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Online education of engineering students: Educational platforms and their influence on the level of academic performance

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Abstract

The World Health Organization announced the COVID-19 pandemic, which led to considerable disruption of the global education system and required an early adaptation of the educational process. In addition to the resumption of the educational process, it was necessary to preserve the academic performance of students of higher educational institutions, including engineering ones. This study aims to develop a curriculum for engineering students to increase their level of success. Igor Sikorsky Kyiv Polytechnic Institute (Ukraine) hosted the study. The sample consisted of 354 fourth-year students of the Engineering and Chemistry Faculty: 131 "Applied Mechanics", 133 "Industrial Engineering", and 151 "Automation and Computer-Integrated Technologies". The sample included students of the Faculty of Computer Science and Computer Engineering: 121 "Software Engineering", and 126 "Information Systems and Technologies" – 154 students from the 1st year and 60 students from the 2nd year. The study was conducted during 2019–2020. The data includes grades for in-line classes and final test scores. The result of the research has shown that modern digital tools such as Microsoft Teams, Google Classroom, Quizlet, YouTube, Skype, and Zoom, among others, have provided a highly effective educational process. The results of the educational process are as follows: 63+23+10 students received "Excellent/Perfect" (A) in 2019, 65+44+8 in 2020; 146+64+20 and 159+81+18 received "Good (B, C)", respectively; 135+64+30 and 120+27+31 "Satisfactory" (D, E), respectively; – 10+3+0 and 10+2+3 "Unsatisfactory" (F), respectively. There was a tendency to increase the average score. The researchers found that the learning models were different before (offline) and during (online) the COVID-19 epidemic. However, the academic results of students were not different. The authors can conclude that e-learning (distance, online) is possible when training engineering students. The introduction of a new, jointly developed author's course "Technology of mechanical engineering in Medicine and

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Pharmacy" will also allow future engineers to be more competitive in the labor market.

Keywords Academic performance · COVID-19 pandemic · Distance learning · Educational engineering · Higher education

1 Introduction

The COVID-19 coronavirus pandemic and global quarantine resulted in numerous problems for the economy, business, and healthcare and, of course, for education. Nowadays, all spheres of life exist in an offline and online format. Due to pressing circumstances, there was an imperative to urgently modify and adapt work methodologies. According to UNESCO 2020 data, more than 1.5 billion students cannot attend classes due to COVID-19 in 165 countries (UNESCO, 2020). The pandemic forced the modern scientific community to adapt quickly and use new teaching methods, including distance and online learning. In addition, each teacher overcame the internal emotional, physical, and economic consequences of the pandemic (UNESCO, 2020, 2022).

Each educational institution had to adapt quickly to the modern conditions of providing educational services. Students and teachers switched to a new format of work to avoid spreading coronavirus infection (UNESCO, 2020). Distance learning should enable the achievement of the best positive results when mastering theoretical knowledge and practical skills of applicants for higher education, including engineering (UNESCO, 2020, 2022). Digitalization of the educational process has expanded opportunities, and, at the same time, complicated the education system. When organizing distance learning, it is important to consider the learning model, the pace of mastering materials, the number of students, pedagogical skills and the role of teachers and students, and the goal, interaction, and feedback (Shparik, 2020).

To enable a smooth educational process, the use of the internet, gadgets, educational programs, platforms, resources, and instructional tools is essential. Mobile applications are effective to increase the motivation of students to study (Omirzak et al., 2021). Most of the offers are available for free and in several languages. The modern adaptation of the educational process uses:

- digital learning management systems (Google Classroom, Moodle, Schoology, Blackboard, Century Tech, Class Dojo);
- systems specifically designed for mobile phones (Funzi, KaiOS);
- systems with extended offline functionality (Kolibri, Ustad Mobile);
- systems for creating tests (Google Forms, Mentimeter, Webanketa);
- educational materials aimed at independent work (Quizlet – a service in the form of study cards for quickly creating concepts and terms in the form of a game, YouTube);
- mobile reading applications (Worldreader);
- word processors (Microsoft Word, Word Perfect, Chi Writer, Multi-Edit, Open Office);

- applications for electronic presentations (MS PowerPoint, SlideRocet);
- table processors (Microsoft Excel); graphic editors (Paint, Adobe PhotoShop, Adobe Illustrator);
- collaboration platforms that support real-time video communication (Teams, Skype, Zoom) and others (Ivko et al., 2020; UNESCO, 2022).

