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Article

Enriching Traditional Higher STEM Education with Online Teaching and Learning Practices: Students' Perspective

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Abstract: In this paper, we aim to identify online teaching and learning practices that would be beneficial for blended and traditional on-campus education within STEM (Science, Technology, Engineering, and Mathematics) courses. Our university, as well as the majority of higher education institutions worldwide, has had few to no experience in delivering full online courses before 2020. The teaching process was, however, severely affected and modified by the COVID-19 pandemic, forcing an abrupt and unprepared shift towards online education. In this work, we look at the pandemic as causing a very favorable side effect that forced the university to study, test, apply, and evaluate the benefits and drawbacks of online education and assessment methods. The study is a result of joint efforts from different departments at the University of Aveiro, Portugal, connected to STEM undergraduate and graduate programs and is based on a questionnaire targeted towards students. In total, 167 valid STEM students' answers have been collected and analyzed, both quantitatively and qualitatively. As the result, the best teaching and learning practices are identified and the main difficulties and obstacles experienced by students are detected. Some of the problems are common to many higher education institutions, such as the lack of teacher preparation in delivering quality online synchronous and asynchronous classes, technical limitations (network bandwidth/weak equipment), ineffective communication during synchronous classes, gaps in student skills, and low activity of some students and even teachers. We believe that the presented results would allow for improving future on-campus, distance, and blended learning courses, particularly through avoiding less effective teaching and assessment methods and favoring those techniques that students consider more efficient. This ultimately would lead to a more rewarding teaching/learning experience.

Keywords: higher education; science, technology, engineering and mathematics (STEM); online/blended education; teaching and learning practices

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1. Introduction

It is well known that the COVID-19 outbreak has had a significant impact on higher education all over the world. Higher Education Institutions (HEIs) have done an enormous effort to adapt to online teaching and learning in a very short period. Teachers from HEIs strived remarkably to quickly transform their study programs and techniques to online teaching and at the same time keep students engaged. The adjustment, however, came with significant challenges not only in relation to the methodology of the teaching process and the teacher–student interaction, but also in technical aspects, such as simultaneously handling a large number of online sessions by the same video conferencing platform.

The motivation of this study is to analyze the challenges experienced by the teachers and students of STEM (Science, Technology, Engineering, and Mathematics) courses at HEIs. The main goal of this work is to identify the best practices and tools in distance education, based on the point of view of students, with the intention to incorporate such practices in online, blended and traditional on-campus courses.

In this work, we use the terms "distance learning", "distance education", and "online learning" interchangeably to refer to learning without a physical presence in the classroom of either teachers or the students (or both), accomplished with the use of various technologies to facilitate interaction between (and among) students and teachers. Traditionally, distance learning was directed to students with special needs, such as working students, disabled students, and students from remote locations who are not able to attend classes regularly. The associated benefits, such as "learner-centered", "anywhere", "anytime", and "any pace" are well-known synonyms of online learning [1–3]. Contrary to these, distance education demands much more maturity, commitment, and self-discipline from students, compared to the traditional classroom education [2]. Moreover, teachers' investment to online education tends to be much higher because the contents have to be fully adapted to learner-centered activities [2]. The lack of immediate feedback and observable behavior in others are also among the limitations of distance education [4]. That is why online learning has become more popular in recent years, albeit the traditional face-to-face model still dominates, even taking into account the recent much-accelerated enrollment in online courses. According to data from the USA National Center for Education Statistics [5], the percentage of undergraduate students at degree-granting postsecondary institutions who enrolled exclusively in distance education courses in the fall of 2020 varied between ~46% for public institutions, ~35% for private nonprofit institutions, and ~44% for private profit institutions. In the EU, according to data from the Eurostat [6], 27% of people aged 16 to 74 reported that they did an online course or used online learning material in the three months prior to the survey conducted in 2021, a 4% increase compared with 23% in 2020.

STEM-related courses pose additional requirements on conducting successful online education because they do frequently require specialized software and equipment that is usually available only in dedicated university laboratories. This is especially true for engineering courses where the work in a real laboratory is hardly fully substituted by online demonstrations, simulators, or virtual laboratories. Nevertheless, under the pressure of COVID-19 pandemic, the majority of HEIs worldwide were forced to adapt ad-hoc online teaching methods, including for STEM courses. Nowadays, some of those courses continue to function exclusively online, some have switched back completely to the traditional on-campus mode, and some operate in a blended manner.

This study deals with the particular case of distance education at the University of Aveiro, Portugal for students of STEM courses and it is focused on answering the following research questions:

(1) What are the main problems experienced by the students who have had no previous experience in online education?

(2) What are the solutions that promote the increase of interaction between teachers and students, as well as between students, during distance learning, which reinforce the engagement and motivation of students and teachers?

(3) What are the best online teaching practices applied to STEM courses?

(4) What should be recommended for future on-campus, online, or blended education in STEM courses?

2. Relevant Research

Several studies have been directed to analyze different aspects of the massive transition to online education regarding the STEM students' perspective, some of which are briefly reviewed below. The selected studies are grouped according to the main contributions and conclusions drawn.

The literature review was carried out in direct connection with the issues that are investigated in the paper. We were primarily interested in studies devoted to similar research, namely online learning in the context of a pandemic or other natural or climatic cataclysms, the conditions for conducting classes for university students in the field of STEM, and the problems associated.

2.1. Perception of Online Learning

Blizak et al. [7] performed a study focusing on 380 Algerian STEM students. The results showed that the students have a negative perception of online learning, with about 90% preferring traditional or blended learning. The most reported complaint was regarding internet shutdowns or weakness, particularly in rural areas. For these reasons, the main recommendations in this study rely on improving the technological aspects of online learning.

Grynyuk et al. [8] report the results of a study carried out in 65 Ukrainian HEIs based on an online questionnaire. The authors conclude that the mass transition to distance learning was a challenge for most Ukrainian HEIs and that only ~46% of the respondents reported previous experience with distance education. According to this study, just ~40% indicated full realization with distance education, whereas ~50% of respondents indicated partial realization and ~9% indicated no realization. The main obstacles were problems of a technological nature; the lack or insufficient level of methodological knowledge competence of teachers to carry out distance education; and psychological problems associated with the development of motivation, the commitment of teachers, and the establishment of new standards of communication.

Asgari et al. [9] conducted a study at California State University that showed that about half of the students do not have a private space to attend online classes and 55% faced some challenges to keep focused and engaged. These results show consistency with other similar studies carried out at other universities (e.g., [10]). An extended study based on the existing literature, performed by Turner et al. [11], was concerned with justice and integrity among instructors and students of STEM courses. Students from low socio-economic backgrounds faced more difficulties such as bad internet connection, inadequate technologies, or lack of private space. The study suggests some recommendations for distance or/and in-person education, underlying the necessity of inclusive course design that emphasizes group discussion, peer-grading, and group or individual projects of the student's choosing.

In the review by Masalimova et al. [12], the authors analyzed 27 publications related to students' perspectives on distance learning in higher education. According to this review, in some studies, students' attitudes are positive, whereas in other studies their attitudes are negative or moderate. It is also observed that the switch to distance learning was a source of anxiety for students. The authors also noted that in many studies, students prefer on-campus learning to online learning, as they believe that online learning is not sufficiently motivating and does not contribute to students' knowledge. The paper also stresses that poor equipment and a poor internet connection, technical difficulties, and lack of knowledge of remote learning technologies are often cited as distance learning problems.

2.2. Impact of Online Learning on Quality Outcomes

Selco and Habbak [13] focused on 584 STEM students from California State Polytechnic University. They concluded that, despite the difficulties, more than half of the students benefited from the flexibility, convenience, and increased productivity of their studies. The time students normally spent commuting to campus was rather spent getting more sleep, studying, working, and relaxing. Another major benefit was the increased accessibility to course materials posted online. The top ten recommendations to teachers are: focus on learning and knowledge gain, rather than performance; provide a variety of assessments so students can demonstrate what they learned; create a course calendar; record and post class session recordings in a timely manner; provide explicit directions and set realistic expectations for assignments and deadlines; assign more meaningful, less frequent assignments; find ways to build community; incorporate diverse styles of teaching; provide clear videos, computer simulations, or drawings with detailed explanations for activity and lab courses; and, be flexible.

Ellis and Bliuc [14] evaluated the impact of online learning technologies on quality outcomes. The study was conducted at a university in Australia for first year physics students. The profound statistical analysis of the survey results revealed that not all students approached the inquiry-based tasks in ways that were intended by the teacher who designed them. This means that the simple provision of online learning technologies is insufficient to promote their appropriate use. The students have to be guided very carefully in more effective ways of using the tools.

