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Modified Blended Learning in Engineering Higher Education during the COVID-19 Lockdown—Building Automation Courses Case Study

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Abstract: The blended learning method with its supporting electronic tools is a very well-known approach in academic education. In most of its practical applications, direct face to face contacts between students and the teacher as well as students with each other in groups are important elements in the organization of lectures and classes. This is of particular importance in conducting laboratory classes in teaching process for engineers. However, the COVID-19 lockdown in the spring of 2020 closed schools, universities and completely eliminated the possibility of direct interpersonal contacts. These extraordinary circumstances forced changes in the organization of the teaching process, in particular the introduction of distance learning. Therefore, this paper proposes a modified blended learning method as well as describes a case study on its introduction in the education of building automation engineers at a technical university. A new organizational structure of this modified method is presented, with discussion of tools and methods of active distance learning, introduced during the COVID-19 lockdown period. Finally, some experiences, general reflections along with the identification of the preferred forms of distance learning by students are presented. The future works are briefly described as well.

Keywords: e-learning; distance learning; blended learning; flipped classroom; engineering higher education; COVID-19 pandemic; building automation

1. Introduction

Engineering education is a specific sector of the higher education. The effectiveness of teaching and learning processes in this sector is strongly determined by practical exercises, experiments and laboratory classes. Lectures and seminars are important; however, they only support students in the learning process, giving them the possibility to be mentored by lecturer in gaining necessary, substantive knowledge. However, despite the knowledge, technical skills are crucial for engineers, according to the learning by doing paradigm. Therefore, students of engineering courses need access to laboratories, technical equipment and instruments to perform practical experiments, to cooperate with each other and to acquire both technical as well as social skills associated with their technical area [1–3]. In this respect, the organization and development of effective, interesting and attractive laboratory classes for students of building automation technologies is a big challenge for teachers and assistants nowadays, taking into account at least two aspects: (i) rapid technological progress and need of periodic equipment, hardware update (expensive hardware, devices) as well as (ii) related issue of purchasing relatively expensive new equipment (market novelties) and the selection and application of new tools in the didactic process (computers, software, mobile devices, etc.) [4,5]. In addition, the complexity of the challenge increases when the teacher wants to achieve the most far-reaching synchronization between the topics and questions presented during the lectures and the topics, exercises conducted as part of laboratory classes. Moreover, simultaneous introduction and application of new methods to activate students and to use modern e-learning tools implicates extra problems. They have been well known for a long time already and are taken up by academic teachers and lecturers, especially at technical universities, almost every year [6–8].

However, an unprecedented challenge was the COVID-19 pandemic threat that broke out in March 2020 and radically changed in practice all aspects and rules of daily life. In many countries across the world, governments have needed to subject people to prolonged periods of lockdown, ordering them to stay at home with strongly limited personal contacts outside [9–11]. In this situation, all kinds of schools and universities were closed for several weeks as well. Therefore, responding to the call to not stop teaching and learning during the suspension period, formulated in Poland by the Ministry of Science and Higher Education, universities were forced to undergo significant transformation activities and completely change the rules of teaching—both for lectures and laboratory classes, especially in technical courses [12–14]. The impossibility of direct contact between lecturers, assistants and students as well as students with each other, forced them to organize works and exchange information in a new way, remotely, at a distance. Moreover, the restrictions and limitations in access to the laboratories, with their specialized infrastructure, introduced by university rector in orders related to the COVID-19 lockdown [15,16], additionally complicated the situation, considering the need to organize laboratory classes with experiments and exercises. Those new circumstances and organizational conditions determined the work of teachers, lecturers and assistants during the summer semester of the 2019/2020 academic year at many universities around the world as well as at the AGH University of Science and Technology in Krakow, Poland (AGH-UST).

This paper presents a case study based on the experiences gathered by the author as a lecturer and laboratory assistant working at the AGH AutBudNet Building Automation Laboratory (ABNLab) during that extraordinary period, along with methods and solutions developed and provided for students of building automation courses. However, it should be mentioned that they were developed for two slightly different groups of students, which determined different approaches in the teaching process and selection of tasks, activities, etc. The first group were students of the Faculty of Energy and Fuels (1st semester of 2nd degree MA studies) and the Faculty of Geology, Geophysics and Environmental Protection (6th semester of 1st degree engineering studies) which do not have an electrical engineering background. Therefore, only basic technical aspects of building automation technologies and systems have been presented for them, with extended information about their applications in buildings for monitoring energy consumption and active energy management in buildings. The second group were students of Electrical Engineering with specialization in Industrial Automation and Building Automation at the Faculty of Electrical Engineering, Automatics, Informatics and Biomedical Engineering (1st semester of 2nd degree MA studies), and a course Intelligent Building Systems during this semester is crucial for them, providing more advanced, detailed technical information about several building automation technologies as well as substantive knowledge about building automation standards. Considering this differentiation, teaching approaches presented in the paper are unique, also due to the fact that during the lockdown period traditional course programs had to be broken, and one of the most important aspects was the need for academic teachers to react as quickly as possible to the new circumstances and the recommendations ordered in principle ad hoc by university authorities. Although the solutions and tools introduced by the author are not new, it should be taken into account that the responsible introduction of a new formula and organization of the classes, using remote communication and several new e-learning and online tools, usually requires long-term preparation of a new program and subsequent stages for the lectures and practical classes, as well as information materials for their participants [17–19]. In the case presented in the paper, there was no time for an in-depth and precise formulation of the organizational principles, but what mattered was the speed of reaction and preparation of lectures and more importantly laboratory classes in a new formula, which would allow for the effective transfer of knowledge and other practical skills to students. Since the ABNLab staff had several years of experience in implementing some elements of e-learning supporting work with students, the author and his colleagues decided to use and develop them as a supplement to a new challenge. In this way, a modified blended learning (BL) approach was proposed and formulated. A presentation of its concept and basic implementation elements, with short results and future implications discussion, is the main contribution of this paper. Moreover, the identification of the preferred forms of distance learning by students, based on their opinions and answers gathered up in results of short summary surveys, is an additional aim of this paper.