The identification of both the advantages and disadvantages of distance learning can enable a balanced approach to the educational process, resulting in improved effectiveness. The positive aspects of distance learning include using special applications for pre-recorded lectures with audio tracks and visual backdrops. Additionally, practical classes can be conducted in real-time and viewed at any time as desired. Modern platforms and programs allow the creation of various tests of different levels of complexity, practice-oriented situational tasks, algorithms, crosswords, puzzles, random orders of questions, and time parameters for completing tasks. These features provide educators with a wide range of options for designing effective assessments and promoting student learning. Furthermore, online platforms allow providing students with group and individual tasks and demonstrate any visual material (Vorona-Slivinskaya et al., 2020). The negative aspects of the distance learning process include the following:

- lack of team spirit; decreased socialization of those involved in the distance learning process;
- shortage of real-world communication between the students and teachers, teachers' charisma to attract students to the learning process and interest in disciplines;
- inaccurate evaluation of students' oral answers; the prolonged influence of computers;
- sedentary lifestyle;
- physical inactivity;
- visual impairment;
- overload of the central nervous system;
- lack of socialization (Ivko et al., 2020).

1.1 Literature review

The contemporary provision of educational services involves the utilization of distance and online learning formats. The scientific research of scientists Nuankaew and Nuankaew (2021) highlighted aspects of the academic performance of students studying engineering at Thai universities during the pandemic. This research studied traditional (offline) and modern (distance, online) teaching and learning. The collected and analyzed data showed that the students' results did not differ in offline and online learning formats (Nuankaew & Nuankaew, 2021).

Saienko et al. (2021) studied the issue of students' creative thinking skills in Ukraine and Portugal during the COVID-19 pandemic. This study confirmed insufficient creative thinking skills. The results showed that most teachers would like to pay much attention to creative skills in both countries. Role-playing games are more

common in Portugal as part of a creative approach, while projects (project-based learning) are more commonly used in Ukraine. Creative skills are essential for both Ukrainian and Portuguese students: they tried new experiments, explored new ways to solve problems, created new associations and interdisciplinary connections, and chose new sources of information (Saienko et al., 2021).

The experiment of Jacques et al. (2020) also studied remote learning and knowledge evaluation during the COVID-19 pandemic. The experiment took place at the State University in Tours, France, and assessed the potential of two digital platforms – Microsoft Teams and Zoom. Engineering students confirmed their satisfaction with the learning process using remote tools and the level of proficiency of these tools by their teachers. The researchers also found that distance learning did not reduce the academic performance of engineering students (Jacques et al., 2020).

Engineering students from Mexico and Chile (Quezada-Espinoza et al., 2021) studied the professional significance of physics. Their findings reveal factors that influence the training and retention in the curricula of engineering students. The experiment was conducted with the participation of 1323 students. The results showed that it was necessary to change the design of physics courses, including exercises when the students experienced real-life situations in the classroom, emphasizing the engineering part of the problem; to promote active learning strategies when the students participated in building their learning using interdisciplinary approaches (Quezada-Espinoza et al., 2021).

Researchers Stefanovic et al. (2021) studied the peculiarities of virtual internships for engineering students in several countries in Southeastern Europe. They used modern digital web technologies and platforms in the experiment. This tool contained specialized components supporting specific tasks, such as a database of internships, lectures, evaluations, company profiles, and tasks. The proposed model and digital platform made it possible to adapt solutions for virtual tasks flexibly, efficiently, and cheaper (Stefanovic et al., 2021). Researchers Dindar et al. (2021) compared experienced and inexperienced teachers' mastering online learning technologies during the COVID-19 pandemic in Finland. The results showed no differences between the two groups of teachers in terms of expected academic performance, effort, efficiency, and satisfaction (Dindar et al., 2021).

Alqudah et al. (2021) and a team of scientists studied Jordanian students' anxiety indicators during the COVID-19 pandemic. They also analyzed the influence of quarantine restrictions on distance learning resulting from strict state isolation measures. The sample consisted of 736 undergraduates. The level of anxiety was assessed using the Hamilton Anxiety Scale. The results showed that 22.76, and 40.6% of the participants experienced anxiety. Such factors as quarantine and distance learning negatively impacted the anxiety levels of university students during the COVID-19 pandemic (Alqudah et al., 2021).

