Using a Variety of Interactive Learning Methods to Improve Learning Effectiveness: Insights from AI Models Based on Teaching Surveys

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Abstract
The last decade has brought far-reaching changes in higher education, leading institutions to shift some or all instruction online. This shift to distance learning has contributed to a more significant need for active learning: changing students from passive knowledge consumers into proactive knowledge producers using interactive teaching practices. The present study joins an emerging body of literature examining the relationship between active learning, the online environment, and students' performance. In this study, we examined the effect of four interactive learning methods (combined with technology) on students' overall assessments of the class, the clarity of the teaching, and the perceived effectiveness of online distance learning. The data source for the research is teaching evaluation surveys filled out by undergraduate and master's students. In total, we analyzed ~30,000 surveys completed by ~4,800 students from 23 departments, covering 1,265 classes taught by 385 lecturers. We used both classic statistical and AI-based methods. Our findings suggest associations between high use of interactive learning methods and higher student evaluation scores, higher perceived effectiveness of distance learning, and clearer course teaching. A more interesting finding indicates that not only the extent of use, but also use of a variety of interactive learning methods significantly affects the perceived clarity of teaching and learning effectiveness. Based on the findings, we recommend that academic staff integrate a variety of interactive teaching methods, and especially short knowledge tests, in their courses (both online and frontal). Beyond these results, the prediction model we built can be used to examine what mix of different interactive learning methods might improve students' evaluations of any given course.

Keywords: active learning, interactive learning methods, student evaluation, online learning

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The COVID-19 pandemic brought far-reaching changes in many realms of life, not least among them higher education. In the face of the pandemic, institutions around the world closed their (physical) doors and shifted all or most instruction online (e.g., via videoconferencing software such as Zoom, Microsoft Teams, etc.). Researchers have investigated the implications of this shift to distance learning on various aspects of the student experience, including satisfaction, course quality evaluations, self-regulated learning, and well-being (Ho et al., 2021; Holzer et al., 2021).

Active learning is a philosophy of teaching that, over the past two decades, has captured the interest of higher education institutions around the world (Johnson & Johnson, 2008). In essence, active learning entails transferring responsibility for learning from the lecturer to the student (Michel et al., 2009). That is, active learning is intended to replace the traditional frontal model in which lecturers take responsibility for the learning process, while students are passive listeners (Minhas et al., 2012; Hyun et al., 2017). Active learning practices include a variety of methods designed to support learning through meaningful interactions between the lecturer and students and between students themselves. Many active learning practices developed in recent years are supported by digital tools, which are intended to enhance this interactivity.

With the advent of COVID-19, traditional face-to-face (F2F) learning in physical campuses was abruptly halted, and academic staff were required to shift their courses online quickly with little or no warning. Under these conditions, both lecturers and students faced many challenges that hampered learning effectiveness. Yet after a period of adjustment following the onset of the pandemic, students and lecturers became aware of the advantages of online learning (along with the disadvantages). As such, the COVID-19 pandemic has created a reality that is not reversible. Even as pre-pandemic norms have begun to return in many areas of life, more and more academic institutions, often under the recommendation (or coercion) of regulators, are moving towards blended learning.

In online learning, the interactive possibilities enabled by sharing a physical space are eliminated, and lecturers need other means to attract and maintain students' attention. It follows that, in online courses, the sorts of interactive learning methods that fall under the active learning umbrella take on greater significance and even become mandatory (Bell & Federman, 2013). The COVID-19 period therefore offers an opportunity to examine the effect of different active learning practices on various parameters in online courses.

In the present study, we examined how the use of interactive learning methods (combined with technology) in the virtual space affects students' evaluations, along with their perceptions of how clearly the material was taught and the effectiveness of distance learning. The motivation behind the study was a decision in the late 2010s by our academic institute to experiment with elements of interactive learning under the *WeLearn* umbrella (https://welearn.org/#/). As part of this initiative, academic staff were encouraged to integrate active learning using digital and interactive teaching tools in all courses. Specifically, lecturers were encouraged to incorporate four active learning practices into class time: small group work; independent work; student presentations; and short knowledge tests.

To gauge the effects of the new practices, during the 2019–2020 academic year the university began including assessments of active learning in routine teaching evaluation surveys filled out by students. The present study examined the results of surveys distributed at the end of Semester B in 2019–2020 (i.e., in June 2020) and the end of Semester A in 2020–2021 (January 2021). This timing coincided with the onset of the COVID-19 pandemic and the shift to online learning. Thus, we examined *how active learning **in online courses**, and specifically the **extent** and*

variety *of interactive learning methods used, is associated with students' (a) evaluations of the course, (b) perceptions of the effectiveness of distance learning, and (c) perceptions of the clarity of the teaching*. Thus, the present study adds to the literature on both online learning and active learning by examining the role of the latter in a distance learning context.

The data are based on nearly 30,000 surveys completed by about 4,800 students, including women and men in different years of study (first through fourth), who were studying in various departments (e.g., business administration, computer science, nursing) within four different faculties for either a bachelor's or master's degree. All students were enrolled at the same academic institution. The surveys related to 1,265 classes taught by 385 lecturers.

Data on the research questions was analyzed alongside a range of 13 class and student characteristics (e.g., class size, lecturer's gender, student's gender, etc.). Analysis of the data, using a variety of statistical research methods (including the Wilcoxon test and multivariate linear regressions), shows that, above and beyond the effect of class characteristics, high use of interactive learning methods is associated with higher student evaluation scores, higher perceived effectiveness of distance learning, and clearer teaching. Our results suggest that one key feature is the **variety** of active learning methods used, such that the more varied the practices the student experiences, the more satisfied that student is likely to be with the teaching in the class and the greater its perceived effectiveness. Among the four practices examined, our findings show the strongest results for short knowledge tests during classes. Following these results, we hope that the AI-based models we developed for the prediction of students' evaluations will help lecturers and teaching staff to better design and fine-tune their courses and their teaching approaches.