The rest of the paper is organized as follows. Section 2 provides a review of related works and introduces a general framework of a modified BL approach for building automation courses. Information about the case study as well as the methods and tools implemented in the modified learning process during the COVID-19 lockdown period is presented in Section 3. Afterwards, Section 4 provides information on the experiences gathered during the case study with a brief discussion of general reflections and observations. Finally, Section 5 gives the conclusions and future works.

2. Methods, Challenges and Related Work

There are many methods and concepts of using modern digital tools and systems in teaching processes at universities, in particular technical ones. In general, they focus on the possibility of supporting the traditional models and approaches in education, with creating new trends such as hybrid teaching and learning, including completely remote, distance modes as well.

2.1. An E-Learning—Hybrid, Blended and Distance Learning

The remote communication as well as electronic tools and applications for organizing teaching and didactic in higher education have been well known in education sciences and examined over the last thirty years by different teachers, educators, lectures and assistants [20–22]. Their development is related to the rapid growth of popularity and advancement in computer technologies and applications as well as ICT. During these years, a number of methods using both computer technologies and network communication were developed to support organization and implementation of lectures and laboratory classes. Currently, it is possible to indicate two main categories of these methods: the first one (i) e-learning (EL)—methods using computer technologies with various software applications as well as services available on websites, mainly to support traditional learning process and to provide additional activates for students, and the second one (ii) distance learning (DL)—several methods using the similar technologies (computers, ICT, software applications) to organize new kind of learning process, with remote access to the lectures–webinars and laboratories, remote contacts and communication between teacher and students as well as between students themselves [21,23–25].

Nowadays, the EL methods are the most popular ones in the engineering higher education, since they are natural consequence of computers and digital mobile devices expansion, along with resources and services provided by global ICT network—the Internet. Typical methods in this category include: computer-based learning with software tools used for engineering works and activities; web-based learning with technical knowledge and resources provided by companies and other technicians, engineers; digital collaboration giving possibility to exchange knowledge, ideas between students, teachers, lecturers and even other, external specialists; and last but not least virtual classroom and/or laboratory, creating new kinds of environment to conduct experiments, tests, prototyping and eventually remote services with experimental research [21,23]. However, all of the mentioned methods and activities need additional knowledge and skills both from the teachers and students. They should know how to use and interact with digital devices, software platforms and tools. Moreover, the teachers and assistants should organize lectures and laboratory activities taking into account new elements of the EL and provide necessary information, instructions to students for effective work and collaboration during the learning process [26,27]. The second category of methods—DL—is not so popular yet. However, the situation is rapidly changing now, since the COVID-19 lockdown period mentioned in Section 1. First of all, these methods are characterized by physical separation between teachers and students. Therefore, all of the activities and personal or group remote contacts are delivered by different ways and media—mostly organized with ICTs and the global Internet network [21]. Methods from this category are used usually in remote courses, seminars and trainings, organized by companies for external participants to introduce new products, to provide basic or additional knowledge about their technologies, new functions, etc. However, in recent years, they have started to be used in DL as well, with the Massive Open Online Courses (MOOC) services, providing new type of continuous learning not only for students, but for the everyone in society [5,28,29]. According to Potkonjak et al. [5], the MOOCs provide web-based knowledge repositories as well as interactive user forums that help build a community for students, professors and teaching assistants. These tools and services are the result of and the answer to increased demand for continuous distance education in technology and engineering subjects. Based on them, universities, schools and other DL providers are going to expand the number of online specialized courses and trainings, to reach a wider range of recipients and participants. Again, these types of courses should be carefully thought out and prepared, along with the development of a detailed implementation program, preparation of classes and study materials, taking into account various activities, evaluation methods, etc. Required competencies and skills of potential participants should be defined as well [30,31].

At the same time, several approaches to teaching organization were proposed and developed, based on the aforementioned EL and DL methods. The following are the most promoted and discussed in education science recently [25,32,33]:

- Traditional face-to face (f2f) courses supplemented with digital technology and tools (e.g., Power Point or Prezi presentations, online tests, quizzes). In practice, this approach is very conservative, with a low level of active students' commitment as well as non-conventional activities implementation during lectures and classes.
- Hybrid courses and the BL, where lecturer and/or assistants combines different online learning activities and traditional courses, providing some virtual sessions and activities accessed remotely by student. In [34], Hoic-Bozic et al. explain that the BL incorporates online and traditional learning environments, technologies and digital media for learning content delivery, taking into account various teaching and learning methods (both online and traditional). Moreover, group and individual learning activities are considered for effective BL implementation with synchronous and asynchronous interactions between all actors in the learning and teaching processes. That approach allows the building of a variety of frameworks and structures for courses, with high commitment of students and active, mentoring role of teachers and lecturers.
- Flipped classroom (FC) could be considered as a kind or part of the BL, wherein much of the study materials and technical contents are available for students outside the classroom, via virtual platforms, cloud sharing as well as online Learning Management Systems (LMS). Instead of traditional lectures, the classroom meetings are organized in the form of brainstorming, problem-solving discussions, promoting active learning in the presence of the teacher/mentor.

In this context and taking into account that the BL is becoming an increasingly popular form of implementing EL tools and methods in higher education teaching processes, it is particularly suitable for use in the transition from traditional forms of learning and teaching, towards hybrid learning [34,35]. Therefore, a few years ago, the BL approach was selected to be implemented in several courses of building automation in the ABNLab. Along with the advent of possibility to share study and video materials as well as to use various interactive tools of the LMS based on Moodle platform at the AGH-UST, they began to be gradually used during lectures, laboratory classes and active work with students. Some aspects of this implementation are presented in Section 3. However, it should be kept in mind that f2f meetings and contacts between teacher and students are still crucial elements in the structure of courses organized in this way, and according to [34], they provide the most efficient teaching model based on the BL approach. It combines self-paced learning (reading study materials, interactive lessons within the Moodle), live EL (watching video materials and tutorials, using interactive test, questionaries) and last but not least f2f classroom learning with active teacher support.