Qadir and Al-Fuqaha (2020) also investigated how engineering students (electrical engineering, electronics, computer engineering) could study effectively at the time of the global COVID-19 pandemic. They created a manual on how to increase learning skills. To achieve this, it is necessary to remember the goal, work on strengthening cognitive skills, strive for holistic and comprehensive learning, become a learner and develop auto-evaluation skills, take responsibility for learning, focus on developing

"authentic" and lifelong learning skills (Qadir & Al-Fuqaha, 2020). UNESCO stated that alternative approaches, such as online learning at home, should be used to support lifelong learning. Although there are numerous problems, for example, poor self-control, addiction to electronic devices (mobile phones, tablets, etc.), and others. This uncertain and difficult time requires mastering an important skill of the 21st century – the skill of self-regulation (Huang et al., 2020).

At this stage, information exchange and modern adaptation of educational processes are crucial (Appiah-Kubi & Annan, 2020; Chergui et al., 2020; Krulder, 2020; Li & Lalani, 2020; Petrie et al., 2020; Wu et al., 2020). At the same time, the conducted research on using online platforms in teaching engineering students and applying the author's course "Technology of mechanical engineering in Medicine and Pharmacy" complements and deepens the previously conducted research on this problem.

1.2 Problem statement

The adaptation of education to new conditions is significant. It is essential to observe how the new format of studying engineering specialties impacts the level of theoretical knowledge and practical skills. It is also crucial to assess the effect of the distance learning format on academic performance. Indeed, only an integrated approach leads to this end, combining high pedagogical skills, goals, and technological support.

This research aimed to study and compare the academic performance of engineering students of Ukrainian higher education institutions in online learning. The purpose of the study included offering an author's course for improving academic education for engineering students using modern technologies and platforms. The task of the work was to study the academic performance of engineering students in classical learning conditions and pandemic conditions using online platforms.

2 Methods and materials

2.1 Study design

The study employed methods of parametric statistics (normal distribution) and the Fisher criterion method. The study employed methods of parametric statistics (normal distribution) and the Fisher criterion method. Furthermore, the method used for assessing current academic performance corresponded to the European Credit Transfer System.

2.2 Participants of the study

Igor Sikorsky Kyiv Polytechnic Institute (Ukraine) hosted the study. The sample consisted of 354 4th year students of the Engineering and Chemistry Faculty: 131 majoring in "Applied Mechanics", 133 majoring in "Industrial Engineering", and 151 majoring in "Automation and Computer-Integrated Technologies". The sample included students of the Faculty of Computer Science and Computer Engineering:

121 “Software Engineering”, 126 “Information Systems and Technologies” – 154 1st year students (Discrete mathematics) and 60 2nd year students (Data analysis in information systems). Undergraduates aged 18-21-23 years (22.02 ± 0.53) participated in the study, of which 91% were boys and 9% were girls. The experiment did not include students in the 1st-3rd years.

2.3 Procedure

The study took place from the 2019 to 2020 academic year. The sample group was divided into two periods: the 2019 academic year, which was a period of regular classical learning (offline), and the 2020 academic year in an unusual teaching format (distance and online).

The educational process for engineering students involves studying the material through lectures, practical (laboratory, seminar) classes, and the student’s independent work. The modern work format requires teachers’ effective use of time in lectures and practical classes, while students must study independently.

Modern digital tools like Microsoft Teams, Google Classroom, Quizlet, YouTube, Skype, Zoom, and others are used to ensure a highly effective learning process. Multimedia presentations created in Microsoft PowerPoint are used to present theoretical material in the form of lectures. The presentation slides contain the main, interconnected, logically presented material. The presentation is supplemented with oral information indicating specific examples of practical engineering. Each lecture contains a plan with questions that typical curricula of academic disciplines recommend. To increase the efficiency of the educational process and stimulate memorization of the lecture material, the presented material has the form of hierarchies, processes, cycles, matrices, pyramids, diagrams, tables, and figures. The online learning format uses recorded lectures with a video/audio backdrop, available 24/7.

Practical classes are in real-time. In practical classes, teachers focus on acquiring knowledge and their further use in the form of practical skills in future professional activities. They involve the students in practical lessons and evaluate the student’s progress. Upon receiving feedback, the students mobilize their thinking, knowledge, skills, and abilities and, thus, achieve high educational activity results. During practical classes, the students learn to be democratic, communicate with each other, think critically, and make their own thoughtful decisions. A set of educational and methodological documentation covered each practical lesson, including samples, regulatory documents, scientific and methodological literature, standards, catalogs, and protocols. The complex of educational and methodological documentation also includes test tasks, structural and logical chains, schemes, situational tasks, and more. In addition, the students fill out a specially designed workbook with tasks during practical lessons.