Background

Active Learning: Definition and examples

Active learning has been explored with increasing intensity over the last two decades. The literature offers different definitions of active learning. According to Felder and Brent (2009, p. 2), "Active learning consists of short course-related individual or small-group activities that all students in a class are called upon to do, alternating with instructor-led intervals in which student responses are processed and new information is presented." Prince (2004, p. 1) defined active learning more broadly as "any instructional method that engages students in the learning process." Many researchers prefer to define active learning in opposition to traditional learning, where students are expected to be passive recipients, doing only what is required of them, while the lecturer takes responsibility for the learning process (Mazur & Hilborn, 1997; Hake, 1998; Prince, 2004; Johnson & Johnson, 2008; Edwards, 2015). In the present study we follow this approach, defining active learning broadly as any set of methods that, when employed in the classroom, draw students out of their passive comfort zone into an active zone, where students commit to sharing responsibility for their own learning with the lecturer.

More precisely, active learning comprises a range of techniques that motivate students to engage with the material at higher levels, whether as individuals, in pairs, or in teams. They may include presenting complex issues in new contexts, encouraging students to consider a variety of solutions, presenting information in different ways, and providing immediate feedback (Khan & Madden, 2016). Specific active learning techniques include the following:

- **Peer learning.** In peer learning, students learn by teaching, a method which is known to be highly effective. Peer learning can take place in several ways. The first is student presentations, where students prepare material at home to present to their peers (and the lecturer) in class (Boud et al., 1999). The second is the inverted (or flipped) classroom, where students first learn material independently at home, and then work through questions or complex problems together in class. This is the reverse of the common practice where new content is introduced in the classroom, and then students work on mastering that content at home (Mazur & Hilborn, 1997; Bishop & Verleger, 2013; Jensen et al., 2015). Finally, in team-based learning (TBL), also known as collaborative learning, students work together on a series of group assignments in which they practice using course concepts to solve problems (Michaelsen & Sweet, 2008).
- **Peer evaluation.** In peer evaluation, students are required to evaluate the learning outcomes of others, usually on an indicator basis. Through this process, they improve their own understanding, application, or analysis of concepts learned in the course (Sengupta, 1998).
- **Case-based learning**, also called dilemma-based learning (Farashahi & Tajeddin 2018), is a well-established approach in which students are asked to apply their knowledge to real-world problems. As such, they learn by doing, while also developing interpersonal skills as they integrate and assess the perspectives of different team members. Case-based learning can be supported easily via collaborative digital tools like digital mind maps.

Other commonly used active learning methods include blended learning, simulations, role-playing, knowledge tests, active discussions, and more.

Discussions of active learning methods in the literature distinguish between two sets of orthogonal parameters: whether they employ multimedia/digital technologies; and whether the class meets in a physical (F2F) or virtual space (online, remote, or distance learning). A wealth of contemporary apps and technologies mean that most active learning methods can be carried out even in online classrooms (for example, small work groups can meet in breakout rooms on Zoom, while students can share content on virtual bulletin boards using the Padlet app). Some research has examined how different active learning tools affect measures of student satisfaction and perceptions of learning face-to-face versus distance learning. For example, Parrish et al. (2021) used embedded mixed methods to examine how students' perceptions of classroom community varied between face-to-face and online courses in the presence and absence of team-based learning (TBL). They found that students in online TBL courses experienced a similar sense of classroom community and connectedness as those in face-to-face courses. The present study adds value to this literature, in light of the transition in academia to distance learning necessitated by the pandemic.

Table 1 outlines the four course types created by the two sets of parameters. The present study is concerned only with the cell at top right—virtual classes employing digital technology.

Table 1
Active Learning Parameters

Class environment / Technology	**Physical**	**Virtual (online)**
Digital	Class meets F2F; active learning exploits multimedia/ digital tools and software	Class meets online; active learning exploits multimedia/ digital tools and software
Non-digital	Class meets F2F; active learning includes only F2F components	Class meets online; active learning limited to verbal, whole-group activities.

Active Learning Combined with Multimedia/Digital Tools

In the context of digital technologies, multimedia refers to interactive digital tools that employ more than one type of media, such as text (alphabetical or numerical), symbols, images, audio, video, or 3D (Guan et al., 2018). Many different multimedia applications are currently on the market, designed for different disciplines (e.g., mathematics, social sciences, natural sciences, physiology, and physical education), different age groups, and different goals (Abdulrahaman et al., 2020). Some applications have been found to significantly support and facilitate learning, while for others only marginal success has been recorded. For example, Dori and Belcher (2005) reported on the Technology-Enabled Active Learning (TEAL) project, conducted at MIT, in which media-rich software used for simulation and visualization was combined with group interaction in specially designed freshman physics classes. Most students who participated in the project reported that they would recommend the TEAL course, citing the benefits of interactivity, visualization, and hands-on experiments, which were enabled or supported by the technology. Milovanovic et al. (2013) and Werdiningsih et al. (2019) examined the use of multimedia tools in the context of mathematics and computer training, respectively. In both studies, students were divided into a control group, where lectures were given in the traditional way, and an experimental group, where interactive multimedia tools were used during the lessons. In both studies, students in the multimedia group demonstrated better theoretical and practical knowledge, and Milovanovic et al. (2013) also found that students in the multimedia group were more interested in the material being studied.