Batra and Palsole [4] evaluated the use of technology for interaction between teachers and students and among students. The authors designed a survey directed to undergraduate and graduate students of STEM courses in Texas. The key study conclusion is that the students prefer asynchronous courses to synchronous ones, because of greater flexibility. A higher degree of satisfaction is achieved for courses that used active methods and designed interactions rather than courses that just had expository explanations. The authors also noticed that first-generation students show lower satisfaction with the interaction in online courses and claim that more student engagement is required.

In [15], the authors conducted a Strengths, Weaknesses, Opportunities, and Challenges (SWOC) analysis of online learning, based on a systematic review of the literature. The most important indicators of Strength of online learning are time and location flexibility, catering to a wide audience, broad availability of courses, and immediate feedback. Weaknesses are technical difficulties and psychological issues: a learner's capability and confidence level, time management, distractions, frustration, anxiety, and confusion. The study showed that the intensive use of online education has created the following Opportunities: scope for innovation and digital development, design of flexible programs, possibility to strengthen such skills as problem solving, critical thinking, and an innovative pedagogical approach. Finally, the Challenges were mainly related to solving unequal distribution of ICT infrastructures, low quality of education, digital illiteracy, digital device, and technology cost and obsolescence.

3. Methods

3.1. Research Context

This study is aimed at assessing the perception of students regarding the abrupt and massive transition to distance education and its effect on the learning process of students of STEM courses. More specifically, this study tries to identify challenges and good practices of teaching/learning methodologies and ICT tools used in asynchronous and synchronous online interactive STEM education, as well as the development of innovative solutions promoting the increase of the interaction between teachers and students, reinforcing the engagement and the motivation of all those involved in the teaching/learning process. The survey covers two periods of study: the second semester of 2019/2020 (when the first lockdown had been announced) and the academic year 2020/2021 (the new lockdown was decreed in the first semester).

3.2. Study Design, Participants, and Data Collection

To answer to the research questions, a survey methodology was followed that consisted of collecting data using an online questionnaire directed to students of STEM courses at the University of Aveiro, Portugal.

The questionnaire was first validated by the university's Communication, Image, and Public Relations Services (confirming that norms of the General Data Protection Regulation are respected) and then an invitation was sent to students by e-mail by secretaries of the departments teaching STEM courses asking them to answer to an online questionnaire, anonymously. The questionnaire was available at students' disposal from June 26th to July 9th, 2021. In total, about 600 students had been reached and 167 valid answers have been collected.

The questionnaire consisted of 31 questions of the following types:

- Closed-ended questions, allowing for enumerating the most used tools and/or learning/teaching methods (suitable for quantitative analysis).
- Three/five-point Likert scale questions, indicating how much the respondents agree/disagree with a given statement.
- Open-ended questions, identifying the major challenges that the students faced during online learning and also to give an opportunity for students to suggest ways of improving distance education (suitable for qualitative analysis).
- The questions were logically divided in five categories:
- **General**—general questions about the respondents' profile (gender, age, level of studies, etc.).
- **Preparation**—questions that deal with the preparation of classes and are mainly related to distance learning tools and techniques.
- **Delivery**—questions that are connected with the process of knowledge delivery.
- **Assessment**—questions related to different assessment models and difficulties encountered in their application.
- **Evaluation**—questions aimed to measure the overall degree of satisfaction with online education.

3.3. Data Analysis

To analyze the answers to closed-ended and Likert scale questions, an Excel spreadsheet for PCs was used. The frequencies of the pre-defined answers were computed and represented graphically in the form of histograms and 2-D pie charts.

Answers to open-ended questions, where students were asked about the difficulties experienced during online learning and invited to make suggestions for improving, were collected and analyzed by the authors qualitatively. The most typical answers are presented in the paper, as well as answers reporting on some special situations/suggestions/solutions.

To deepen the study and examine relationships that might not be readily evident, a statistical analysis of some answers was performed using the software tool IBM SPSS [16]. The analysis focused on the potential influence of both gender/study level on the answers and the required learning activities on the popularity of a certain course. Counting how many cases exist in a particular category of a variable is an analysis that was performed in this study when examining categorical data from respondents' replies. These calculations can be organized into a frequency distribution table [17]. To perform the statistical analysis, the simple frequency distributions corresponding to the respondents' answers were considered as the base (categorical) data. To relate the categories of one variable with the categories of the second variable, a cross tabulation [18] was used. In addition, the Chi-square test [19] was applied in order to understand if a certain relationship is statistically significant (it was defined that a relationship is statistically significant when the p-value is lower than 0.05).

4. Survey Results

4.1. General Category

From the 167 valid answers collected from the students of various STEM courses, 100 are males, 63 females, and 4 did not specify gender. In total, 55% of the responses were received from undergraduates, 41% from graduates, and 4% from doctoral students. The majority (69%) of respondents are enrolled in engineering courses,25% in science, 20% in technology, 19% in mathematics, and 1% in physics. A total of 77% of the students have never taken an online class before, 15% have some asynchronous online activities, and 8% participated in synchronous online courses. We define here as synchronous those courses where the teachers and students are required to stay online and interact in real-time. In contrast, in asynchronous activities, the teachers and students are required to be online, but not simultaneously; the students are supposed to use materials available online and to interact but not in real-time.

Regarding distance learning devices, almost all the students worked with a portable computer (93%) but other devices were also used: mobile phones (47%), multiple monitors (21%), desktop computers (18%), and tablets (11%).

4.2. Preparation Category

The students were asked to indicate the type of assistance they received from the university and to compare their class preparation workload with that of the traditional education. The results are presented in Figures 1 and 2 and show that the students received quite a wide range of support from the university, including instructional videos, manuals, and online training. The majority of students (61%) observed that their preparation workload has increased when compared to the traditional on-campus classes, whereas 26% believe that it remained unchanged.

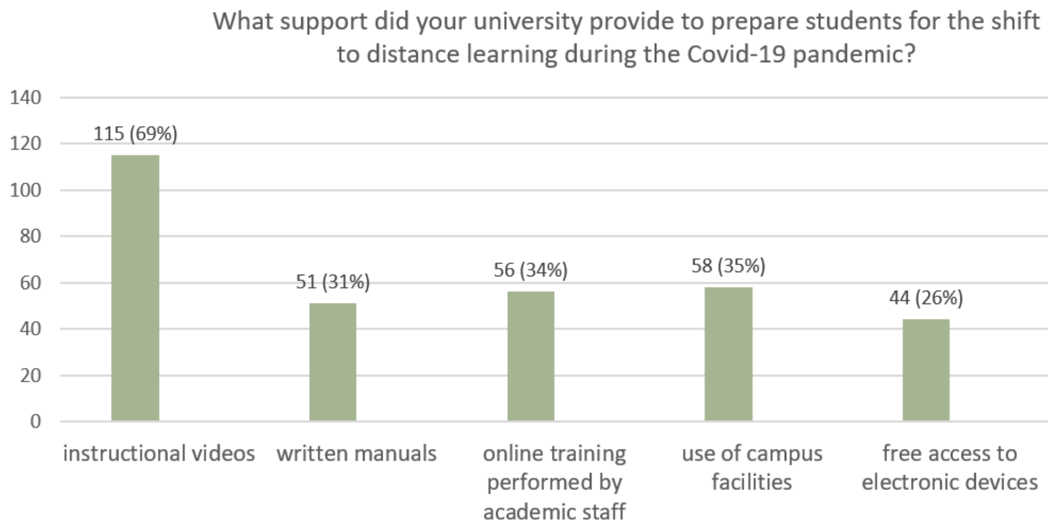

Figure 1. The support provided to students by the university to prepare for online learning.

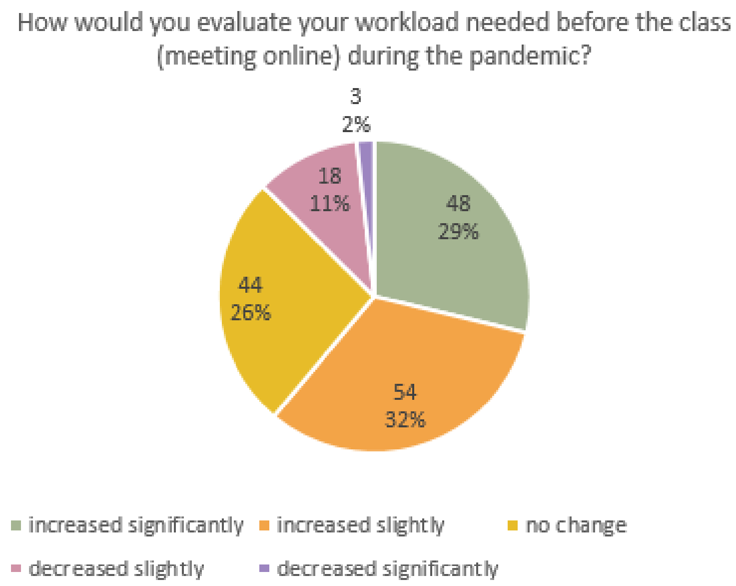

Figure 2. The preparation workload in online learning compared to traditional education.

