural effects.
   - Horizontal and vertical stability.
   - Horizontal stability—centers of rigidity and mass.
   - Rigidity and mass centers—earthquake planning.
   - Constructive and architectural structural failures and design principles.
6) Steel Structure Design (asynchronous: 65%, synchronous: 35%):
   - Repetition—reactions and internal forces.
   - Flow of forces in a shed structure and design principles of components.
   - Design according to stresses in the direction of the axial section and bending.
   - Design according to perpendicular stresses for a shear section.
   - Design according to declining calculations.
   - Design of pressed elements.
   - Design of a shed.
   - Design of rods.
7) Concrete Structure Design (asynchronous: 75%, synchronous: 25%):
   - Properties of reinforced concrete and design principles based on standards.
   - A borderline state of destruction.
   - Limiting the strains in a rectangular section.
   - Design of rectangular beam and ceiling.
   - Design of section and ceiling.
   - Load modes and design types.
   - Longitudinal reinforcement in a rectangular section.

- Principles of reinforcement for cutting and penetration.
- Short design of columns.
- Design of foundations.

College B—Bezalel Academy of Arts and Design, Faculty of Architecture, second year:

8) Building Engineering 2 (asynchronous: 60%, synchronous: 40%):
   - Center of gravity in steel profiles.
   - Inertia torque in steel profiles.
   - Calculations of declines in steel beams according to tables.
   - Selecting a profile according to the permissible decline criterion.
   - Buckling and stresses
   - Trusses—tensing and pressing the components of the structure.
   - Concrete—introduction.

2. Method

2.1 The Study Framework

Attitudes of students who took quantitative courses in 2020–2021 were examined with respect to asynchronous and synchronous learning of these courses.

2.2 The Research Questions

The following research questions were structured to measure students' views of the effectiveness of asynchronous learning of quantitative courses in comparison to synchronous learning of this type of courses:

1) Which method, asynchronous or synchronous learning, has a better contribution (if any) to the learning process of quantitative courses in higher education?
2) Is there a clear preference for one method over the other?

2.3 Population and Samples

Population: All higher-education students taking quantitative courses.

Samples: 84 students in College A and 56 in College B (140 students overall) who studied the eight courses mentioned above (seven in college A and one in college B). Part of each course was given in asynchronous learning and another part, in synchronous learning (as detailed above).

The questionnaire was anonymous, and the rate of response was as follows:

- College A—53.85% (84 out of 156):
  - First year—41.33% (31 out of 75)
  - Second year—79.49% (31 out of 39)
  - Third year—52.38% (22 out of 42)
- College B—53.84% (56 out of 104).

The overall rate of response in the two institutions together was 53.85% (140 out of 260).

2.4 Data Analysis

The 39 items in the questionnaire were divided into six factors. Cronbach's alpha was calculated in order to test the degree of homogeneity of each factor's constituent items.

These are the six factors and their constituent items:

Quality of learning

1) *Asynchronous learning quality*: The quality of the lecturer's explanations and voice, speed of progress, clarity of presentation of various components, efficiency of presentation of all relevant topics.
2) *Synchronous learning quality*: The quality of the Zoom lecturer's explanations, the speed of progress, the clarity of the presentation of various components in the Zoom, efficiency of presentation of all relevant topics in the Zoom.

Contribution to learning

3) *The contribution of the asynchronous alternative to learning*: Possibility to repeat and understand incomprehensible topics, saving time compared to Zoom lectures, possibility to repeat the material at flexible hours, selection of the appropriate pace, unlimited number of repetitions of the material, possibility for a better understanding of the material compared to the Zoom rate.
4) *The contribution of the synchronous alternative to learning*: Possibility to learn and understand the course topics, saving time compared to pre-prepared videos, advantage of lessons given on pre-arranged dates, possibility to repeat the material at flexible hours, unlimited number of repetitions of the material, possibility for a better understanding of the material compared to pre-prepared videos.

Preferred method

5) *Preference for asynchronous learning over synchronous*: Learning through Zoom is not necessary while there are video clips, preference of videos over Zoom lessons, videos allow flexibility in time and place, videos are a complete replacement for Zoom lesson, the topics in the video can be better understood than in Zoom lesson, it is easier to concentrate on watching videos compared to the Zoom lessons, asynchronous learning has a contribution to time saving.
6) *Preference for synchronous learning over asynchronous*: Learning through videos is not necessary while there are Zoom lessons, preference of Zoom lessons over videos, Zoom learning is better because the dates are pre-set, learning through Zoom is a complete substitute for videos, the topics in Zoom lessons can be better understood than through videos, it is easier to concentrate on the Zoom lessons compared to watching videos, synchronous learning is better because questions can be asked, it is accompanied by asynchronous learning (the recorded lessons) and it has a contribution to time saving.