Balzotti and McCool (2016) examined whether the flipped classroom model could be extended by using digital platforms. To this end, they integrated into undergraduate courses a set of video modules that documented the opinions of experts on course-related topics. The researchers found that these videos, which simulated informal in-class conversations, expanded the possibilities of the flipped classroom model. The course instructors also reported that the use of digital platforms increased student engagement.

Werdiningsih et al. (2019) examined different multimedia tools and concluded that such tools are most effective when chosen to suit characteristics of the class and discipline. Abdulrahaman et al. (2020) also found that the design and sophistication of multimedia applications must be adapted to the learning process.

To summarize: The above studies show that using active learning combined with multimedia tools increases students' engagement and satisfaction with the course.

Related Works

In this section, we review studies with a similar goal to our work. Recall that we are interested in how diverse active learning methods (combined with technology), used in online courses, affect (a) students' overall evaluation of the course; (b) their perceptions of the clarity of the teaching; and (c) their perceptions of the effectiveness of distance learning.

We found in the literature a wide variety of studies dealing with active learning methods and their effects on students' perceptions, behavior, and success: learning satisfaction, performance, academic skills (e.g., time management), personal skills (e.g., self-esteem), commitment, and more (Sahin, 2007; Armbruster et al., 2009; Fisher et al., 2021; Mou, 2021; Parrish et al., 2021). Yet some of these studies do not explore online courses, and some chose to examine different effects than ours. In this section, we focus on the literature that investigates online courses with goals germane to our research goals.

Many studies have explored the relationship between distance learning and students' engagement (Cole et al., 2021), satisfaction (Sahin, 2007; Liaw, 2008; Stefanovic, 2011; Landrum, 2020; Ho, 2021), emotions (Ghaderizefreh & Hoover, 2018), and more. Sahin (2007) explored the characteristics of online learning environments using data collected via a survey of 917 undergraduate students. Results show that (a) personal relevance, (b) instructor support, (c) active learning, and (d) authentic learning were significantly and positively related to student satisfaction. It should be recalled that the capabilities of distance learning technology in 2007 were lower than those of the present day, suggesting that active learning might be even more relevant and useful in contemporary online courses. Ho and colleagues (2021) examined the effect of Emergency Remote Learning (ERL) on students' satisfaction with a sample comprising 425 students from multiple university departments in Hong Kong. While their research questions focused mainly on comparing machine learning and traditional multiple regression models as predictive tools, their results also showed that students prefer face-to-face learning over remote learning. In addition, the following factors influenced the satisfaction score: (a) the instructors' efforts, (b) the appropriateness of the assessment methods, and (c) the perception of online learning being well delivered. Ghaderizefreh and Hoover (2018) examined the effect of online learning on students' emotions and satisfaction with their online learning experience, as well as the effect of students' emotions on their satisfaction. The results show that the students' reports of higher understanding and greater use of illustrations to explain the material were associated with greater enjoyment and lower levels of anger, anxiety, and boredom. Additionally, higher levels of enjoyment and lower levels of anger and boredom increased student satisfaction with the online learning experience.

A few works have examined students' perceptions of the clarity of teaching and the effectiveness of online learning. Liaw (2007) investigated the effectiveness of the Blackboard e-learning system, in addition to students' satisfaction and behavioral intentions, by questioning 424 university students. The study's results showed a strong influence of multimedia instruction, interactive learning activities, and e-learning system quality on the effectiveness of distance learning. Arevalo et al. (2021) assessed both the clarity of teaching and difficulty of earth and space lessons in online personalized learning classes involving interactive approaches (such as task cards). The researchers found that the interactive approaches were useful as an intervention in online distance learning. In addition, lessons taught clearly were considered to be easier.

Table 2 provides an overview of relevant works, mapped according to study characteristics (including reference to data source, sample size, no. of classes in the sample, and whether a predicted model was presented), a list of dependent variables in the study, and independent

variables in the study (including reference to whether the study examined the use of interactive learning methods, and, in particular, a variety of learning methods; class/course characteristics; student characteristics; and other characteristics).

As can be seen from Table 2, most of the reviewed studies deal with student satisfaction or evaluations, and only a few refer to students' perceptions about the clarity of teaching and the effectiveness of distance learning. In addition, only a few of the reviewed studies refer to interactive methods in online learning, and their effect on the outcome variables of interest in this study. The previous studies most similar to the present work are those of Liaw (2007) and Arevalo et al. (2021), described above. The present study expands on that previous work by examining how specific interactive learning methods affect the perceived clarity of teaching and the effectiveness of distance learning. In addition, we investigated the effect of using a variety of interactive methods, which to best of our knowledge has been addressed only minimally.

Table 2
Overview of Relevant Works, Mapped According to Study Characteristics

	Study characteristics				**Independent variables in the study**				
Reference	**Sample size and source**	**No. of classes in the sample**	**Predicted model?**	**Dependent variables in the study[1]**	**Use of interactive learning methods**	**Use of a variety of learning methods**	**Class/course characteristics**	**Student characteristics**	**Other characteristics**
Current work	~30,000 teaching surveys	1265	Yes	1,2,3	Yes (4 specific methods)	Yes	1. class size, 2. lecturer's gender, 3. semester 4. % of male students, 5. % of stu. with disabilities, 6. % of non-native speakers	1. gender, 2. faculty, 3. year of study	None
Ghaderizefreh & Hoover, 2018	29 questionnaires	1	No	1,4	No	NA	None	1. age, 2. experience in online learning	1. understandability, 2. illustration, 3. level of expectation, 4. difficulty, 5. lack of clarity, 6. pace, 7. enthusiasm, 8. fostering attention
Landrum, 2020	88 questionnaires	1	Yes	1,5,6,7	No	NA	None	1. gender, 2. age	None
Liaw, 2007	424 questionnaires	1	Yes	1,7,10	Yes (without specifying methods)	NA	None	1. gender, 2. study field, 3. experience in online learning, 4. attitudes to e-learning	1. perceived self-efficacy, 2. multimedia instruction, 3. e-learning system quality