4.3. Delivery Category

This category's questions aim at:

- discovering whether face-to-face (i.e., camera on) communication is important in synchronous classes;
- identifying the most popular software tools used for online learning (including all: applications, videoconferencing/communications tools, learning environments, social networks);
- identifying what type of education (distance or on-campus) do the students prefer;
- detecting activities that contribute most to reaching a higher degree of motivation when learning remotely;
- comparing the students' in-class activity and interaction levels to that of traditional on-campus classes;
- distinguishing the most effective learning activities according to the students' appreciation of their progress and outcomes;
- isolating the least effective learning activities according to the students' appreciation of their progress and outcomes.

Some of the results are presented in Figures 3–7 and summarized below. The majority of students (62%) consider face-to-face communication with cameras on to be very important in distance learning. In terms of videoconferencing/communication tools, Zoom and MS Teams are the most popular, at 100% and 87%, respectively. It should be noted that the students did not have the opportunity to choose the tools for conducting synchronous and asynchronous activities, since these were imposed by the teachers. Kahoot and Mentimeter were rated as the most prevalent poll/quiz platforms, whereas for social communication, the university learning management system was mainly used.

A total of 73% of the students definitely prefer on-campus learning to distance learning; 60% of the students consider online support from teachers to be very important for achieving a higher degree of motivation during distance learning and 50% consider self-assessment of progress to be meaningful. In total, 59% of the students noted that their in-class activity decreased compared to the pre-pandemic period. The students confessed that many of their colleagues were not engaged in synchronous online classes. As for favorite learning activities, according to the statistical analysis reported in Section 5.2, students prefer solving exercises, watching videos, expository real-time writing/drawing/demonstration from an instructor, and taking notes during online classes. The students strongly prefer avoiding grading other students.

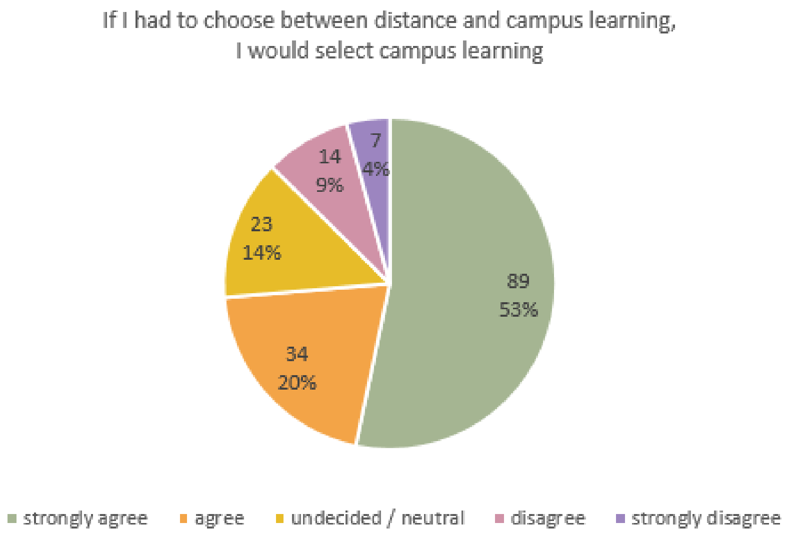

Figure 3. Students' appreciation of distance and on-campus learning.

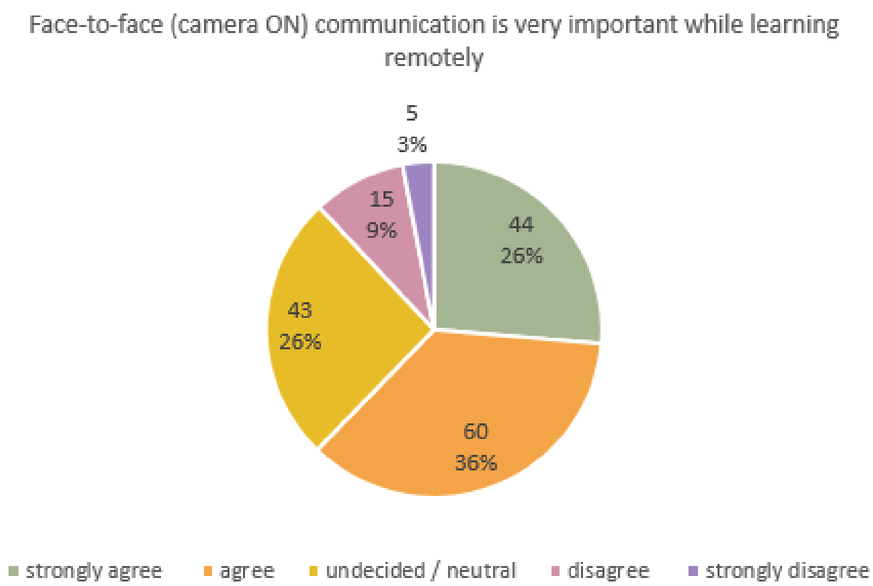

Figure 4. Students' appreciation of importance of using cameras during synchronous sessions.

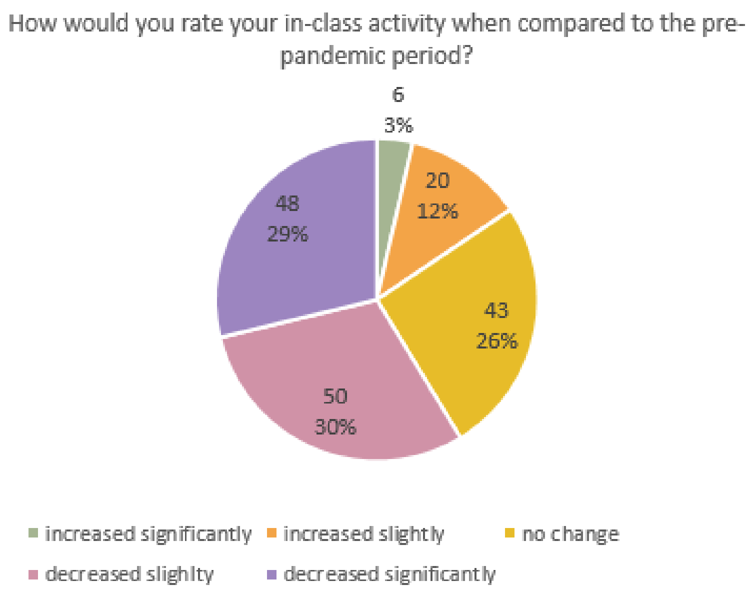

Figure 5. Comparison of in-class activity in online and on-campus learning.