Professional skills and abilities are especially important in modern conditions of specialist training. To this end, interactive teaching methods include business games, briefings, conferences, discussions, dialogues, consultations, contests, brainstorming technology, situational learning methods (“case study”), training, and others. This approach makes it possible to facilitate the learning process and activate the students’ thinking and behavior, including their ability to analyze the information received,

their creative approach, formulation of their opinion, and expression of it correctly. Additionally, this approach can help simulate various situations and teach independence in decision-making.Such teaching methods allow students to immerse themselves in professional activities.

Surgery classes are an important form of interaction between teachers and students. The classes can be face-to-face or, thanks to digital technologies, Microsoft Teams, Skype, and Zoom meetings. A teacher can also interact with students by e-mail. They can use computer applications for final classes. The applications make it possible to simultaneously check the level of knowledge of numerous students and ensure the absence of subjective influence on assessment.

To improve the academic education of engineering students, the authors of the EF from Kuban State Agrarian University named after I.T. Trubilin (Russia) and the EF from Igor Sikorsky Kyiv Polytechnic Institute (Ukraine) developed the author's course "Technology of mechanical engineering in Medicine and Pharmacy". This course is an important discipline in the training of engineers, which equips a modern specialist with the knowledge, practical skills, and abilities necessary to perform professional functions. The introduction and implementation of this course allow engineering students to be more in demand both in the national labor market and in European countries. This course provides for the number of study hours – 60 h, and 2 ECTS credits, which include 10 lectures, 20 practical classes, and 30 unsupervised activities. Additionally, the classroom load is 50%. The course content provides for the study of the application, classification, features of technological equipment and hardware, technical requirements for diagnostic and medical equipment, equipment for sterilization and disinfection, specialized equipment for neurosurgery, ophthalmology, urology, endoscopy and enteroscopy, dentistry, otorhinolaryngology, obstetrics, and gynecology.

The course includes the study of instruments and devices for punctures, injections, and transfusions. Additionally, it covers the study of equipment used in the manufacture of pharmaceutical and medical products.

While studying this course, a virtual/real visit to the modern pharmaceutical company "Darnitsa", which is a major national manufacturer and a leader in the segment of pharmacy sales, is also provided. Upon successful completion of this course, specialists acquire skills in solving specific technical problems and improving existing and developing new technical processes in medicine and pharmacy. They will be able to link scientific discoveries with the medical and pharmaceutical needs of a person and business.

2.4 Data collection

The collected data include grades for in-line classes (practical, laboratory, and seminar) and final scores for exams. The purpose of selecting the periods was to compare the academic performance of students of the same academic level. The researchers evaluated the current academic performance according to the European Credit Transfer System (ECTS). The evaluation of all applicants for the higher education of the group takes place at each practical lesson with grading. The maximum number of higher education applicants' points is 200 points, including a maximum of

120 points for current academic activities and a maximum of 80 points for the final score. After mastering the discipline, a student can get 180–200 points ("Excellent/Perfect" (A)), 179 – 170 points ("Good" (B)), 169 – 160 ("Good" (C)), 159 – 141 points ("Satisfactory" (D)), 140 – 121 points ("Satisfaction" (E)) and 120 points or lower ("Unsatisfactory" (F)). The study evaluated the final learning outcomes after passing examinations. The KPI has a 100-point rating scale: 95–100 points ("Excellent/Perfect" (A)), 85–94 points ("Very good" (B)), 75–84 ("Good" (C)), 65–74 points ("Satisfactory" (D)), 60–64 points ("Satisfactory" (E)) and 59 points or lower ("Unsatisfactory" (F)).

2.5 Statistical data analysis

The researchers used Microsoft Excel 2007 to process statistical data and analyze the study results. They evaluated the nature of the data distribution using the χ-square test. Methods of parametric statistics (normal distribution) were used for the statistical processing of the obtained results. The Fisher criterion was utilized by the authors to test the hypothesis regarding the membership of two variances to a common population and to determine whether they are equal or not. The reliability of the differences between the samples was assessed using the Student's t-test. Quantitative values were presented in the form ($x \pm m$), where x is the arithmetic mean, and m is the error of the mean. The comparison results were considered at a significance level of 0.05. The exclusion criteria were junior-year students and 3rd-year students.