[1] Dependent variables in the study: (1) evaluation/satisfaction scores, (2) clarity of teaching, (3) effectiveness of online learning, (4) emotions, (5) self-efficacy, (6) self-regulation, (7) usefulness, (8) perceived learning, (9) academic performance, (10) behavioral intentions, (11) difficulty in course, (12) learning outcome

Sahin, 2011	917 surveys	7	Yes	1	Yes (without specifying methods)	No	1. class type	1. gender, 2. department	1. instructor support, 2. student interaction & collaboration, 3. personal relevance,4. authentic learning, 5. student autonomy
Ho et al., 2021	425 questionnaires	NA	Yes	1	No	NA	None	1. gender, 2. mode of study, 3. year of study	1. readiness, 2. accessibility, 3. instructor-related factors, 4. assessment-related factors, 5. learning-related factors, 6. self-concern
Eom et al., 2006	397 quantitative surveys	?	No	1,8	No	NA	1. course structure, 2. instructor, 3. feedback, 4. interaction, 5. instructor facilitation	1. self-motivation, 2. learning style	None
Hassan et al., 2021	328 surveys	?	Yes	1	No	NA	None	1. gender, 2. age, 3. field of study, 4. academic degree, 5. year of study, 6. CGPA, 7. work status, 8. working conditions, 9. being a parent	1. perceptions of workload, 2. availability of technical support, 3. fear of failing in courses, 4. perceiving teachers as more demanding, 5. unable to catch up with academic tasks, 6. confidence in future career

Gray&DiLoreto, 2016	187 surveys	1	No	1,8	No	NA	1. course structure /org., 2. instructor presence	None	1.learner interaction, 2.student engagement
Al-Adwan, 2021	537 surveys	80	Yes	1,7,9	No	NA	1. instructor quality, 2. course content quality	None	1. self-regulated learning, 2. education system quality, 3. support service quality, 4. system use
Kuo, 2014	180 surveys	26	Yes	1	No	NA	1. course category, 2. programs offering the course	None	1. self-regulated learning, 2. internet self-efficacy, 3. learner-content interaction, 4. learner-learner interaction, 5. learner-instructor interaction
Parahoo, 2016	834 questionnaires	1	Yes	1	No	NA	None	None	1. student interactions, 2. IT/administrative staff interaction, 3. faculty empathy, 4. reputation of university, 5. physical facilities, 6. faculty feedback
Limperos, 2015	259 quizzes	1	No	3,12	No	Yes	None		1. experience with instructor 2. instructor credibility
Choy & Quek, 2016	227 surveys	1	No	1,9	No	NA	None	1. age, 2. academic level	1. teaching presence, 2. social presence, 3. cognitive presence

Arevalo et al., 2021	129 question naires	1	No	2,11	Yes	NA	None	1. socioeconomic status	1. task performance, 2. emotion regulation, 3. collaboration and engagement with others

Research Objectives

Our research examines the relationship between active learning in an online course, class characteristics, and three outcome metrics: students' evaluation scores, perceptions of the effectiveness of distance learning, and perceptions of the clarity of teaching in the course. The source of the data is routine student evaluation surveys administered at the end of the semester.

Based on the above, we formulated the following **research questions:**

RQ (1) *How do interactive learning methods in an online course affect students' evaluations of the course alongside different class and student characteristics?*

RQ (2) *How do interactive learning methods in an online course affect students' perceptions of the effectiveness of online learning alongside different class and student characteristics?*

RQ (3) *How do interactive learning methods in an online course affect students' perceptions of the clarity of teaching in the course alongside different class and student characteristics?*

RQ (4) *Does use of a variety of learning methods in an online course affect students' evaluation of the course?*

RQ (5) *Does use of a variety of learning methods in an online course affect perceptions of the effectiveness of online learning?*

RQ (6) *Does use of a variety of learning methods in an online course affect perceptions of the clarity of teaching in the course?*

We have three dependent variables and 13 independent variables: four for the different interactive learning methods (numbered 1–4), and nine for characteristics of the student and the class (numbered 5–13). We elaborate on these variables in Table 3.

Table 3
The Study's Dependent Variables and Independent Variables

Dependent variables	1) Student evaluation (a teaching evaluation from the student's point of view). 2) The student's perception of the effectiveness of online (distance) learning. 3) The student's perception of the clarity with which the course was taught.
Independent variables	1) Use of small working groups for discussion, thinking through, or performing a task (using breakout rooms on Zoom). 2) Independent work during lessons. 3) Student presentations during lessons. 4) Short knowledge tests during lessons (e.g., quizzes and questionnaires). 5) Class size (number of students; classes range from less than 10 to over 100 students). 6) Lecturer's gender. 7) Student's gender. 8) Student's faculty (one of the following: Social and Community Sciences, Marine Sciences, Engineering, Economics and Business Administration). 9) Semester in which the class was taken (Semester B in 2019-2020, or Semester A in 2020-2021). 10) % of male students in the class. 11) % of students in the class with learning disabilities (based on data held by the university's student accessibility office). 12) % of Arab students in the class. Arab students are a cultural and linguistic minority in the country and in particular in the institution, and the language of instruction is their second language. Therefore, we found it appropriate to examine this variable as well. 13) Student's year of study. Students in their first through third years of study were working toward a bachelor's degree. Students in their fourth year of study were primarily studying toward a master's degree, while typically also working in the industry.