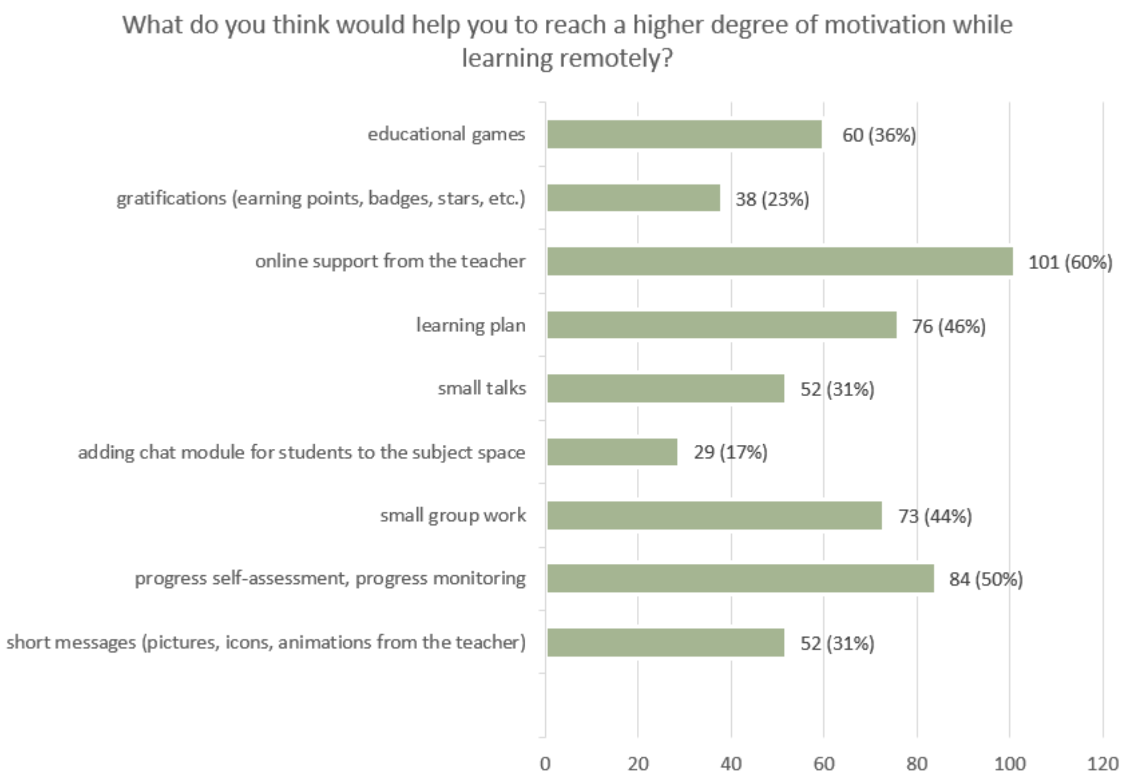

Figure 6. Sources of motivation envisioned by the students.

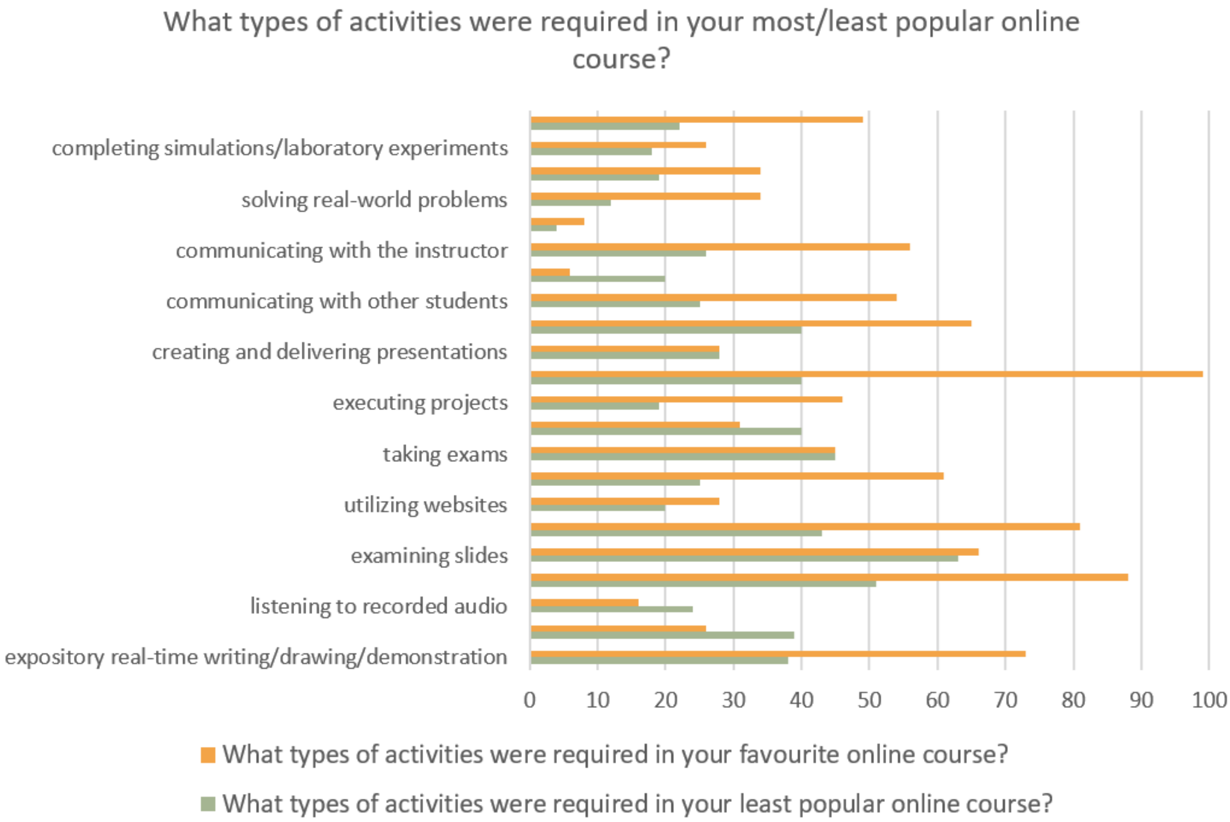

Figure 7. Types of activities required in the student's most and least favorite online courses.

4.4. Assessment Category

At our university, a mandatory online assessment was introduced during the lockdown. Only in very exceptional cases, on-campus assessment was allowed.

It is known that student cheating is a big problem worldwide. According to ICAI [20], 95% of students admit to some form of cheating in higher education. In an effort to prevent fraud in student assessments, several measures have been applied, including limiting the number of students in a virtual room, a mandatory camera, and identification of all students by an identity card. Many teachers required using a second camera focusing on the student's workspace and deferred to specialized software, such as Safe Exam Browser.

The assessment part of the students' questionnaire is directed towards monitoring the learning outcomes achieved through distance learning methods and techniques. Five questions were proposed in this category, and the answers to some of them are summarized in Figure 8.

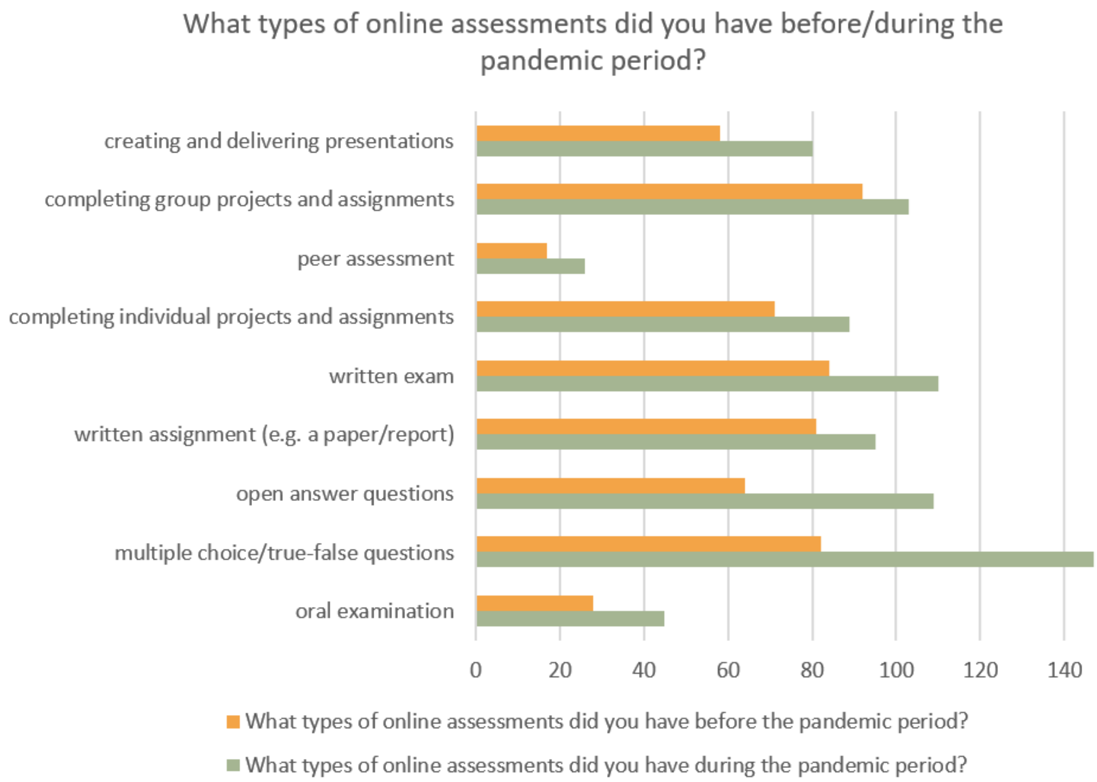

Figure 8. Types of online assessment used at the university before and during the pandemic period.

It can be seen that all assessment forms used in on-campus education continued to be applied during online education with the proportion of written exams and multiple-choice questions (which are also part of the written examination) having increased. The survey shows that the students rate the online assessment procedures implemented at the university as fair (32%) and fair enough (54%). At the same time, a large number of students state that their effort to achieve the same grade when compared with the pre-pandemic period increased (19%) or increased slightly (28%).