2.2. Modified Blended Learning Approach—COVID-19 Lockdown Impact

As already mentioned in Section 1, the COVID-19 lockdown introduced in the spring of 2020, with all its limitations in the field of f2f contacts, resulted in the need of transition to fully remote work with students in the learning process. While it is possible to change the BL approach into the framework with distance meetings and works, this process requires additional mental and technical preparation, both from teachers and students. Moreover, this situation was completely surprising for both mentioned parties. At the same time, each of them was aware of the necessity to continue the courses and activities, especially the laboratory ones. Therefore, the BL approach implemented already in some of the courses in the ABNLab was modified, taking into account COVID-19 lockdown guidelines and restrictions as well as the transition of all communication between students and teachers to remote mode. In this way, the DL was fully implemented in the courses based on the BL approach, with several additional new tools and activities supporting this new mode of communication and interpersonal contacts. A general framework and the main elements of this COVID-19 lockdown strategy, essentially created on an ongoing basis during the summer semester in 2020, are shown in Figure 1.

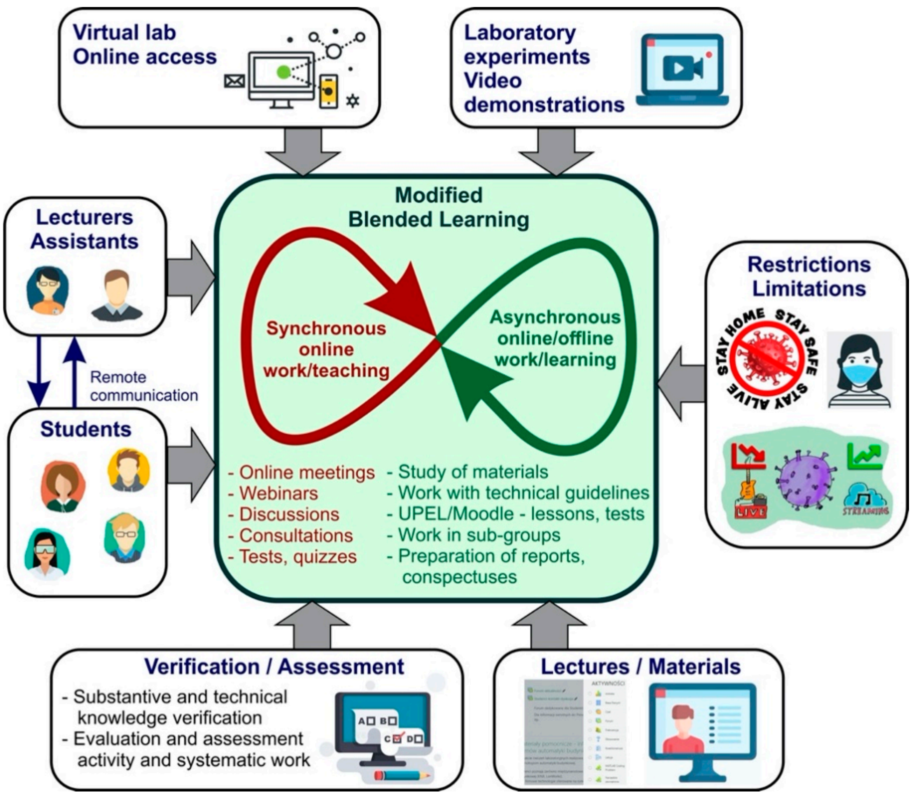


Figure 1. A general framework of the modified blended learning approach for building automation courses with lectures, laboratory classes and other activities caried out in remote formula.

From a practical and an operational point of view, the organization of such a platform for the remote exchange of information and the implementation of activities both for students and teachers in online and offline modes was possible mainly thanks to the University E-Learning Platform named UPEL. The UPEL has been the LMS available for all of the AGH-UST researchers, teachers and students for several years. It is based on the Moodle platform, very popular in organization of EL and DL approaches [28,36,37]. Moreover, the Google Suite as well as the Microsoft 365 services and tools were used and incorporated into the teaching and learning processes (with licences for the AGH-UST).

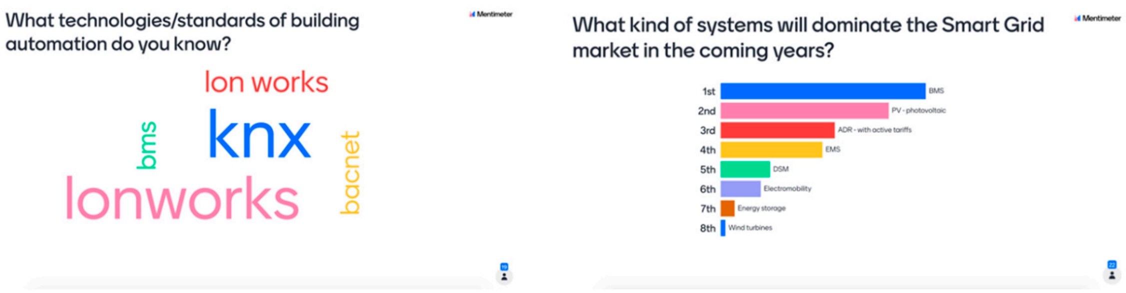
3. Building Automation Courses—New Frameworks, Concepts and Tools

As mentioned before, the BL approach with some EL tools and methods had been implemented and used in the processes of teaching and activating students during the classes in the ABNLab at AGH-UST for a few years already. However, the traditional approach, with classroom meetings and f2f contacts was still an important and fundamental component of this teaching strategy. In this paper, a case study showing the modified BL approach with remote communication and DL methods is presented, based on different approaches introduced for two aforementioned groups of students with various expectations and technical background. The methods, tools and then modifications, changes and developments are presented and explained in the following subsections.