Tables 1–3 present the six factors, their internal reliability and the questions in the questionnaire that address each factor. It should be noted that the Cronbach's alpha for all factors is 0.8 or higher and for two factors, it is higher than 0.9. This indicates very high reliability.

The factors are divided to three main groups: Quality of learning (asynchronous and synchronous), the contribution to learning of both methods and the preferred method (asynchronous or synchronous).

Table 1. Quality of learning—factors and reliability

Factors	Questionnaire's questions
Asynchronous learning quality	The lecturer's explanations in the videos are clear.
Alpha=0.883	The lecturer's words (in the videos) are said in a clear voice.
	The lecturer's explanations are given at a moderate pace (not too fast).
	The various components are presented clearly (mathematical formulas, graphs and tables).
	The videos present and illustrate well all the topics they deal with.
Synchronous learning quality	The lecturer's explanations in Zoom are clear.
Alpha=0.880	The various components are presented clearly (mathematical formulas, graphs and tables).
	The pace of the lecturer's progress in the material suits me (not too fast).
	The lecturer presents and illustrates well all the relevant topics

Table 2. Contribution to learning—factors and reliability

Factors	Questionnaire's questions
The contribution of the	The videos allow me to go back and understand topics I did not understand in a previous viewing.
asynchronous	Pre-made videos save time compared to Zoom lectures.
alternative to learning	The videos have a significant advantage as they allow me to repeat the material at times that are convenient to me.
Alpha=0.800	The videos have a significant advantage as they allow me to repeat the material at a pace that suits me.
	The videos allow me to repeat the material an unlimited number of times.
	The videos allow me to better understand the material compared to Zoom lessons.
The contribution of the	Zoom lessons allow me to learn and understand the topics in the course.
synchronous	Zoom lessons save time compared to pre-made videos.
alternative to learning	Zoom lessons have an advantage as they are given at predetermined times.
Alpha=0.897	The Zoom lessons have an advantage because they can be repeated through the recordings uploaded to the course website.
	Zoom lessons allow me to repeat the material an unlimited number of times.
	Zoom lessons allow me to better understand the material compared to pre-made videos.

Table 3. Preferred method—factors and reliability

Factors	Questionnaire's questions
Preference for asynchronous learning Alpha=0.923	When pre-made videos are provided, there is no need for a Zoom lesson. Videos are better than learning by Zoom. I would rather learn mostly by watching a video than listening to a Zoom lesson. Videos have a significant advantage because I can learn at a time and place that suits me. Videos are a complete substitute for a Zoom lesson. I can understand most of the topics presented in the video better than by listening for a Zoom lesson. It is easier for me to concentrate on watching the video than to concentrate on the zoom. Learning through videos saves me time.
Preference for synchronous learning Alpha=0.946	When a Zoom lesson is given, there is no need for videos. The Zoom lesson is better than videos. I prefer to learn mostly by listening to Zoom lessons than watching videos. Zoom lessons have an advantage over videos because the dates are pre-set. A Zoom lesson is a complete replacement for videos. I can understand most of the topics presented in the lesson given in Zoom, better than by watching the videos. It is easier for me to concentrate on the Zoom than to watch videos. I prefer to study using Zoom because questions can be asked. Zoom classes have an advantage because they combine synchronous learning (live lessons) and asynchronous learning (live lesson recordings uploaded on the course website). Learning by Zoom saves me time.

For each factor, a mean score and standard deviation were calculated. In addition, the following statistical tests were performed ($\alpha <= 0.05$) :

College A:

1) ANOVA: In order to check if there are significant differences between the following groups relating to all factors - first, second and third year of study.

Both colleges:

2) Paired Samples T-test: It was conducted in order to check if there are significant differences between the following factors:
   - The quality of asynchronous and synchronous learning.
   - The contribution of asynchronous and asynchronous learning.
   - The degree of preference for asynchronous learning and synchronous learning.

3. Results

Students were asked about the six factors characterizing asynchronous and synchronous learning, mentioned above. Table 4 shows the mean scores and standard deviation of the six factors for College A, relating to each year separately.