2.6 Ethnic principles

The study was conducted in compliance with the provisions of the Ethical Principles for Conducting Scientific Medical Research with Human Participation approved by the Helsinki Declaration. The instructor acquainted the participants with the objectives, procedures, and research methods. They signed an informed consent to participate, and the researchers took all measures to ensure anonymity.

2.7 Limitations of the study

One of the limiting factors of this study is the gender of the participants: gender was not taken into account in the study, which could also have influenced the obtained data. As this experiment was conducted in only one educational institution, the results may not reflect the impact on the academic achievement level of online education platforms for engineering students across the country.

3 Results

The academic performance of 354 + 154 + 60 students participating in the experiment was evaluated based on the results of the sessions. Academic performance was studied by the number of "Excellent/Perfect" (A), "Good (B, C)", "Satisfaction" (D, E),

Table 1 Data on the students' academic progress in offline and online study

Courses/Number of Students	Academic year	
	2019	2020
131 "Applied Mechanics", (142 Students)	A=30 (21.13%) B=19 (13.38%) C=31 (21.83%) D=25 (17.61%) E=33 (23.24%) F=4 (2.82%)	A=32 (22.54%) B=21 (14.79%) C=33 (23.24%) D=23 (16.20%) E=30 (21.13%) F=3 (2.11%)
133 "Industrial Engineering" (98 Students)	A=15 (15.31%) B=25 (25.51%) C=17 (17.35%) D=21 (21.43%) E=18 (18.37%) F=2 (2.04%)	A=19 (19.39%) B=25 (25.51%) C=23 (23.47%) D=14 (14.29%) E=14 (14.29%) F=3 (3.06%)
151 "Automation and Computer-Integrated Technologies" (114 Students)	A=18 (15.79%) B=26 (22.81%) C=28 (24.56%) D=18 (15.79%) E=20 (17.54%) F=4 (3.51%)	A=14 (12.28%) B=28 (24.56%) C=29 (25.44%) D=20 (17.54%) E=19 (16.67%) F=4 (3.51%)
126 "Information Systems and Technologies", 1st year (94 students)	A=8 (8.51%) B=25 (26.60%) C=15 (15.96%) D=19 (20.21%) E=24 (25.53%) F=3 (3.19%)	A=27 (28.72%) B=39 (41.49%) C=8 (8.51%) D=14 (14.89%) E=5 (5.32%) F=1 (1.06%)
121 "Software Engineering", 1st year (60 students)	A=15 (25.00%) B=18 (30.00%) C=6 (10.00%) D=13 (21.67%) E=8 (13.33%) F=0 (0.00%)	A=17 (28.33%) B=25 (41.67%) C=9 (15.00%) D=2 (3.33%) E=6 (10.00%) F=1 (1.67%)
121 "Software Engineering", 2nd year (60 students)	A=10 (6.49%) B=11 (7.14%) C=9 (5.84%) D=15 (9.74%) E=15 (9.74%) F=0 (0.00%)	A=8 (5.19%) B=11 (7.14%) C=7 (4.55%) D=12 (7.79%) E=19 (12.34%) F=3 (1.95%)

and "Unsatisfactory" (F) grades (Table 1). There was a tendency to increase the average score.

The study results showed that the student's academic performance did not differ when using classical (offline) and distance (online) learning formats ($p>0.05$). The results of the disciplines confirmed the statement: 63 students received "Excellent/Perfect" (A) in 2019 and 65 in 2020; 46 and 159 "Good (B, C)", respectively; 135 and 120 "Satisfaction" (D, E), respectively; and10 and 10 "Unsatisfactory" (F), respectively. The average score was 3.74 and 3.79, respectively (Figs. 1, 2 and 3). This is only the 4th year.