4.5. Evaluation Category

This section presents the results of the survey on the quality of the adopted distance learning techniques and methods. Students' answers to the question about their concern immediately after switching to online learning show that they experienced a wide variety of, and sometimes contradictory, feelings (see Figure 9).

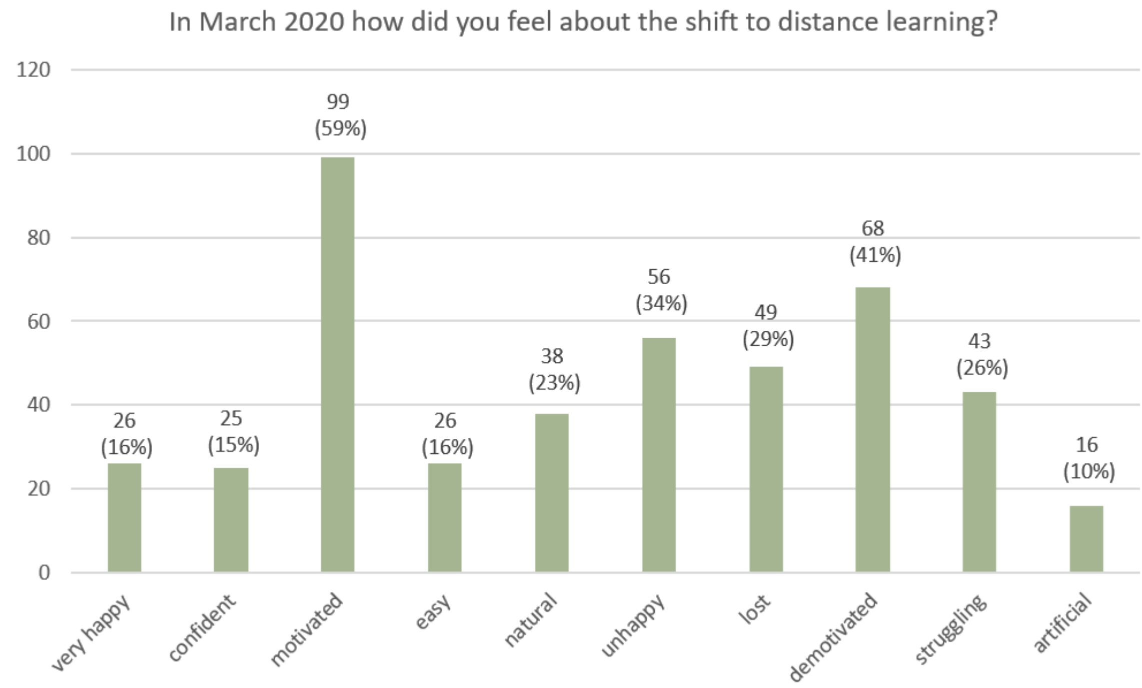

Figure 9. Students' feelings about the shift to distance learning.

The perception of students when they abruptly changed to online learning was a mix of positive and negative emotions. In total, 59% of students were motivated and 41% were demotivated. From the positive to the negative perception, 16% felt very happy, confident (15%), considered online learning a natural (23%) and easy change (16%), whereas 34% reported that they felt unhappy, lost (29%), and struggling (26%).

Figure 10 shows all the variety of negative challenges mentioned by the students. During the massive online experiment, the students reported that events related to assessment were the ones that caused more anxiety; taking exams was the most stressful event (54%), followed by creating and delivering presentations (38%).

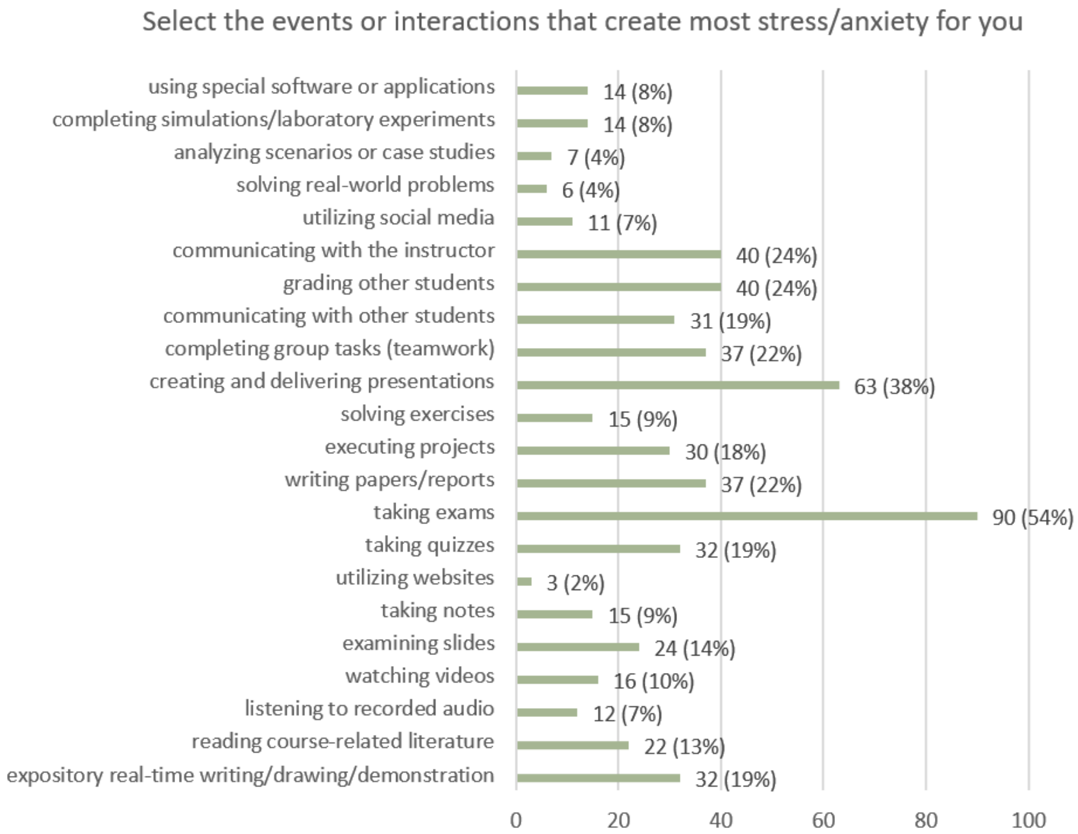

Figure 10. The most stressful/anxious events mentioned by the students.

The survey showed that the students liked the many forms of classes chosen by their teachers, which reflects the variety of answers to the question about the most effective activities for their online learning. Figure 11 illustrates the most popular activities proposed by the STEM teachers.