Table 4. College A—factors' mean scores and standard deviation divided to years

Factor	Year of study	N	Mean	S.D
Asynchronous learning quality	1	30	4.57	.86
	2	30	4.83	.47
	3	24	4.89	.24
Synchronous learning quality	1	30	4.59	.70
	2	30	4.64	.73
	3	24	4.67	.55
The contribution of the asynchronous alternative to learning	1	30	4.89	.31
	2	30	4.84	.31
	3	24	4.98	.056
The contribution of the synchronous alternative to learning	1	29	3.60	1.32
	2	30	3.91	1.04
	3	24	3.34	1.04
Preference for asynchronous learning	1	27	4.52	.81
	2	30	4.53	.49
	3	22	4.78	.42
Preference for synchronous learning	1	26	2.98	1.20
	2	30	2.55	1.20
	3	22	1.84	.69

There was no significant difference in the mean scores of all factors, except the sixth (preference for synchronous learning), relating to the three years of study (ANOVA, $\alpha \le 0.05$). Based on Post Hoc Test ($\alpha \le 0.05$), it can be concluded that with respect to the sixth factor, there is no significant difference between the first and second year ($p = .468$). However, there are significant differences between the first and third year and between the second and third ($p = .001$ *and* $p = .028$ respectively). Therefore, Table 5 shows the mean scores of the three years aggregated, except for factor 6, where the first and second year are presented together, while the third year is presented separately. To allow comparison between factors 5 and 6, factor 5 is presented in addition to the total also separately for the first and second year together and for the third year. In addition, Table 6 shows the mean scores of the six factors for College B.

Table 5. College A - factors' mean scores, standard deviation and ANOVA results

No.	Factor		N	Mean	S.D	ANOVA
1	Asynchronous learning quality		84	4.75	.61	$F_{(2,81)} = 2.318, p = .105$
2	Synchronous learning quality		84	4.63	.66	$F_{(2,81)} = .089, p = .915$
3	The contribution of the asynchronous alternative to learning		84	4.90	.27	$F_{(2,81)} = 1.894, p = .157$
4	The contribution of the synchronous alternative to learning		83	3.64	1.17	$F_{(2,80)} = 1.583, p = .212$
5	Preference for asynchronous learning	1st+2nd year	57	4.52	.66	$F_{(2,76)} = 1.469, p = .237$
		3rd year	22	4.78	.42	
		Total	79	4.60	.61	
6	Preference for synchronous learning	1st+2nd year	56	2.75	1.21	$F_{(2,75)} = 6.725, p = .002$
		3rd year	22	1.84	.69	

Table 6. College B - factors' mean scores and standard deviation

No.	Factor	N	Mean	S.D
1	Asynchronous learning quality	56	4.90	.22
2	Synchronous learning quality	55	4.88	.31
3	The contribution of the asynchronous alternative to learning	56	4.71	.58
4	The contribution of the synchronous alternative to learning	55	3.94	1.01
5	Preference for asynchronous learning	55	4.22	.97
6	Preference for synchronous learning	53	2.66	1.21

The basic requirement for comparing the effectiveness of two methods is that both are of high quality. Therefore, a prerequisite for the research was checking the quality of the asynchronous and synchronous learning. If this

condition held, the effectiveness of the various methods could be tested. The findings in both institutions show that the quality of these characteristics was high: learners gave the asynchronous learning quality excellent mean scores of 4.75 out of 5 (College A) and 4.90 (College B) while the quality of the synchronous learning also received high mean scores of 4.63 out of 5 and 4.88 respectively (Tables 5–6, Items 1–2).

A paired sample T-test ($\alpha \le 0.05$) examined asynchronous and synchronous learning quality. Results showed a significant difference between them in college A ($t_{(83)} = 2.110, p = .038$) and no significant difference in college B ($t_{(54)} = .313, p = .755$). Although there is a significant gap between the quality of asynchronous and synchronous learning in institution A, this gap is small and it can be said that the quality of learning in college A in both methods is high.

3.1 The First Research Question

The first research question explored the hypothesis that there might be an advantage to one of the two learning methods over the other concerning their contribution to the learning process. The third and fourth items in Tables 5–6 confirm that assumption. According to students' views, the factor "The contribution of the asynchronous alternative to learning" (no. 3) was ranked very high, receiving scores of 4.90 (college A) and 4.71 (college B) out of 5.