The researchers found that the learning models differentiated before (offline) and during (online) the COVID-19 pandemic. However, there was no difference in the academic performance of the students. The authors can conclude that e-learning (dis-

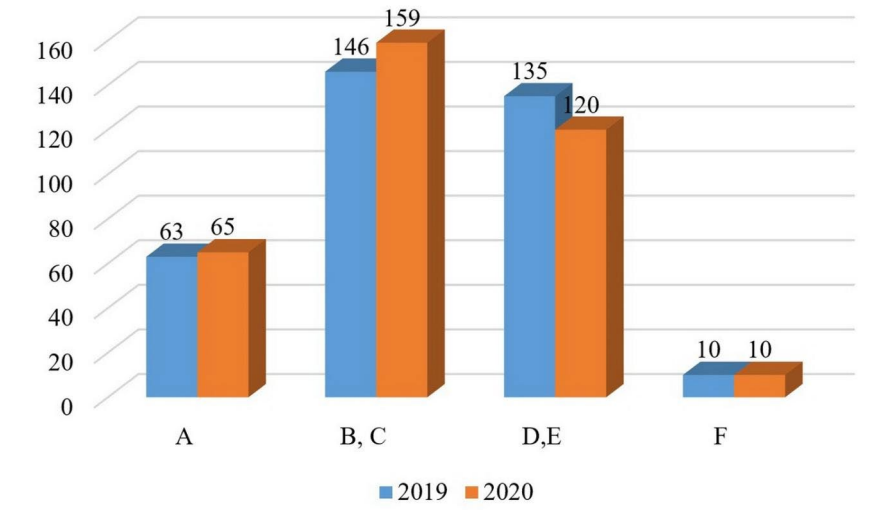

Fig. 1 Academic performance of engineering students in offline and online learning formats in 2019–2020, 4th year

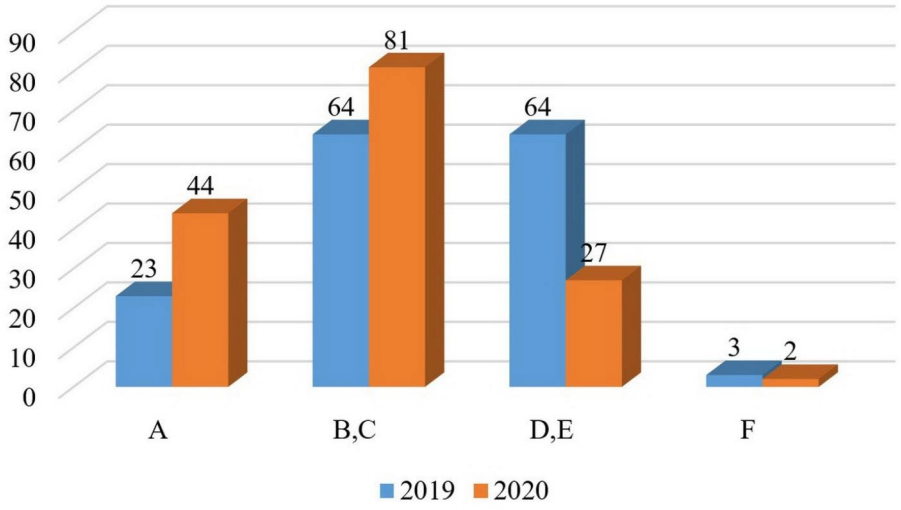

Fig. 2 Academic performance of engineering students in offline and online learning formats in 2019–2020, 1st year

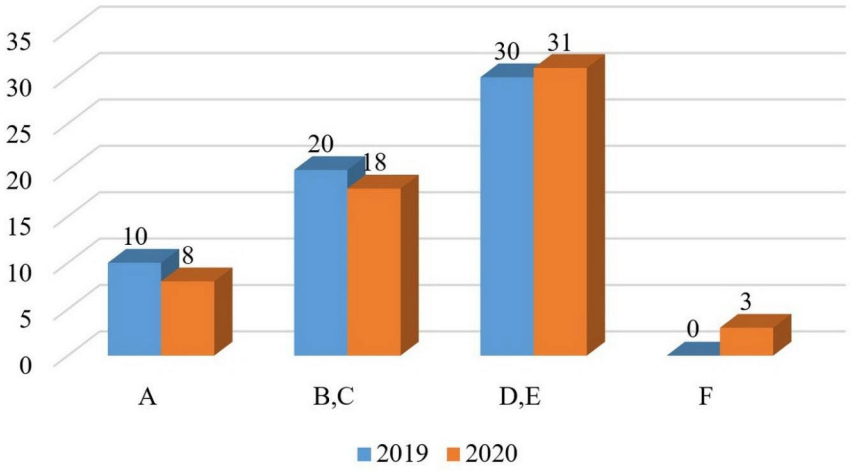

Fig. 3 Academic performance of engineering students in offline and online learning formats in 2019–2020, 2nd year

tance, online) is possible when teaching engineering students. Thus, the study showed that modern digital tools such as Microsoft Teams, Google Classroom, Quizlet, YouTube, Skype, Zoom, and others provided a highly effective educational process.