Methods

As described above, the research relied on evaluation surveys filled out by students at the end of Semester B in 2019–2020 (i.e., in June 2020) and the end of Semester A in 2020-2021 (January 2021). Such surveys are routinely distributed by academic institutions to assess measures of student satisfaction and teaching quality. The surveys examined for the present study included, for the first time at our institution, questions related to the use of interactive learning methods. Machine learning models and probabilistic statistical tools were used to address the research questions.

It should be noted that following the onset of the COVID-19 pandemic, all educational institutions in the country were ordered to close for in-person studies as of March 15, 2020. Semester B in the 2019–2020 academic year began on March 8, 2020. Therefore, the Semester B survey relates to the first semester following the enforced shift to distance learning.

Participants and Procedure

As noted, survey participants were all students at the same academic institute. Survey questionnaires were distributed among 4,515 students in the 2019–2020 Semester B survey, and among 4,853 students in the 2020–2021 Semester A survey. Two thousand and sixteen students (a response rate of 45%) returned completed surveys in Semester B, and 2,778 (a response rate of 57%) in Semester A. Students were asked to complete a survey for each class in which they were registered. In total, we analyzed 29,382 surveys, covering 1,265 classes taught by 385 lecturers.

The analyzed surveys related to classes in 23 departments in all four of the institution's faculties (Social and Community Sciences, Marine Sciences, Engineering, Economics, and Business Administration). All surveys analyzed referred to lecture-style classes. We excluded seminars as these are held in small groups, and do not incorporate digital teaching tools. Because participants returned surveys anonymously, we do not know the overall number of males and females who responded to the survey. However, this figure is known for each class.

Measures

Each survey included several items designed to elicit students' overall assessment and specific perceptions regarding the course. We used a partial set of these items to address our research questions. The used items are presented in Table 4. Items 1–3 refer to student evaluation measures; for each one, students were asked to rate their degree of agreement or evaluation on a scale from 1 (lowest) to 6 (highest). Items 4–7 refer to interactive learning. Students were asked to report the frequency with which the four interactive learning methods were used in the class, from 1 (never used) to 4 (used very frequently. Our three dependent variables were defined based on survey items 1–3 as follows: course evaluation scores were based on item 1, clarity of teaching the course material was based on item 2, and the perceived effectiveness of remote learning was based on item 3.

Table 4
Selected Items Used in this Study

#	Question	Scale
1	Overall assessment (evaluation)	1–6
2	Clarity of teaching in this class	1–6
3	Effectiveness of distance learning in this class	1–6
4	Use of small working groups for discussion, thinking through, or performing a task (using breakout rooms on Zoom)	1–4
5	Independent work during lessons	1–4
6	Student presentations during lessons	1–4
7	Short knowledge tests during lessons (e.g., quizzes and questionnaires)	1–4

Analytical Strategy

Descriptive and inferential statistics.

Due to the non-normal distribution of the course evaluation scores, we used nonparametric statistical tests. Specifically, the Wilcoxon unpaired test was used to compare between evaluation scores in classes taught by male lecturers versus female lecturers; between evaluation scores from male students versus female students; and between evaluation scores from students working toward a bachelor's degree versus a master's degree.

Pearson and Spearman correlations were used to calculate the correlation between evaluation

scores and the percentage of Arab students in the class. Pearson correlations were also used to calculate the correlation between evaluation scores and the student's year of study.

To overcome potential bias due to diversity in class sizes, we created class-related entries based on the average measures for each class. These entries include average evaluation scores and average use of interactive learning methods (as reported by students in the surveys). Wilcoxon nonparametric tests were used to compare the extent to which interactive learning methods were used between male and female lecturers and between lecturers from different faculties. Spearman correlations were used to calculate the correlation between the extent of use of interactive learning methods and the three dependent variables: course evaluation scores, clarity of the teaching, and the perceived effectiveness of remote learning.

To examine the effect of using a variety of interactive learning methods, we defined two groups of classes: (a) those which made high use of a variety of interactive learning methods, using at least three different interactive learning methods in most of the lessons; and (b) those which made little or no use of interactive learning methods, with no more than one interactive learning method being used only once in the class. Wilcoxon unpaired tests were used to compare the three dependent variables between the two groups. Classes that fell in the middle range, using a small number of interactive learning methods and using them less often, were not examined in this analysis.

Multivariate linear regressions and prediction models.

Interval parameters were normalized to range between 0 and 1. Multivariate linear regressions were used to predict scores for course evaluation, clarity of the teaching, and perceived effectiveness of remote learning, based on the independent variables: the six class characteristics (number of students, semester, lecturer's sex, percentage of male students, percentage of Arab students, and percentage of students with learning disabilities) and the four interactive learning methods (small working groups, independent tasks, student presentations, and short knowledge tests). Multivariate linear regressions were also conducted for each faculty separately.

To create a prediction model and to evaluate the performance of the multivariate linear regression, we randomly split the data into a training set (80% of the data) and a test set (20%). Multivariate linear regressions were built based on the training set and tested on the test set. The process was repeated 1,000 times and the average root mean square error (RMSE) for both the training and the test sets were calculated for each model. We compared the average training RMSE to the average test RMSE and to the standard deviation of each of the sets. All statistical analyses and prediction models were conducted using Matlab© version R2021b.

Findings

We present our findings for the general and univariate statistics in sections 5.1 and 5.2. Sections 5.3 and 5.4 describe the multivariate analyses addressing the research questions defined in section 3.