On the other hand, the factor "The contribution of the synchronous alternative to learning" was ranked much lower, receiving scores of 3.64 and 3.94, respectively. The gaps between these two factors are high: 1.26 (4.90–3.64) in college A and 0.77 (4.71-3.94) in college B. Moreover, based on a paired sample T-test ($\alpha \le 0.05$) , the difference between these two factors in both institutions is statistically significant:

College A: $t_{(82)} = 9.723, p = .000$, College B: $t_{(54)} = 4.517, p = .000$

According to students' views, asynchronous learning has a great advantage over synchronous learning. Students say that the first type of learning is helpful for repetition and understanding unclear topics, it saves time compared to Zoom lectures and it allows to repeat the material flexibly and better understand it.

The following students' quotes from the open-ended question convey this notion:

College A

"Quantitative courses should be in pre-recorded video, the lecturer is excellent and explains everything clearly, the recorded lectures are clear."

"I succeeded in the courses "Statics", "Structure Theory C", "Concrete Structure Design" and "Steel Structure Design" thanks to the recorded lectures."

"Asynchronous lectures allow for repetitive and even accelerated viewing. Just as we sometimes watch a TV series on Binge to keep the information fresh from one episode to the next, so it is with asynchronous learning. It allows us to practice according to feeling and need, control the speed of explanation and repeat the same explanation as many times as necessary so that we understand each issue in depth. The format of asynchronous videos uploaded as a uniform playlist to YouTube, is successful in my opinion and conveys the material in the best way. Video library format through the course website is less successful because access to the site is a bit cumbersome, the freedom of play with Zoom recordings is limited compared to the freedom of playing on YouTube and almost no continuous transition between one video and another is possible."

"Learning through videos has helped me a lot to focus on the material. It was possible to repeat relevant issues and understand them well."

"A great advantage of asynchronous learning is the availability of the lecturer for personal assistance and his good spirit that makes it possible."

"Learning through videos has helped me a lot to focus on the material. It was possible to repeat relevant issues and understand them well."

College B

"Since the semester was very difficult and stressful, the form of learning through videos helped me get a maximum score on the test! I really very much appreciate your clear way of learning and thank you so much!"

3.2 The Second Research Question

The second research question explored the hypothesis that there might be a clear preference to one of the two learning methods over the other, namely, students will be willing to use only one method and give up the other. The fifth and sixth items in Tables 5–6 confirm that notion. According to students' views, the fifth factor

"Preference for asynchronous learning" was ranked high, receiving scores of 4.60 (college A) and 4.22 (college B).

On the other hand, the sixth factor, "Preference for synchronous learning" was ranked extremely lower, receiving scores of 2.75 (college A—1st+2nd year), 1.84 (college A—3rd year) and 2.66 (college B). The gaps between these two factors are huge and with respect to third year students in College A, the gap is even greater: 1.76 (4.51−2.75) in college A—1st+2nd year, 2.94 (4.78−1.84) in college A—3rd year and 1.57 (4.23−2.66) in college B. Moreover, based on a paired sample T-test ($\alpha \leq 0.05$), the difference between these two factors is statistically significant:

College A—1st+2nd year: $t_{(55)} = 9.130, p = .000$

College A—3rd year: $t_{(21)} = 14.261, p = .000$

College B: $t_{(52)} = 6.063, p = .000$

According to students, asynchronous learning is absolutely preferred over synchronous learning. Students say that when moving to asynchronous learning, synchronous lessons become unnecessary, the learning process and level of understanding improve and it is easier to concentrate and learn with greater flexibility without limitations of location and/or time.

The following students' quotes from the open-ended question convey this notion:

College A

"There were classes where students attracted a lot of attention and for me personally it was very difficult to concentrate. The pre-recorded lessons were excellent."

"Videos save a lot of time, and make learning better—short and focused. Learning through Zoom takes valuable time. It is better for everyone to progress at their own pace and if necessary, devote the remaining time to practice, than to spend a lot of time learning through Zoom."

"Asynchronous learning has contributed much more to me than synchronous learning although both methods are preferable compared to face-to-face learning. In asynchronous learning, my level of attention is much higher and the material can be repeated and completed without limitations."

"The topics explained via video are clearer to me than those presented in Zoom lessons. This can be seen in my exam notebook - the mistakes are in the topics I have learned in the Zoom classes. Also, in Zoom lessons, too many questions are asked, and this causes the lecturer, despite being outstanding and special, to lose concentration."

"It is highly advisable to continue using pre-recorded lessons. This alternative allows students to study the subject with maximum flexibility as compared to the constraints of a fixed timetable."

"The videos are more convenient to learn because there are no stops of questions from other students and I can listen at my own pace and at my own time. Also, the big advantage in addition to the videos is the availability of the lecturer for personal assistance and his good spirit that makes it possible."