3.1. Lectures in the Blended Learning Mode and with E-Learning Tools

The basic EL solution and tool introduced within all of the courses in the ABNLab allowed the providing and sharing of study materials as well as presentations from lectures in the form of PDF files and graphics shared within the UPEL platform. However, it is worth emphasizing that during the pandemic lockdown, when many of university teachers began to use it extensively, UPEL's administrators introduced restrictions on the amount and the volume of shared files. Therefore, other services such as Google Drive and the OneDrive from Microsoft were introduced, with links available for students in UPEL courses. In the next step, the work of students with the study materials has been and continuously is becoming more active, with the possibility of tracking and even assessing students' activity by the teacher, thanks to the Lesson Module available on the UPEL/Moodle platform. Nedeva et al. [38] explain that the Lesson Module allows the addition of entire lessons with links to the study materials and additional knowledge sources that guide the student in self-learning process, based on her/his answers. Such a concept of moderated individual work was introduced within the courses, allowing subsequent stages in obtaining knowledge by students as well as the verification of their self-learning in the form of quizzes, with the possibility to check and improve the answers. This way the Lesson activity in the UPEL could be considered as a kind of a flowchart with several, subsequent stages of learning. The students proceed through the stages only by answering the questions correctly, working individually or in groups with asynchronous discussion. Moreover, the lessons are available for students according to the course schedule, correlated as much as possible with the topics carried out as part of the laboratory exercises. This approach has opened the way for the effective introduction of an FC formula within the lectures, where the teacher moderates a discussion with students on a new topic and they actively and creatively use knowledge gained during self-learning with the Lesson Module [18–20]. In practice, at the beginning of such lectures, the author of this paper organized a short online survey, pre-questionnaire in open formula with active participation of students and presentation of current answers collected from their smartphones and/or laptops. An example of the results graphic view from such a pre-questionnaire is shown in Figure 2.

In this case, the Mentimeter platform [39] was used to build a survey and to present its results. Several options of the organization of questions in both open and closed formulae were used by the author, with reporting tools as well as archiving the results of surveys and quizzes. This short activity is very attractive and liked by students, who are willing to engage in unconventional activities during the lectures and classes, especially in online, synchronous mode, using their smartphones or laptops which they always have [40,41]. At the same time, the lecturer gains their attention, commitment and interest (waiting for other people's results, lecturer's comment, developing of the topic). Then, the role of the lecturer is to moderate further discussion, indicate the most important issues and problematic threads in a given topic and systematize the information achieved by students. Sometimes, at the end of the lecture, a short test to summarize and verify on the acquisition of the most important issues and new information discussed during the lecture could be proposed, without assessing students but with a summary of comments. Another online tool—the Slido platform [42]—with short tests including a few questions is effective for this purpose. Then, topics and main issues for the next lecture are introduced with brief information about which study materials are recommended to students for their own, individual work. Bearing in mind all this information, it should be emphasized that the preparation of lectures in such form, with discussion and activities attractive for students is very time-consuming. However, as shown by the author's experiences, they bring very positive results in students remembering the most important issues discussed during the lectures, but also a lot of personal satisfaction, resulting primarily from attracting students' attention during the lectures as well as their activation during the period of individual learning.



(**a**) (**b**)

Figure 2. Synchronous online presentation of the results/answers for two questions from the activating pre-questionnaire introduced at the beginning of the lecture organized in the form of a problematic discussion within the flipped classroom formula. The survey carried out using the Mentimeter platform with results presented graphically: (**a**) word cloud form; (**b**) bar chart (details provided within the text).

3.2. Lectures with Distance Learning During Lockdown—New Concepts and Tools

All the methods and tools presented in the previous subsection work better or worse in the normal conditions of university operation. However, the outbreak of the COVID-19 epidemic in spring 2020 and the suspension of teaching activities, forced a complete reorganization the formula of the lectures and their correlation with laboratory classes [9,11,43]. Therefore, for a quick reaction to the new reality in the education process for the first group of students mentioned in Section 1, it was decided to use the previously prepared and online available repositories of study materials as the basis for organizing a new formula of asynchronous individual learning, supported by online synchronous discussions and moderation meetings by MS Teams channels [24,37]. At the first meeting after the COVID-19 lockdown beginning (one week after introducing), the students were instructed what study materials to view and where they are available within the UPEL courses. For most of the PDF files with technical information and guidelines, the most important elements and information were marked graphically and/or with comments in the content of the file. In this way, students knew what to look for and pay special attention to in the texts and what information was important and necessary to understand the technical issues; this was discussed in subsequent lecture webinars and during the laboratory classes. An additional, new and very important element of verification of the knowledge acquired during the individual learning of students in asynchronous mode was short quizzes-tests (with tools provided by the UPEL platform such as a Test-Quiz Module as well as the Lesson Module with short questions at the end of the lesson). They were used to track students' progress in reading the study materials and learning specific technical aspects of the building automation technologies, with additional points added in a UPEL's Gradebook Module. This is an example of the BL approach implementation in modified, completely remote, distance mode of teaching and learning, with active student participation despite the lack of direct contact. This activation resulted in the increased exchange of information between students and the lecturer observed in discussion forums within the UPEL courses and high amounts of additional inquiries and questions to the lecturer.