Effects of Student and Class Characteristics on Evaluation Scores

Course evaluation scores were statistically significantly higher for classes taught by female lecturers (mean: 5.0, median: 5.17, std: 0.7) than male lecturers (mean: 4.8, median: 5.0, std: 0.8), $p < 0.001$. In addition, evaluation scores were statistically significantly higher when given by female students (mean: 5.0, median: 5.0, std: 1.3) than by male students (mean: 4.7,

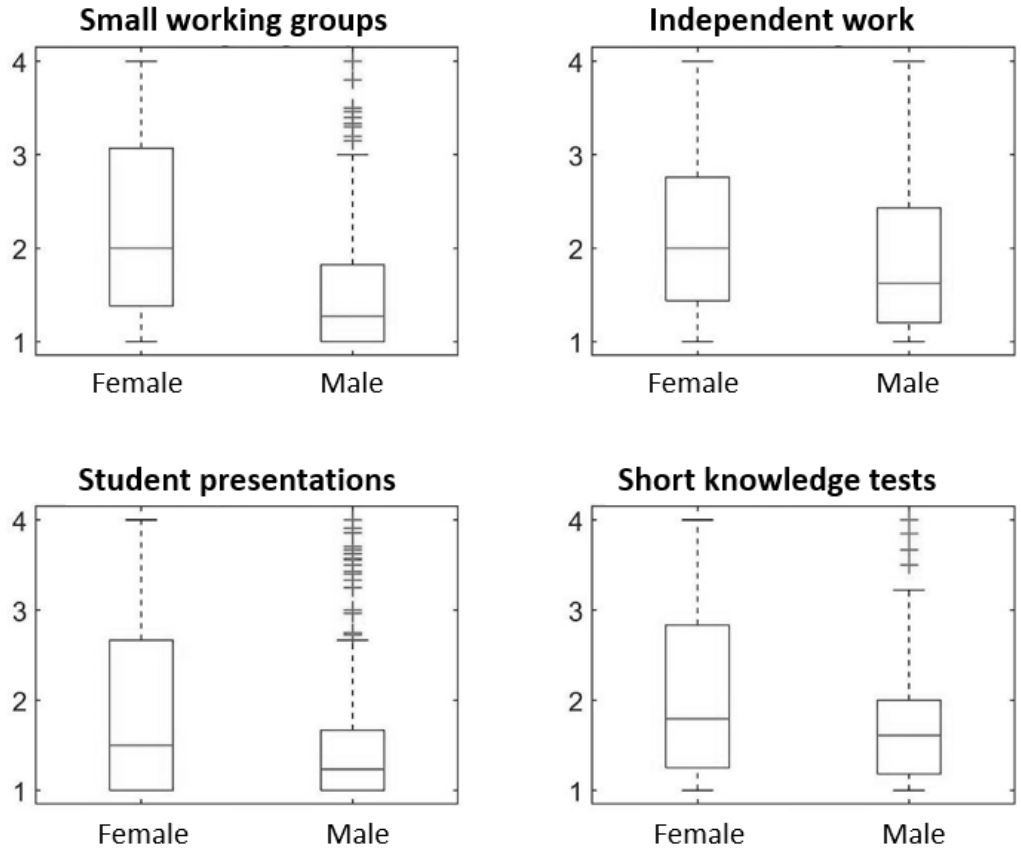
median: 5.0, std: 1.4), $p < 0.001$. Arab students tended to provide slightly higher evaluation scores in comparison to students who belonged to the Jewish majority group ($R = 0.1$, $p < 0.001$). There was no statistically significant correlation between evaluation scores and the student's year of study ($R = -0.05$).

Effects of Interactive Learning Methods on Evaluation Scores, Perceived Effectiveness of Remote Learning, and Perceived Clarity of the Teaching

All interactive learning methods were statistically significantly more used by female lecturers compared to male lecturers (see Figure 1). Of note, use of these tools differed between different faculties. Specifically, classes in the faculty of Economics and Business Administration used more small working groups and more independent work during lessons compared to the other faculties; classes in the faculty of Social and Community Sciences used more student presentations compared to the other faculties; and class in the faculty of Marine Sciences used more short knowledge tests compared to the other faculties.

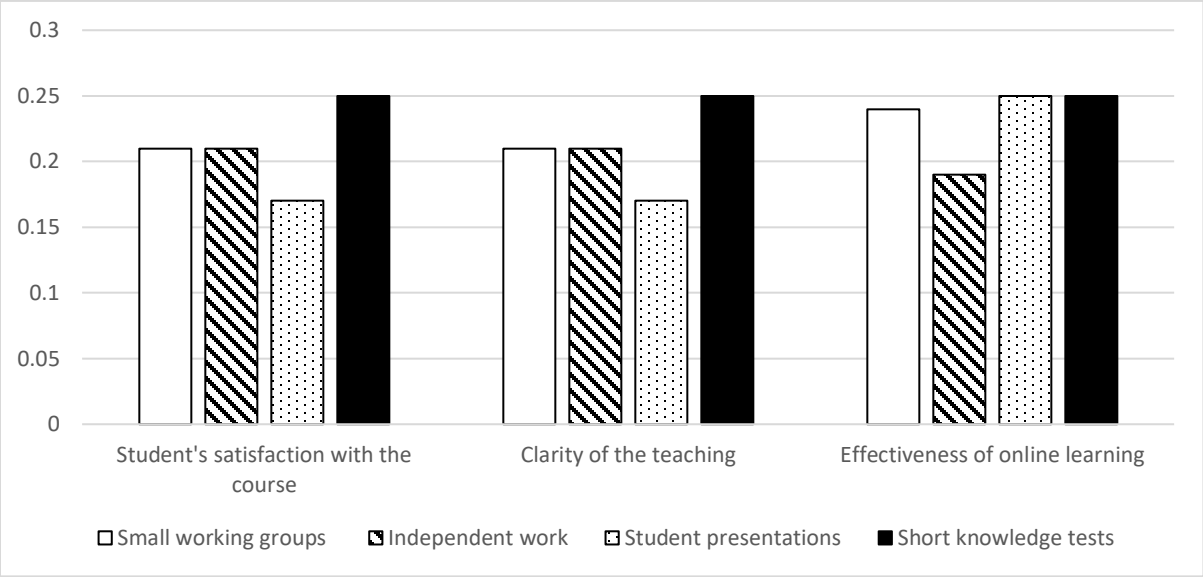
Figure 1

Use of interactive learning tools by female vs. male lecturers (working groups / independent work / presentations / knowledge tests). All comparisons by gender were statistically significant ($p < 0.001$)