College B

"Because asynchronous lessons can be viewed without time and location constraints, I am better able to prepare for the lesson and create an optimal space for learning. This is especially true in relation to quantitative courses where naturally, each student has a different pace. In addition, once the lecturer records the lesson in advance, the explanations are very clear, the sentences are accurate and the lesson becomes shorter and more focused."

"The pre-made videos were surprisingly clear and understandable!! It was so fun to learn with their help at my own pace when it suited me. Zoom lectures are important to ask questions but in my opinion, the questions greatly disturbed class progress. Many thanks to the lecturer for the investment!!!

"Zoom lectures help in understanding the material by asking my own questions and especially those of others. Despite this, the recorded lessons are more convenient because more material can be learned in less time. Also, the fact that it is unnecessary to be present in class on pre-arranged days and hours, helps me to learn everything in my own time."

"The recorded lectures were understandable and even sometimes repetitive which allowed the material to be absorbed gradually and clearly!! It was very pleasant for me to study in this way without any background comments from the students so that it was possible to stay focused throughout the lecture and understand it. Because of this, I prefer learning through pre-recorded videos rather than Zoom lectures."

"I did most of the learning through video and recordings and it was successful. Synchronous learning was difficult for me because the pace did not suit me. The situation where students ask questions and the lesson is interrupted, is difficult for me. Before the test, I watched all the recordings, including those of the synchronous lessons that also went through an excellent editing process. In that way, I was able to stop and go back to a point I did not understand and was able to study at hours that suited me. In my opinion, if all the lessons were asynchronous, the learning would have been better and more efficient."

"I personally preferred the pre-made videos because it was really organized and I have a personal responsibility for the time, so it helped me concentrate."

"I mostly prefer recorded lectures because of the convenience of the time I watch the lecture and because it is continuous and focused which has really helped me concentrate. The lecturer's availability for questions during the week, greatly helped to successfully complete the learning process."

4. Discussion

Quantitative courses in higher education have always been difficult and demanding because they involve complex principles and procedures and students are required to deal with complicated problems. With the outbreak of the COVID-19 crisis and the need to move immediately to distance learning, the challenge involved in undertaking such courses has become even more significant. Suddenly, there was pressure on academic institutions to urgently move from traditional face-to-face learning to full distance learning.

Some faculty members have chosen to teach remotely in a synchronous setting using tools such as Zoom or equivalents. Many of them used the synchronous tools in the same way as they did in class. Others, have chosen to use asynchronous tools, that is, to pre-produce videos that were supposed to be a digital replacement for a face-to-face lecture.

The research literature that deals with asynchronous and synchronous learning, indicates that each format has advantages and disadvantages. Thus, while asynchronous learning makes it possible to overcome time and location constraints, synchronous learning does not depend on location while learners must participate at the same time (Bernard et al., 2004; Van der Keylen et al., 2020; Xie et al., 2018). In contrast, the key benefit of synchronous online learning is that it enables real-time interpersonal communication, natural language use, and instant feedback (Blau et al., 2017; Lim, 2017).

As noted earlier, research findings regarding the effect of synchronous and asynchronous learning on student performance are not without ambiguity, that is, it is not definitely clear which method is better (Nieuwoudt, 2020; Northey et al., 2015). Other studies suggest that synchronous environments enable learning management through group work or video discussions, which supports students' social interaction with each other and with their teachers. In contrast, asynchronous environments are more content-focused and as such, more suited to enhancing students' interaction with learning materials (Alqurashi, 2019; Fabriz et al., 2021). The current study addressed the above ambiguity while focusing on quantitative courses, known for their special complexity and the difficulties associated with their learning. Therefore, it examined which method is better and why, based on the point of view of the learners. Two main issues have been examined: the contribution of each method to the learning process and whether one of them is significantly superior to the other and may even replace it.

The findings show that asynchronous learning of quantitative courses has a greater contribution to learning (average grade in college A: 4.90, college B: 4.71) than that of synchronous learning (college A: 3.64, college B: 3.94). The gap between the contribution to the learning process of the two methods is statistically significant. The reasons are: Asynchronous setting allows learners to go back and understand topics that were unclear initially, it saves time compared to synchronous learning, allows to repeat the material at convenient times, pace and location and in general, it allows for a better understanding of the material.