The next part of the DL organization was webinars dedicated to the transfer of substantive knowledge in the synchronous mode. For this purpose, the Virtual Class Module was used, provided by the UPEL platform and based on one of popular online webinar platforms—the ClickMeeting [44] offering various tools to organize meetings in the convention: the moderator and group of participants. The author of this paper used several of them in his lectures–webinars in distance mode. First of all, a video camera transmission, giving the students a substitute of direct contact with the lecturer (a face view, emotions, gestures, etc.) and with active communication on chat in question and answer (Q&A) mode. These two tools create effective (as far as possible) environment for active reactions, comments, questions and suggestions both for students and the lecturer. The Q&A mode was particularly helpful, since it allowed posts-questions from students with a different colour to be distinguished and shown in a separate panel. This option was used to group chat posts and organize short Q&A sessions at the end of the webinars. Moreover, this approach allowed the systematization of the content and effectively conduct the lecture providing substantive knowledge and then comment and answer for students' questions—without "missing" them and being too distracted during the presentation. The chat discussion and its history were saved after the webinars in the form of a text file, giving the lecturer the possibility to analyze even more complicated questions or problems and to answer them in offline asynchronous communication mode [31]. There were other useful tools used during webinars as well such as sharing a desktop for showing the presentation slides, documents, guides and websites as well as an interactive board to draw drawings, schemes and write calculations, equations, etc.

Since asynchronous, individual work is an important element in the DL method, after obtaining the consent of the students, all of the webinars were recorded in the form of video files (*.mp4), using the OBS Studio tool [45], recommended by the coordinators from the AGH-UST e-Learning Centre. Those files were accessible to view online only by students as registered participants of the UPEL courses. Such option allowed students to freely continue their individual learning, with the possibility to repeat the content presented during the webinars and refer it to the information available in the study materials and presentations from the lectures. The acquired and required substantive knowledge was verified in the form of quizzes–tests organized twice in the semester, through the UPEL platform, usually with closed and some open questions. The results of the tests were assessed and added to final grade for each of the students.

The last new element of the DL in the modified BL approach was preparing reports in small groups, related to topics set by the lecturer, based on technical and commercial knowledge as well as information available in scientific journals, technical magazines and on websites. This kind of long-term activity was proposed in particular for the first group of students without an electrical engineering background, in order to activate and mobilize them to expand their knowledge related to the applications of building automation devices and systems in those main areas. Taking into account the work in a completely remote mode, an additional innovative element was introduced to evaluate and verify of the systematic work of students on reports. They had to post notes, chat and discussion posts, found materials—files or websites—using an interactive board provided by the Padlet online platform [29,46,47]. For that, a virtual board was prepared, with sections dedicated for each sub-group (topic) and access protected by a password. In this way, all of the students had the possibility to add their posts and materials for evaluation and assessment as well as to observe activity of other students and sub-groups. Moreover, with this approach, the teacher as the moderator of the virtual board can observe students' activity, evaluate it and suggest directions for next steps, searches and report developments for different sub-groups. The main view of the Padlet board is shown in Figure 3.

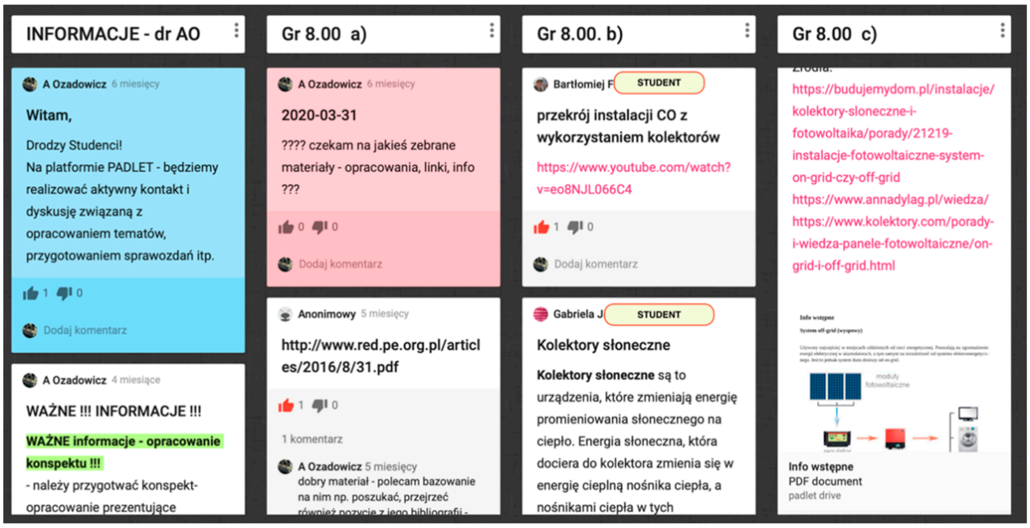


Figure 3. The Padlet board with several columns for sub-groups to add their posts, materials, comments and teacher's suggestions (screenshot with the original, real view—posts are in Polish and they contain students' questions, contributions, remarks and lecturer's comments and suggestions).

In this context, it is very important to advise students to search for scientific and technical knowledge and information on technology development trends in scientific journals, conference materials, licensed by the AGH-UST Library in e-journal databases (e.g., IEEE Xplore, Scopus, ScienceDirect-Elsevier or Springer). Students of technical faculties are not always aware of the existence and availability of these databases, so it is worth taking the opportunity to shape such awareness and the possibility of using them in technical reports. In this way, the work of student groups on technical topics also shapes their additional soft skills. They are important nowadays to be effective in companies, technical research teams and other institutions. At the end of the semester, final reports from sub-groups concluding their works were assessed as well. This element of interactive work within the Padlet board proved so positive that it is planned to continue to use it also in the coming years, as it allows students to obtain a high level of activity during the semester and effectively shape the path of their more conscious work—individual and group.

3.3. *Laboratory Classes Supplemented with E-Learning Tools*

Laboratory classes are a specific element of the engineering teaching and learning process, considering implementation of the e-learning and especially DL methods and tools, since they are mainly based on direct contacts of students with teacher and laboratory infrastructure, on real experiments with devices, laboratory stands, etc. Nevertheless, changes seem inevitable. Technological progress, widespread use of ICT networks with global Internet and cloud services, social media and virtual tools along with the daily use of mobile devices by students and teachers all force changes in the approach to the organization of laboratory classes in this area [4,5,48]. However, the development of appropriate standards and learning programs is time-consuming and costly. In practice, it also requires a complete reorganization of the laboratory operation principles. Hence, the relatively slow trend of changes in this regard is observed in education practice at technical universities.