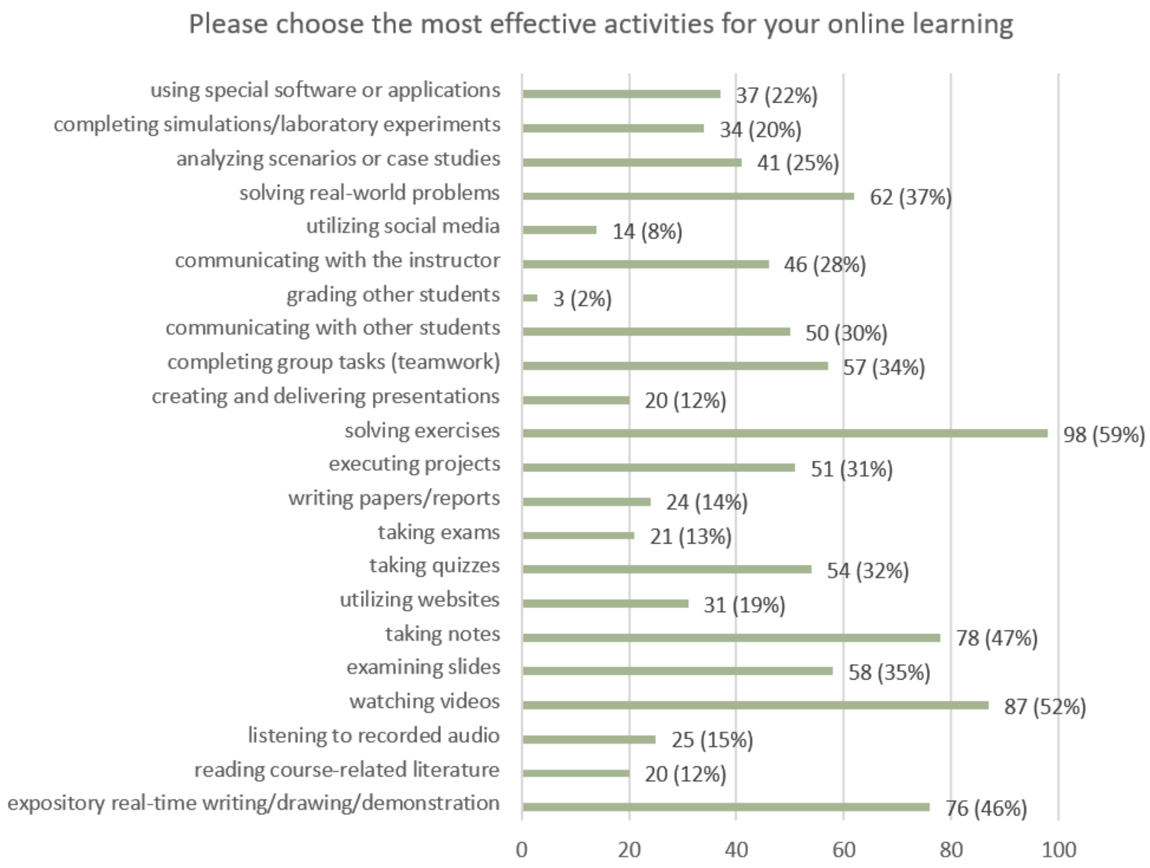

Figure 11. Level of popularity of the activities proposed by the teachers in online learning.

The most effective activities during online learning pointed out by the students were solving exercises (59%), watching videos (52%), taking notes (47%), and expository real-time activities (46%). Less relevant, but also mentioned as effective, were solving real-world problems (37%), examining slides (35%), completing group tasks (34%), taking quizzes (32%), executing projects (31%), and communicating with other students (30%) and with the instructor (28%).

When asked about the engagement of their peers/classmates during synchronous distance classes, many students (~48%) confessed that they were generally not sufficiently engaged and only 20% of respondents positively evaluated the engagement of their colleagues. Concerning the general level of satisfaction with the shift to distance learning provided by the university, the opinions were divided between satisfied and strongly satisfied (11% and 30%, respectively); undecided or neutral (33%); and unsatisfied and strongly unsatisfied (17% and 9%, respectively).

In total, 66% of students believed that the lack of personal on-campus contact affected their motivation and only 11% of students believe that the level of their motivation is the same. Regarding attendance, the majority of students (88%) answered that, in general, they participated in more than 30% of classes. The main reason for the lower attendance indicated by 35% of students who attended less than 60% of classes was lack of motivation (86%), followed by dissatisfaction with teachers' performance, choice of tools and materials, lack of time, personal problems, and technical difficulties. Only 3% of students indicated that they attended fewer classes due to economic reasons.

In addition to the fixed-answer questions, the students had some open questions. The first was about which aspect of online learning was the most challenging. About 36% of respondents indicated that concentration and focusing attention on classes were their main challenges. Some students considered the assessment system to be a challenge. A total of 8% of the students expressed explicitly that they did not like distance learning, and that “theoretical classes should be a place for bidirectional discussion, therefore, they should be on-campus, if possible.” About 9% of respondents were more pessimistic: “...but the reality is that the student doesn’t learn anything when compared to on-campus classes…” At the same time, some students mentioned positive aspects of distance learning.

The second open-answer question concerns how distance learning could be improved. The most popular proposal (about 36%) was to change the way of teaching. Students prefer “less expositive classes”, and instead would like to have more exercises solved in classes. They consider that the classes should be shorter and more dynamic with “interactive activities and quizzes“. Some students showed that they needed more contact/pressure/monitoring from teachers. The use of online whiteboards was highly appreciated. The students expect more engagement and more interaction from the teachers, more project executions, and real-world problems. They consider that distance learning should be “a mixture between asynchronous (e.g., brief theoretical exposition) and synchronous (e.g., further developments, answers to student questions, solving problems) activities”. Another proposal was to “...reduce the workload and apply a mandatory ‘camera-on’ policy to ensure that the teacher does not lose motivation”. Many students want to keep records of classes to rewatch them after, suggesting that teachers could prepare supporting videos, slides, and notes that would be made available for independent work.

It is worth noting that when evaluating their overall experience in online learning, about half of the students reported that they developed learning skills with the use of online tools and education strategies (56%), whereas the remaining did not feel that their skills were affected.

5. Statistical Analysis

5.1. Gender and Degree Level Influence

The Chi-square test was performed on a selected number of questions, to understand if there is a relationship between the answers and gender, which could mean that learning strategies should be redirected regarding gender. However, as shown in Table 1, the Chi-square test revealed that gender does not affect the answers.

Table 1. *p*-value for the relationship between the answer to selected questions and gender or degree.

Variable	Gender	Degree
Preparation workload in distance learning compared to the traditional on-campus education.	0.792	0.556
Importance of using cameras during synchronous sessions.	0.129	0.452
Preference for distance or on-campus learning.	0.631	**0.005 ***
Comparison of in-class activity in distance and on-campus learning.	0.072	**0.003 ***
Assessment procedures in distance learning compared to the traditional on-campus education.	0.768	0.797
Effort to achieve the same grades in distance learning compared with the traditional on-campus education.	0.882	**0.003 ***
Degree of engagement during synchronous distance classes.	0.513	0.143
Satisfaction in the first semester of distance learning.	0.066	0.099
Satisfaction in the second semester of distance learning.	0.521	0.424
Importance of personal on-campus contact on motivation.	0.396	**0.004 ***

Development of learning skills through the use of online tools and online education strategies.	0.558	0.086

* *p*-value < 0.05.

Regarding the study degree attended by the respondents, the Chi-square test returned that for four questions the respondents would reply differently if they were undergraduate or graduate students (Table 1). Although a general preference for on-campus learning is observed (Figure 3), undergraduate students have a much more pronounced preference for on-campus learning than the graduate ones. A significant proportion (42%) of undergraduate students experienced a significant decrease in their in-class activity in distance learning, in comparison with 13% of the graduate students; on the other hand, the graduate students report making a greater effort to achieve the same grades in distance learning as in on-campus learning, compared to undergraduate students (Table 2). Finally, personal on-campus contact with teachers and colleagues has a greater impact on undergraduate students' motivation (75%) than on that of graduate students (53%). These data emphasize that learning strategies should be adapted to the students' degree level, in order to maximize their learning experience.

Table 2. Comparison of students' in-class activity and effort to achieve the same grades for distance and on-campus learning.

Variable		**Decreased Significantly**	**Decreased Slightly**	**No Change**	**Increased Slightly**	**Increased Significantly**
In-class activity for distance learning compared to on-campus learning	undergraduate students	42%	23%	23%	10%	2%
	graduate students	13%	37%	29%	15%	6%
Effort to achieve the same grades for distance learning as on-campus learning	undergraduate students	19%	23%	21%	21%	17%
	graduate students	2%	18%	21%	38%	22%

5.2. Learning Activities Influence on the Popularity of Online Courses

The answers to the questions "What types of activities were required in your favorite online course?" and "What types of activities were required in your least popular online course?" were cross-analyzed statistically. The objective was to understand whether the type of activities required in a certain course could affect its popularity. Cross tabulation was considered, to analyze whether each activity, independently, would affect the popularity of the course. In addition, a Chi-square test was used to determine if the relationship is statistically significant.

From the statistical analysis performed, one can conclude that the hypothesis that the students prefer a certain online course increases if it includes the following activities:

- solving exercises (1st position, 59% of the respondents; ***p* = 0.000 ****);
- watching videos (2nd position, 52% of the respondents; ***p* = 0.000 ****);
- taking notes (3rd position, 47% of the respondents; ***p* = 0.000 ****);

- expository real-time writing/drawing/demonstration by the instructor (4th position, 46% of the respondents; ***p* = 0.000 ****);
- solving real-world problems (5th position, 37% of the respondents; ***p* = 0.000 ****);
- completing group tasks (teamwork) (7th position, 34% of the respondents; ***p* = 0.000 ****);
- taking quizzes (8th position, 32% of the respondents; ***p* = 0.000 ****);
- executing projects (9th position, 31% of the respondents; ***p* = 0.000 ****);
- communicating with other students (10th position, 30% of the respondents; ***p* = 0.000 ****);
- communicating with the instructor (11th position, 28% of the respondents; ***p* = 0.000 ****);
- analyzing scenarios or case studies (12th position, 25% of the respondents; ***p* = 0.000 ****);
- using special software or applications relevant to the course (13th position, 22% of respondents; ***p* = 0.000 ****);
- not grading other students (22nd position for grading other students, only 3% of the respondents chose grading other students as effective for their online learning; ***p* = 0.000 ****
- ** p-value < 0.05.