Beyond that, it can be concluded that among students in quantitative courses there is a considerable and statistically significant preference for the asynchronous alternative (college A: 4.60, college B: 4.22) over the synchronous one (college A—1st+2nd year: 2.75, 3rd year: 1.84, college B: 2.66). Preference for asynchronous learning is noticeable in relation to all students, but the gap is widened greatly among third-year students. A possible explanation for this is that students who are no longer new and have gained extensive experience in learning processes, understand the benefits of asynchronous learning better and they prefer it even more than students with less experience.

The reasons for this general preference are that the transition to asynchronous learning makes synchronous lessons unnecessary, the learning process and level of understanding improve and it is easier to concentrate and learn with greater flexibility and without limitations of location and/or time. Beyond that, it turned out that the

format of a collection of asynchronous videos uploaded as a single playlist to YouTube, is successful and contributes to better learning than the access to Zoom recordings where each clip is displayed in a separate link. The great advantage of a playlist is the possibility of a continuous transition from one video to another without delay.

Another significant advantage of asynchronous learning is achieved provided that pre-prepared videos undergo a rigorous laboratory control and editing process as required by the VBL (Video-Based Learning) model (Ghilay, 2018a). As mentioned earlier, all the videos used for asynchronous learning in the study, have undergone such a careful control and editing process. Therefore, two main goals have been achieved: providing better explanations and improving learning, that is, being more effective and on the other hand, significantly shortening the duration of lessons and thus saving time resources.

Moreover, for students, it is possible to completely give up synchronous learning and focus on asynchronous only. This finding is certainly surprising, innovative and raises further thinking as to the desired way to be preferred in distance learning of quantitative courses in higher education.

In addition, the apparent advantage of synchronous learning, namely, the ability to provide real-time feedback (Blau et al., 2017; Lim, 2017), has also been found to exist in asynchronous learning, provided that lecturers operate in accordance with OTLA (Ghilay & Ghilay, 2013) or ODL (Ghilay, 2017b) models for asynchronous learning. These models that have been applied in the research, require the daily involvement of the course lecturer so that the students get real-time answers to their questions. Consequently, asynchronous learning can overcome its main drawback compared to synchronous learning when it comes to providing feedback and thus may be preferable in all respects. The current study confirms this preference when it comes to quantitative courses, but later on, it is worthwhile to extend it to other types of courses, such as multi-text.

Unfortunately, despite the clear preference for asynchronous learning revealed in the present study, many lecturers prefer to repeat themselves in a synchronously inefficient manner whenever they teach the same course. A possible explanation for this phenomenon may be a natural human tendency to act in a way which in the short term seems comfortable, easier or perhaps similar to familiar face-to-face learning. Entering the world of asynchronous learning may require technical and pedagogical learning before action can be taken and this may be daunting.

In many cases, lecturers prefer to adopt the synchronous alternative instead of investing a large one-time effort in good preparation of an asynchronous course and continuous investment of small focused efforts. The purpose of such focused activity is to assist only students who need assistance without investing unnecessary energies towards all learners and all subjects. Such an approach is more efficient, cost-effective for all stakeholders and allows for better progress while providing a better learning experience. In this way, after proper and meticulous development of an asynchronous course, it can be benefited for years, assuming that the course is designed to be given in the long run. However, such an orderly process was difficult to carry out in some institutions during the COVID-19 crisis because it was required to move to distance learning very quickly and without proper preparation. Nevertheless, it will be possible to do this later while returning higher education to routine.

5. Conclusions

Studying quantitative courses in higher education is difficult because learners must assimilate complicated theories and acquire the ability to solve complex problems. When moving to distance learning of such courses, the challenge may even increase.

The current study points to a clear and distinct advantage of asynchronous distance learning of quantitative courses compared to synchronous learning. Therefore, asynchronous learning may be a much better solution for online distance learning of such courses. Thus, it is advisable to recommend lecturers who teach this type of courses remotely, to move from a synchronous to an asynchronous setting, even if this requires a significant investment in the short term. In the long run, many benefits are expected for all involved, students and lecturers. The adoption of such a change requires the development and assimilation of training programs to enable the academic staff to become familiar with the adequate technology and pedagogy, using appropriate software. Relevant technology and pedagogy principles, as well as additional skills required, can be acquired through the following models designed for asynchronous distance learning: TMOC: Training for the Management of Online Courses, OTLA: Online Teaching, Learning and Assessment and ODL: Online Distance Learning (Ghilay, 2019; Ghilay, 2018a; Ghilay, 2018b; Ghilay, 2017a; Ghilay, 2017b; Ghilay & Ghilay, 2014; Ghilay & Ghilay, 2013).

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