Therefore, at the ABNLab, the first stage of the BL approach implementation was the introduction of UPEL courses with sharing the study materials as well as instruction guides for laboratory exercises for all of students. Since a wide spectrum of technical and application issues is covered in several subjects within the laboratory, this situation requires the teachers to develop different approaches that will provide a balance between theoretical, substantive knowledge and installation and integration practice, necessary for building automation engineers. For example, at the beginning of laboratory classes for subject Intelligent Building Systems, with students from the second aforementioned group, during the first few meetings at the laboratory, the concept of an active, moderated technical discussion is introduced and supported by technical demonstrations at the stands of various technologies. At the first meeting, the teacher explains the organizational concept of the initial laboratory classes based on this FC formula and introduces links to study materials and additional technical information for the individual work of students before the next classes [49–51]. Then, next few meetings in the laboratory are conducted in the form of workshops, based primarily on the knowledge acquired by students, with different activities for them during the demonstrations and integration works at the laboratory stands. This formula of classes has been working for several years and is willingly taken up by students. The main purpose of it is to provide students with the necessary theoretical knowledge in the area of network construction, features and functions of devices available at the laboratory stands, as quickly as possible. The teacher presents technical details and concepts using and explaining industry-specific technical terminology, so that in the next phase of laboratory classes, students can more consciously start the effective work on experiments at laboratory stands with instructions and guides dedicated for them.

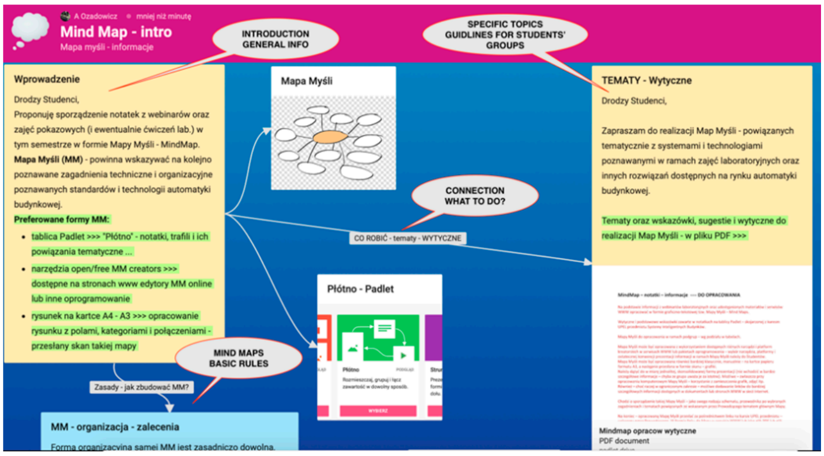
A similar approach was also introduced during laboratory classes for students from the first group, without an electrical engineering background. However, in this case, the technical knowledge and the most important practical information, allowing students to use devices at laboratory stands, are transferred mostly in the first few lectures. In this slightly modified concept, the workshops sessions in laboratories with equipment demonstrations cover a wider spectrum of practical and application issues, related to the support of energy meters with data interfaces to the automation network and to the functions needed in energy management systems. The knowledge and practical skills are verified in the form of a quiz–test carried out remotely on the UPEL platform and the assessment of reports from subsequent laboratory exercises, prepared by students and transferred in electronic form through the Tasks tool by the UPEL platform [52,53].

3.4. Laboratory Classes with Distance Learning Model—Modified Approach and Solutions

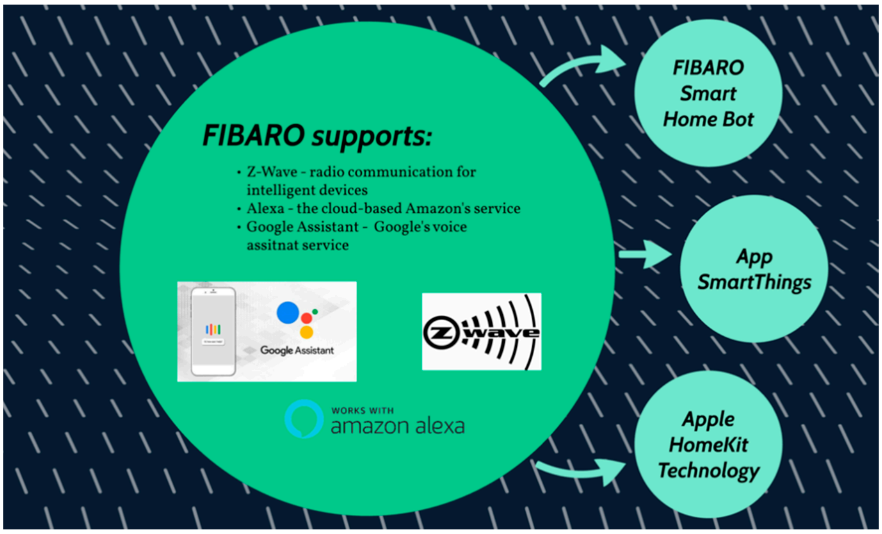
All of the BL and FC approaches as well as class forms, briefly described in the previous subsection, need access to laboratory space and stands for students. This access has been eliminated with the introduction of the COVID-19 lockdown and restrictions, in practice from the beginning of the laboratory classes cycle (the second week of March 2020), almost to its end (the first week of June 2020). At that time, it was very surprising and positive that the university authorities took action in an extreme way to make available to academic teachers new, licensed tools and programs for remote work with students, both in synchronous and asynchronous modes. Similar activities took place also in other universities in Poland and all over the world, since the EL and DL "in the blink of an eye" became the only possible methods of organizing classes and interpersonal contacts [10,54,55]. Such a dynamic nature of organizational changes also determined the dynamic approach of the teachers from the ABNLab to the organization and implementation of laboratory classes in extraordinary circumstances. Therefore, after the suspension of classes at the university and a short period (about a week) to develop even a rudimentary program of further activities in the remote work mode, the first action was contacting by e-mail the groups of students assigned to laboratory classes for the summer semester. After the students' response, the teachers sent them the initial guidelines with information about the dedicated UPEL courses and how to sign up. This allowed for the transition of the contact mode to remote messages sent by forums available in the UPEL courses. Finally, three subjects with laboratory exercises were realized during the aforementioned semester. Their programs, tools and teaching methods were slightly different, but based on the BL and FC approaches implemented in previous academic years, with a few modifications due to the necessity of DL mode.