Importantly, there were statistically significant correlations ($p < 0.05$) between the use of interactive learning methods and the three dependent variables: course evaluation scores, clarity of teaching, and the perceived effectiveness of remote learning (see Figure 2).

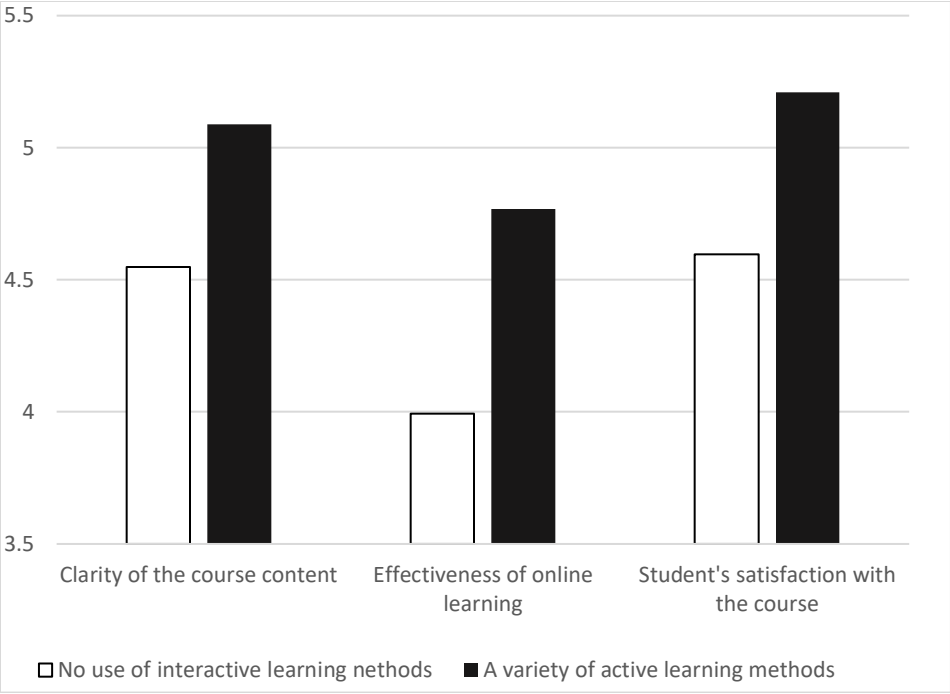
Figure 2
Spearman correlation coefficients between the use of interactive learning tools and course metrics. All correlation coefficients were statistically significantly different from zero.



Effects of Using a Variety of Interactive Learning Methods

Comparison of the three dependent variables (course evaluation scores, clarity of teaching, and the perceived effectiveness of remote learning) between classes which used a variety of interactive learning methods and those that made little-to-no use of interactive learning methods shows that all three variables are statistically significantly higher in classes where lecturers made high use of a variety of interactive learning methods ($p < 0.001$). See Figure 3.

Figure 3
Comparison of the three variables between classes which used a high variety of learning methods vs. classes which used few or no interactive learning methods. All comparisons were statistically significant (p < 0.01)



Multivariate Models

Multivariate linear regression models were built to find the relative contribution of each of the studied features for predicting the three dependent variables. All models were statistically significant ($p < 0.001$). The contributions of each variable (teta values) and their statistical significance are shown in Table 5. In brief, both evaluation scores and perceptions of clarity of teaching were higher in courses with lower proportions of male students and of students with learning disabilities, and in courses that made high use of short knowledge tests and independent tasks. However, these outcome metrics (evaluation scores and perceptions of clarity of teaching) were not statistically significantly associated with the use of small working groups or with student presentations ($p < 0.05$). Clarity of teaching (but not evaluation scores) was also statistically significantly associated with the lecturer's sex: courses taught by female lecturers were reported as clearer relative to courses taught by male lecturers.

Remote learning was perceived as more effective in courses with many students, taught by female lecturers, taken in Semester A with a lower percentage of male students, a lower percentage of students with learning disabilities, and a higher percentage of Arab students. Regarding the four interactive teaching methods, remote learning was perceived as statistically significantly more effective in courses that used independent work, student presentations, and short knowledge tests, but not in courses that used small working groups. Of all the interactive teaching methods, student presentations and short knowledge tests showed the greatest contribution to the perceived effectiveness of remote learning.