On the contrary, no conclusion can be drawn about the popularity of a certain online course that includes the following activities:

- examining slides (6th position, 35% of the respondents; $p = 0.7360$);
- completing simulations/laboratory experiments (14th position, 20% of the respondents; $p = 0.195$);
- using websites (15th position, 19% of the respondents; $p = 0.204$);
- listening to recorded audio (16th position, 15% of the respondents; $p = 0.177$);
- writing papers/reports (17th position, 14% of the respondents; $p = 0.228$);
- taking exams (18th position, 13% of the respondents; $p = 1.000$);
- reading course-related literature (19th position, 12% of the respondents; $p = 0.072$);
- creating and delivering presentations (19th position, 12% of the respondents; $p = 1.000$);
- using social media (21st position, 8% of the respondents; $p = 0.240$).

6. Discussion

In the present study, the great majority of students (92%) have never attended real online classes; however, they were technologically prepared for the transition to online learning. The majority of students reported using laptops for online learning (93%), although the use of smartphones (47%), desktops (18%) and tablets (11%) was also mentioned, showing that several students did not restrain themselves to a single device. Some students also mentioned the use of multiple monitors (21%), which is another signal of technology wealth. In addition, the support from the university included instructional videos, manuals, and online training focused on preparing the students for the massive shift to online learning, albeit the students were already familiar with the university platforms used on a regular basis prior to online learning. Only 5% of the students mentioned technical problems, such as internet weakness or issues with the webcam and microphone. This situation is in line with other developed countries (e.g., [13]) and is very different from the circumstances reported in less developed countries (e.g., [7,8]). This is, in our opinion, the main reason why 40% of our students reported being satisfied with the shift to online learning provided by the university, and why 60% felt motivated with it.

6.1. Preparation

Most of the students (61%) reported that the workload needed before classes increased with online learning, a few that their workload decreased (13%), and only 26%

mentioned that their preparation time did not change. This correlates with other studies (e.g., [21,22]).

6.2. Delivery

In our study, 62% of the students considered "camera on" mode as important and only 12% preferred "camera off" mode. This aligns with the findings in previous studies [23] confirming the importance of inclusive eye contact. In contrast to this, Selco and Habbak [13] reported that 60% of the students had no preference between camera on or off and the remaining 40% were divided in half regarding this preference. At California State University, the engineering students pointed out some issues during online classes or online exams concerning on/off cameras [9]: in total, 48% of the students did not have cameras on their devices or they felt uncomfortable using them.

In our study, the majority of the students (73%) preferred on-campus learning to online learning. This is somehow lower than the ~90% reported in countries where the technical problems were significant (e.g., [7]). Prince et al. [24] observed that the percentage of STEM students satisfied with a course initially taught on campus and abruptly shifted to the online environment, dropped from 87% (on campus) to 59% (online), and Selco and Habbak [13] observed that 90% of the analyzed students ranked on-campus learning as effective against about 10% ranking online learning as effective. According to Al-Mawee et al. [22], the majority of the inquired students felt that they did not learn as much as they would have learned in face-to-face classes, which corresponds to the results of our survey.

According to our analysis, the majority of the students (66%) mentioned that the lack of personal on-campus contact with peers and teachers affected their motivation. This is consistent with the study by Selco and Habbak [13], where the second most reported negative aspect of switching to online learning was "feeling disconnected from people and learning" and the eighth was the "difficulty to find motivation".

Regarding strategies to increase motivation, in our study, students consider that online support from teachers (60%), progress self-assessment (50%), having a learning plan (46%), and small working groups (44%) help reaching higher degrees of motivation. This is in line with Batra and Palsole [4] who claim that students feel a much higher degree of satisfaction with courses that used active methods and interactions rather than courses that just had expository videos. Preference in having a learning plan as a motivational method aligns with the conclusions of Mou [25], who claims that using a weekly diary with goal settings has a positive effect on students' time management, self-motivation, and performance. Only 17% of the survey respondents considered chat modules for students to be motivational.

About one quarter of the surveyed students considered that their in-class activity did not change when compared to the pre-pandemic period; for 15%, the activity increased and for about 60%, it decreased. This is in line with the results of the survey conducted by the Times Higher Education [26], showing that student in-class participation has dropped compared with before the pandemic, with 54% of students reporting lower participation, with only 9% noting an improvement. As indicated by Ellis and Bliuc [14], to guarantee that in-class activities are really effective, students must be guided very carefully by teachers so that the tasks are approached in ways that were intended by the lecturer who designed them.

6.3. Assessment

In our survey, the students reported an unbalanced effort to achieve the same grades when compared with the regular assessment, with the students' effort being either increased (47%) or reduced (30%), with only 23% mentioning no effort change. In other studies (e.g., [13]), it was also observed that many students struggled with the increased difficulty of assessments, time restriction, stress, and anxiety of possibly being falsely accused. Asgari et al. [9] also reported that about 40% of engineering students had technical difficulties and time management issues during online assessments. As reported in Lucas [27], the overall assessment model needs a profound structural revision, which would reinforce students' skills and competencies and allow for tracking their progress.

The students inquired at our university reported that taking exams (54%) and creating and delivering presentations (38%) provokes much more stress and anxiety than utilizing websites (2%), solving real-world problems (4%), and analyzing scenarios or case studies (4%). This indicates that assessment is the main cause of stress for students. However, taking quizzes (19%) and working in teams (22%) do not have the same negative effect as the other assessment methods. Other recent studies [28,29] also confirm that problem-solving and hands-on projects effectively promote STEM education.

Several students mentioned the heavy workload with assignments, a large amount of work after classes, designed to compensate for the fact that too much class time was used to show videos, and a "crazy amount of projects". Some students felt that this extra work was not accompanied by sufficient support from the teachers. Actually, watching lecture videos is regarded as one of the most favorite learning activities by our students and they do recommend continuing to record synchronous lectures (even in on-campus or blended learning) for further consultation. This opportunity could be especially beneficial for good students who would like to understand and clarify all the lecture contents that they did not have a chance to do synchronously. However, it can also generate a negative side effect, as confirmed by Williams [26], with students thinking that they would watch videos when really required (before the exam), so there is no need to engage actively in classes.

6.4. Evaluation

In our study, the prior perception of students when they abruptly changed to online learning was a mix of positive and negative emotions. A significant number of students could not decide if they felt satisfied with the shift to online learning, but the majority was pleased with the shift. From the first to the second semester of exclusively online learning during the analyzed period, the percentage of satisfied students at our university increased from 40% to 50%, which is in line with Selco and Habbak [13]. However, in our study, about a quarter of the students were shown to be dissatisfied with the shift to online learning, a number that remained unchanged one semester later.

Other studies point out that Master's students were more positive towards online learning than Bachelor's students [4,7,21,22]. In our study, we observed statistically different answers from undergraduate and graduate students.

6.5. Study Limitations

To conclude, the main survey results are in line with the previous work, albeit a number of contradictions reported above, are detected. The novelty of the present study is given by quite broad coverage of students coming from different STEM courses, comprising various fields and levels of study. The executed statistical analysis permitted identifying the differences in the online learning process appreciation according to the maturity level and gender of the students.

The presented study has a number of limitations. First of all, only the students' perspective has been analyzed. To get a more complete picture, teachers' opinions have to be taken into account and correlated with the students' learning process appreciation. This is the part of the future work of the same authors' team. Second, more profound and advanced analysis methods could have been applied. For instance, the performed statistical analysis focused on the influence of gender and study level on the answers and on the correlation between the learning activities and the popularity of a certain course. Other aspects could have been explored such as the influence of students' age, the distance from home to the university, and others, but the authors consider them less relevant. Third, the research involved relatively small population samples, with a limited number of quantitative instruments. On the other hand, the work covered several STEM study levels and areas, which reinforces the robustness of the findings. Fourth, this study was conducted with students from the same culture and social background. Dissimilar results may have been achieved if the same study were executed with students with a very different profile. These limitations notwithstanding, the results of the study provide recommendations on how to improve on-campus, distance, and blended STEM learning courses and provide promising evidence about students' involvement.

7. Conclusions and Recommendations

The analysis of the students' survey results allows for delivering some recommendations, mainly aimed at increasing the students' motivation and engagement as well as identifying their in-class activities that are directly correlated with the students' appreciation of their progress and outcomes.