One of the subjects organized in this formula was the Intelligent Building Systems, mentioned in the previous subsection, covering a full cycle of 14 weekly laboratory classes for students of the 1st semester of the 2nd degree master's studies. For this subject, the most important aspect of laboratory classes is to familiarize students with technical and organizational basics for several different standards and technologies of building automation. Therefore, to provide them this knowledge and its practical aspects, the author of this paper decided to prepare video demonstrations of laboratory stands, with automation devices and integration software used during the exercises. However, taking into account COVID-19 restrictions, even recording those videos was difficult and only possible after about 3 weeks from the first announcement of the decision to suspend classes, when only university employees were able to conditionally get to the laboratories to carry out their research and teaching. Five video demonstrations were finally recorded, showing and discussing the equipment available on laboratory stands dedicated for 5 different building automation technologies. They were carried out in relation to the exercise instructions prepared earlier for the course and available to students in the UPEL course repository. For some of the demonstrations, additional photos and graphic files were produced as well, with software screenshots, to better visualize the most important elements such as names of network variables, data and settings. After the final processing, the videos were shared with students by the Google Drive repository available for the teachers of the AGH-UST as a licensed tool, with links published in the UPEL course. Moreover, by implementing the modified BL with the FC approach, successively, before each sharing of the next video demonstration during the semester, an introductory webinar was organized for students, using the Virtual Class Module (the ClickMeeting) from the UPEL platform. In those webinars, all technical aspects regarding a specific building automation technology were discussed and explained with discussion and Q&A sessions on chat. Referring to the aforementioned first 3 weeks at the beginning of the lockdown period, it should be explained that after a few days of the suspension of classes, students were obligated to start interactive individual learning with study materials in the form of moderated lessons within the UPEL courses. Moreover, several short quizzes–tests were prepared for them for self-verification and to concentrate their learning process on the most important technical aspects, related to technologies considered in the next classes. In this way, after two weeks, it was possible to quickly introduce laboratory classes in a fully remote, DL approach, along with the transfer of the most important substantive and technical knowledge and last but not least with preliminary verification of the learning outcomes.

Beside the asynchronous DL moderated by the teacher as a key part of the teaching process during the lockdown period, a new innovative element of the modified BL approach was implemented in laboratory classes for the subject Intelligent Building Systems. Instead of reports from subsequent laboratory exercises, the teacher asked the students to prepare reports on the most important technical and functional aspects of the modern building automation technologies in the form of a Mind Map (MM), developed by small subgroups of 3–4 students. Each of the subgroups was assigned to a topic related to specific technology and/or the modern, latest solution of building automation systems. Based on the online materials suggested by the teacher (websites of companies, technologies; materials with technical information; technical webinars and video tutorials on the YouTube, etc.), students were obliged to prepare their MMs presenting the most important issues related to the assigned topic. This MM formula was presented by the teacher in the dedicated webinar along with a short discussion of topics and guidelines for the organization of the maps as well as introduction of different tools for building MMs in electronic form—several websites and the Padlet platform. The Padlet was used by the teacher during the webinar as well to show mentioned guidelines in the form of a small MM as an example for students—according to learning by doing approach. After the initial surprise of an unusual formula of learning and reporting, the students showed a lot of commitment and ingenuity in creating their maps. They used various tools in their works, and one of the groups built even an interactive MM using a presentation tool—Prezi [56]. Such a convention of presenting knowledge and technical information has brought the intended effect of education in the form of acquiring new knowledge by students and the ability to unconventionally present it, categorize, logically combine related issues and elements of building automation technologies. A fragment of the teacher's guidelines in the Padlet platform and a selected scan of the MM in Prezi are presented in Figure 4.



(**a**)



(**b**)

Figure 4. The Mind Maps as a method of interactive presentation of technical knowledge and gained during laboratory classes: (**a**) Padlet and a fragment of the teacher's guidelines (original view in Polish with additional comments and explanations in English); (**b**) Prezi and one of the screens of the interactive Mind Map prepared by students (about technologies supported by the Fibaro building automation solution).

Another new and innovative element of the modified BL approach in DL for laboratory classes was a virtual discussion with students on technical solutions offered by one of the building automation companies, presented in online tutorials. This activity was inspired by the marketing information from one of the newsletters and developed "on the fly" during the semester. The remote discussion with students was organized in the form of a seminar–webinar, using the aforementioned Virtual Class tool on the UPEL platform, along with ongoing comments related to the content presented in the tutorial video, available on the company's YouTube channel. Moreover, after the online discussion, students were obligated to find additional technical information about specific elements of the solution on the company's website (some specific elements assigned to the small groups of students by the teacher) and provide a conspectus for a short presentation of these elements in the PDF file. The PDFs were gathered in the Task Module on the UPEL platform and briefly summarized at the next discussion meeting, along with the evaluation and assessment. Additional value and learning outcome for the students was the gaining of ability to work independently with the technical materials and marketing information, critical selection of valuable information as well as preparation of a short technical report presenting new technical solutions and features [18,57].