Table 5
*Multivariate Linear Regression Models to Predict Evaluation Scores, Clarity of Teaching, and Perceived Effectiveness of Remote Learning**

Model (research question)	**Evaluation score (1)**		**Clarity of teaching (2)**		**Perceived effectiveness of remote learning (3)**	
Feature	**teta**	**p-value**	**teta**	**p-value**	**teta**	**p-value**
Intercept	4.71	<0.001	4.83	<0.001	4.02	<0.001
Number of students	~0	0.969	-0.24	0.120	**0.35**	**0.03**
Male lecturer	-0.08	0.083	**-0.12**	**0.013**	**-0.15**	**0.003**
Semester A	-0.02	0.590	-0.03	0.461	**-0.1**	**0.03**
% of male students	**-0.41**	**<0.001**	**-0.40**	**<0.001**	**-0.43**	**<0.001**
% of students with learning disabilities	**-0.81**	**<0.001**	**-0.99**	**<0.001**	**-0.91**	**<0.001**
% of Arab students	0.13	0.394	0.20	0.238	**0.5**	**0.006**
Small working groups	0.001	0.993	-0.17	0.209	0.11	0.23
Independent work	**0.53**	**<0.001**	**0.49**	**<0.001**	**0.36**	**0.018**
Student presentations	0.2	0.085	0.12	0.358	**0.55**	**<0.001**
Short knowledge tests	**0.45**	**<0.001**	**0.53**	**<0.001**	**0.61**	**<0.001**

*Statistically significant associations are in bold font

Linear Regression Models

In the final step, we built linear regression models to predict course evaluation scores based on the faculty, the number of students, the lecturer's sex, the semester, the percentage of male students, percentage of Arab students, percentage of students with learning disabilities, and the use of interactive learning methods. These models were statistically significant ($p < 0.05$). In addition, the low average RMSE for both the training set (0.7) and the test set (0.71) highlight the ability of the models to successfully predict course evaluation scores based on the tested variables. Furthermore, the RMSE values of both the training and test sets were lower than the standard deviation of the evaluation scores (0.75), bolstering the significance of the models.

Repeating the process while excluding the interactive learning variables resulted in higher average RMSE values (0.72 for the training set and 0.73 for the test set). These findings also underscore the importance of interactive learning tools as a source of positive student evaluations.

Discussion and Conclusions

Over recent decades, a large body of work has highlighted the limitations of traditional teaching, based on a frontal model in which the lecturer conveys information and students listen (Laws, 1991; Mazur & Hilborn, 1997; Hake, 1998). For example, students taught under the frontal model tend to be passive and unengaged in lessons, find it difficult to explain the main topics learned in the lesson, and do not express their views in the context of these topics (Fullan, 2001; McDermott, 1991). Such findings gave rise to the active learning framework, based on various methods designed to engage students during the lesson through writing, reading, discussions and other activities. Instead of frontal lectures in which students are passive consumers of knowledge, active learning has the potential to deepen and enhance learning by turning students into proactive knowledge producers (Haidet et al., 2004).

The present study took advantage of the convergence of two events: a move toward greater use of active learning in our academic institution, and the shift to distance learning sparked by the COVID-19 pandemic. Researchers have begun to examine the implications of the COVID-19 period, and specifically those arising from distance learning, on various educational outcomes, such as the psychological effects on students. This study adds to that literature, as well as the literature on active learning, by examining how the use of interactive learning methods in a distance learning environment affects students' evaluations, their perceptions of the clarity of teaching in the course, and their perceptions of the effectiveness of distance learning.

Using Spearman correlations, we found significant positive associations between the three outcome metrics and higher use of each of the four examined active learning methods: small working groups, independent work during lessons, student presentations, and short knowledge tests (Figure 2). However, in multivariable regression models that included the active learning methods along with a variety of class characteristics, only independent work, and short knowledge tests (and not small working groups or student presentations) were statistically positively associated with all three outcome metrics. Of note, these models show that short knowledge tests were not only significantly associated with the perceived effectiveness of remote learning and the clarity of teaching, but they also contribute the most to predicting these two metrics (Table 5). Short knowledge tests encourage students to learn effectively because they provide immediate feedback, and because students may compete with their fellow students over their performance (Cook & Babon, 2017). Therefore, short knowledge tests can lead to greater engagement, an improved learning process, higher evaluations, and increased perceived effectiveness of remote learning.

Another major finding was that these three outcome metrics were higher in classes that made frequent use of a large variety of interactive learning methods, in comparison to classes with little or no use of interactive learning methods. Note, however, that this conclusion stems from a binary comparison of the extreme groups (high use of a large variety of interactive learning methods versus little or no use of such methods) and not from a linear model, since classes that made moderate use of interactive learning methods were not included in this analysis. Therefore, no conclusions can be drawn about the effects of slight differences in the extent or variety of interactive learning methods used.

While we focused on the influence of active learning methods, we also examined several class and student characteristics. We found that female students tend to provide higher evaluation scores, and that female lecturers tend to receive higher scores in comparison to male lecturers. The latter finding contradicts findings published in recent years, in which female lecturers were

given lower scores in comparison to male lecturers (MacNell et al., 2015; Boring & Ottoboni, 2016). These discrepancies may stem from differences in the studies' designs or settings, including cultural differences between participants, different learning environments, or effects of timing. We recommend that future research continue to investigate the role of gender in student evaluations.

This study has several limitations. Most notably, the surveys we used for our data are subjective, and some responses may have been biased, e.g., due to sympathy for or dislike of certain lecturers. Furthermore, some of the surveys may have been filled out carelessly. In addition, we relied on students' reports to measure the use of active learning methods. Finally, as noted above, our conclusions regarding the use of a variety of interactive learning methods, are based on a binary comparison rather than on a continuous linear model.

At the same time, the study has several significant strengths: First, it is based on many participants from different faculties, departments, and years of study. Second, the data derives from evaluations for many courses that were taught under the same conditions. Third, we studied class and student characteristics in addition to the active learning methods. Finally, from a practical perspective, lecturers and administrators can use the outcomes, and particularly the prediction models developed in this study, to plan their own use of interactive learning methods, to improve their students' evaluations, understanding, and learning.

Declarations

The authors declare no conflicts of interest.
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