The students indicated the following actions as being effective for improvement of their learning environment:

- the teachers should be more captivating and open to more innovative distance learning methods;
- the teachers should be prepared to deal with the students' loss of concentration, lack of personal contact, and technical problems;
- the class attendance rate should increase by enforcing greater motivation;
- the classes should be shorter, less expositive, with more exercises solved, accompanied by interactive activities and quizzes;
- the students should be allowed to have more involvement and interaction during classes.

In addition, from the performed statistical analysis, it can be concluded that the hypothesis that the students prefer a certain online course increases if the course includes the following activities:

- active learning activities (solving exercises, solving real-world problems, completing group tasks—teamwork, taking quizzes, executing projects, analyzing scenarios or case studies, using special software or applications relevant to the course, taking active notes);
- passive learning activities (expository real-time writing/drawing/demonstration by the instructor, watching videos, taking passive notes);
- communication (communicating with other students, communicating with the instructor);
- other (not grading other students).

Remote activities should be adapted according to the maturity level of the students so as to optimize their learning experience. The evaluation strategies have to be diversified so as to balance the levels of stress and anxiety experienced by the students. It is clear that much more interactivity is expected from the teachers, who should be enthusiastic enough to gain and keep the students' attention during synchronous classes, and that students consider active learning effective. However, although to a lesser extent, students also assign importance to some passive learning activities. In addition, students consider communication important, which might be a very significant tool to improve their satisfaction within the learning process. We believe that the results of our study, as well as the derived recommendations, would be beneficial for the design and delivering of future blended and on-campus courses, leading to a more rewarding and fascinating learning experience.

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References

1. Hadzieva, E.; Gunčaga, J.; Bose, S.C.; Sotiroska Ivanoska, K. Introductory Survey on Challenges Encountered by University Teachers in Online Teaching of STEM Subjects During COVID-19 Lockdown. *Cent. Eur. J. Educ. Res.* **2021**, *3*, 22–32.
2. Zhang, D.; Zhao, J.L.; Zhou, L.; Nunamaker, J.F., Jr. Can E-learning Replace Classroom Learning? *Commun. ACM* **2004**, *47*, 75–79.
3. Petretto, D.R.; Carta, S.F.; Cataudella, S.; Masala, I.; Mascia, M.L.; Penna, M.P.; Piras, P.; Pistis, I.; Masala, C. The Use of Distance Learning and E-learning in Students with Learning Disabilities: A Review on the Effects and some Hint of Analysis on the Use during COVID-19 Outbreak. *Clin. Pract. Epidemiol. Ment. Health* **2021**, *17*, 92–102.
4. Batra, J.S.; Palsole, S. Survey Design for Evaluating Student Interaction in Face-to-Face and Online Learning Environment. In Proceedings of the American Society for Engineering Education Annual Conference, Virtual Conference, 26 July 2021.
5. NCES. National Center for Education Statistics. Undergraduate Enrollment. U.S. Department of Education, Institute of Education Sciences. 2022. Available online: https://nces.ed.gov/programs/coe/indicator/cha (accessed on 1 September 2022).
6. Eurostat. Interest in Online Education Grows in the EU. European Commission, Eurostat. 2022. Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20220124-1#:~:text=In%20the%20EU%2C%20young%20people,adults%20aged%2035%20to%2044 (accessed on 1 September 2022).
7. Blizak, D.; Blizak, S.; Bouchenak, O.; Yahiaoui, K. Students' Perceptions Regarding the Abrupt Transition to Online Learning During the COVID-19 Pandemic: Case of Faculty of Chemistry and Hydrocarbons at the University of Boumerdes Algeria. *J. Chem. Educ.* **2020**, *97*, 2466–2471.
8. Grynyuk, S.; Kovtun, O.; Sultanova, L.; Zheludenko, M.; Zasluzhena, A.; Zaytseva, I. Distance Learning During the COVID-19 Pandemic: The Experience of Ukraine's Higher Education System. *Electron. J. e-Learn.* **2022**, *20*, 242–256.
9. Asgari, S.; Trajkovic, J.; Rahmani, M.; Zhang, W.; Lo, R.C.; Sciortino, A. An observational study of engineering online education during the COVID-19 pandemic. *PLoS ONE* **2021**, *16*, e0250041.
10. Vielma, K.; Brey, E.M. Using Evaluative Data to Assess Virtual Learning Experiences for Students During COVID-19. *Biomed. Eng. Educ.* **2020**, *1*, 139–144.
11. Turner, L.T.; Adams, J.D.; Eaton, S.E. Academic integrity, STEM education, and COVID-19: A call for action. *Cult. Stud. Sci. Educ.* **2022**, *17*, 331–339.
12. Masalimova, A.R.; Khvatova, M.A.; Chikileva, L.S.; Zvyagintseva, E.P.; Stepanova, V.V.; Melnik, M.V. Distance Learning in Higher Education During COVID-19. *Front. Educ.* **2022**, *7*, 822958.
13. Selco, J.I.; Habbak, M. STEM Students' Perceptions on Emergency Online Learning during the COVID-19 Pandemic: Challenges and Successes. *Educ. Sci.* **2021**, *11*, 799.
14. Ellis, R.A.; Bliuc, A.M. Exploring new elements of the student approaches to learning framework: The role of online learning technologies in student learning. *Act. Learn. High. Educ.* **2019**, *20*, 11–24.
15. Dhawan, S. Online Learning: A Panacea in the Time of COVID-19 Crisis. *J. Educ. Technol. Syst.* **2020**, *49*, 5–22.
16. IBM. IBM SPSS Advanced Statistics V27. International Business Machines Corporation. 2022. Available online: https://www.ibm.com/docs/en/SSLVMB_27.0.0/pdf/en/IBM_SPSS_Advanced_Statistics.pdf (accessed on 1 September 2022).
17. Hafner, A.W. *Descriptive Statistical Techniques for Librarians*, 2nd ed.; American Library Association: Chicago, IL, USA, 1998.
18. Wildemuth, B.M. Chapter 36: Frequencies, Cross-tabulation, and the Chi-square Statistic, 361-372. In *Applications of Social Research Methods to Questions in Information and Library Science*, 2nd ed.; Libraries Unlimited: Santa Barbara, CA, USA, 2017.
19. Byrne, G. A statistical primer: Understanding descriptive and inferential statistics. *Evid. Based Libr. Inf. Pract.* **2007**, *2*, 32–47.
20. ICAI. Facts and Statistics. International Center for Academic Integrity. 2020. Available online: https://academicintegrity.org/resources/facts-and-statistics (accessed on 1 September 2022).
21. Coman, C.; Țîru, L.G.; Meseșan-Schmitz, L.; Stanciu, C.; Bularca, M.C. Online Teaching and Learning in Higher Education during the Coronavirus Pandemic: Students' Perspective. *Sustainability* **2020**, *12*, 10367.
22. Al-Mawee, W.; Kwayu, K.M.; Gharaibeh, T. Student's perspective on distance learning during COVID-19 pandemic: A case study of Western Michigan University, United States. *Int. J. Educ. Res. Open* **2021**, *2*, 100080.

23. Jayasundara, J.M.P.V.K.; Gilbert, T.; Kersten, S.; Meng, L. How UK HE STEM Students Were Motivated to Switch Their Cameras on: A Study of the Development of Compassionate Communications in Task-focused Online Group Meetings. *Educ. Sci.* **2022**, *12*, 317. https://doi.org/10.3390/educsci12050317.
24. Prince, M.J.; Felder, R.M.; Brent, R. Active student engagement in online STEM classes: Approaches and recommendations. *Adv. Eng. Educ.* **2020**, *8*, 1–25.
25. Mou, T.Y. Online learning in the time of the COVID-19 crisis: Implications for the self-regulated learning of university design students. *Act. Learn. High. Educ.* **2021**, https://doi.org/10.1177/14697874211051226 (accessed on 1 September 2022).
26. Williams, S. Class attendance plummets post-COVID. *Times High. Educ.* **2022**, https://www.timeshighereducation.com/news/class-attendance-plummets-post-covid (accessed on 1 September 2022)
27. Lucas, B. Rethinking assessment in education: The case for change. In *CSE Leading Education Series*; Centre for Strategic Education: East Melbourne, VIC, Australia, 2021.
28. Contente, J.; Galvão, C. STEM Education and Problem-Solving in Space Science: A Case Study with CanSat. *Educ. Sci.* **2022**, *12*, 251. https://doi.org/10.3390/educsci12040251.
29. Skliarova, I. Project-Based Learning and Evaluation in an Online Digital Design Course. *Electronics* **2021**, *10*, 646. https://doi.org/10.3390/electronics10060646.