4 Discussion

The results of the academic success of students of educational institutions in Thailand, as in this study, do not differ from the results of classical education. However, there is also a need to develop effective training activities (Nuankaew & Nuankaew, 2021). Researchers from the USA showed an interesting approach to studying the characteristics of distance learning. The respondents noted that 40% of students lost their jobs due to e-learning (Aucejo et al., 2020), which would be interesting to study here. The implementation of mixed online learning with components of traditional classroom-based instruction in Malaysia has presented a multitude of challenges. Problems of self-regulation and problems with the use of training technologies were key issues (Rasheed et al., 2020). There was no such issue in this study. The above is because some digital tools such as Microsoft Teams, Google Classroom, Quizlet, YouTube, Skype, and Zoom are casual to use. Modern research in Bangkok shows that some students may become more individualistic and show a sense of isolation in the conditions of online learning. Therefore, it is necessary to increase the social potential and strengthen the sense of value and usefulness to each other (Gunawan et al., 2020), which may also affect academic success, and that, undoubtedly, is important for studying. The analysis of the physical activity in the Thai adult population showed it decreased (Katewongsa et al., 2021), which, for sure, our students also have. They also used the Fit from Home application, which increased physical activity by 1.5 times. Indeed, this is a possible and important method of improv-

ing the educational process. A Vietnamese study showed that students with different socioeconomic statuses and professional aspirations had different learning habits. It revealed differences in the educational behavior of students of private and public educational institutions (Sohrabi et al., 2020), which would be interesting to study in engineering students. An analysis of data from China, Hong Kong, and Singapore shows that closing educational institutions does not contribute to the fight against the epidemic and negatively influences academic results (Viner et al., 2020), which differs from this study's results. Using fewer digital tools may be the reason. In the USA, they pay special attention to the support of distance learning, its equality and accessibility, and several students' needs for effective education (Reich et al., 2020), which was also noted by the researchers. A study at the Classical University of Senegal resulted in positive outcomes of distance learning (Ba et al., 2019), which is similar to those herein. Chinese studies show rapid adaptation of teachers and students (Tiejun, 2020), which was also noted herein.

Due to the special circumstances associated with the COVID-19 pandemic, all educational institutions faced the problem of online teaching. Most researchers from different countries think about continuous learning of students, including engineering ones, using digital tools and online platforms. It is necessary to do it on the one hand. On the other hand, it can be problematic due to certain conditions.

5 Conclusions

This study found that modern digital tools such as Microsoft Teams, Google Classroom, Quizlet, YouTube, Skype, and Zoom could ensure an effective educational process for engineering students. The study results showed that the student's academic performance did not differ when using classical (offline) and distance (online) learning formats ($p > 0.05$). The results of the disciplines confirmed the statement. Thirty students majoring in 131 "Applied Mechanics" received "Excellent/Perfect" in 2019 and 32 in 2020; 50 and 54 "Good", respectively; 58 and 53 "Satisfactory", respectively; and 4 and 3 "Unsatisfactory", respectively. Fifteen students majoring in 133 "Industrial Engineering" received "Excellent/Perfect" in 2019 and 19 in 2020; 42 and 48 "Good", respectively; 39 and 28 "Satisfactory", respectively; and 2 and 3 "Unsatisfactory", respectively. Eight students majoring in 151 "Automation and computer-integrated technologies" received "Excellent/Perfect" in 2019 and 14 in 2020; 54 and 57 "Good", respectively; 38 and 39 "Satisfactory", respectively; and 4 and 4 "Unsatisfactory", respectively. The tab can supplement for 1st and 2nd-year students. During the study period, there was also a tendency to increase the average score.

The researchers can conclude that introducing e-learning (distance, online format) is reasonable. They also developed the author's course of the discipline "Technology of mechanical engineering in Medicine and Pharmacy" and a set of educational and methodological documentation for this discipline. Such results confirm that the learning models were different before (offline) and during (online) the COVID-19 epidemic. However, the academic results of students were not different. Based on the results of scientific research, it will be possible to develop ways to optimize

and improve educational processes for engineering students in the conditions of e-learning.

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Data Availability Data will be available on request.

Declarations

Conflict of interest Authors declare that they have no conflict of interests.

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