There were two other subjects with laboratory classes realized in the modified BL and FC formulae during the COVID-19 lockdown period, for students form the first group without an electrical engineering background. Obviously, the general concept and framework for these classes were similar to the previously described subject from the second category. However, taking into account the necessity to show and teach the students other practical aspects of the building automation applications in energy monitoring and management, some new activities were proposed. For example, a few laboratory exercises were presented in the video tutorials recorded at the laboratory stands like previously, but the demonstrations were supported by additional information from measurements, network variables and devices' parameter registrations, provided in the form of the graphic files as well as excel tables created by the teacher during the work at the laboratory stand. All information, videos, graphics and screenshots as well as the measurement data and recordings of parameters from the demonstrations were available for students in electronic form within the UPEL course repository. This approach allowed for considerable flexibility of student and teacher contacts and to work in the asynchronous mode, with the possibility of consultation by the forum discussion within the UPEL course [31]. Moreover, it mobilized many students to actively search solutions, necessary methods of data processing in additional, external materials available on various specialized websites (e.g., conversion of data from an energy meter—floating point numbers written in hexadecimal (HEX), to decimal form) and their consultation with the teacher. At the same time, it allowed the teacher to verify and differentiate the assessment of the activity of various students throughout the semester.

A completely new form of activity introduced by the author for those two subjects was two laboratory exercises carried out in the formula of fully remote access to devices and software at the stands in the laboratory. This approach was possible since these exercises were concentrated on devices with the IP network interface (touch panel, advanced controller, so-called smart automation server and energy meters). After the introduction webinar, students received the devices' locations and login details with information about the schedule of the online access to the stands for small groups (2–3 students). Moreover, the exercise instructions and video tutorials were available to them on the UPEL platform. With this knowledge and support tools, students could organize their group synchronous work with the equipment available in the ABNLab and configurate the devices according to the instructions. However, to ensure work safety and possible technical or substantive support, all works were monitored by one of the teachers. Therefore, this formula required the greatest amount of organizational work in the preparation of the exercise scenarios as well as the schedule of their implementation. It was the most time-consuming form of conducting laboratory exercises. However, at the same time, it is worth noting that this approach gives the lecturer the opportunity to work almost directly and synchronously with students, observe their technical skills in operation with software and hardware as well as the ability to effectively use the knowledge and work with technical documentation and guides [5,30,43]. After the online exercises, the students were obligated to prepare short reports with results of their work and with short technical discussion according to guidelines provided by the teachers.

4. Experiences and Reflections Discussion

All of the learning and teaching methods, with tools and solutions described in this paper, especially in Section 3, should be considered as the case study, with its specific circumstances, subjective teacher experiences, level of e-learning tools and management platform implementation at the AGH-UST, etc. However, some general reflections can be formulated on the basis of new experiences from the distance learning and teaching during the COVID-19 lockdown period.

4.1. A Lecturer's and Teacher's Perspective

The first of the general observations concerns the organization and conducting of lectures in distance, remote mode. The case study presented and analyzed in this paper shows that the lectures in their organization concepts are very open to introducing new forms of contact between the lecturer and students as well as any additional activities, both during the lectures and between the lecture meetings. Importantly, even switching to full distance, remote teaching and learning processes is not necessarily associated with the loss of their educational value. Moreover, the author observed a noticeable increase in the effectiveness of students' work in the process of searching and acquiring the knowledge. Hence, it seems very valuable to implement the FC formula for the lectures in the following years, with emphasis on students' individual and group work in the asynchronous mode with study materials in the form of PDF files, dedicated websites and video tutorials. The lecture meetings themselves can be organized in a hybrid formula: traditionally in the lecture hall (f2f contact) and periodically as online webinars. This approach provides additional skills of students in organizing learning and online meetings (familiarization and efficient use of tools), necessary in the following years of their study and professional work. Moreover, according to the FC approach assumptions, the lecture meetings should evolve towards discussions on the issues and technologies learned by students during their asynchronous, individual work. From the author's experience and observation, this approach brings positive results in terms of students' involvement and very high attendance at lectures and webinars.

As the second general observation, it should be noticed that during the lecture meetings (both with f2f contact and online synchronous), students effectively perceive and engage in all forms of activity using mobile devices, such as short questionnaires, tests, quizzes, review of materials and information on websites or other online information channels. Such elements dynamize the message and contact, focus students' attention and they are good starting points for a discussion or summarizing the material and substantial knowledge presented during the lecture. In [7], Kim et al. discuss the role of active student engagement with mobile technology. Their study shows that the academic use of mobile technology involves students beyond traditional classroom contexts. Moreover, according to the results of that study and another presented by Drain et al. [58], the mobile technology that offers educational possibilities that can enhance students' growth in higher education and the students themselves tends to demonstrate better academic outcomes with additional skills in literacy, technical language use as well as information processing.

Next general reflection is related to the laboratory classes where an irreplaceable element, especially in the education of engineers, is the direct contact of students with the hardware and software at the laboratory stands, with teacher's supervision and moderation. However, according to the author's experiences during recent years and the latest COVID-19 lockdown period with classes suspension, a very effective element is the organization of the first few laboratory classes in the BL formula. The essential element in this concept is an asynchronous, individual learning process, when students, moderated by the teacher, study the materials, tutorials and technical information. However, an active technical discussion with students, combined with equipment demonstrations and practical works with their participation, create a new environment for the effective use of the knowledge and even for making mistakes during the work. These mistakes could be eliminated in further learning with additional guidelines and video tutorials (the author of this paper used the VideoAnt [59] tool to provide interactive comments and suggestions for videos on YouTube) and improvements during the next laboratory class or online demonstration. A good and interesting element of diversifying laboratory classes is also the introduction of innovative solutions for reporting both the overall knowledge acquisition and results of practical exercises. In the case study presented in the paper, the MM tool was a new proposition for students in this field, which turned out to be very useful in the activation of students and was well received by a large group of them. The added value of the MM implementation is mobilization of students to work in groups, to actively search together online and offline materials, necessary to prepare maps as well as to stimulate creativity in the selection of the form of their organization and presentation.

4.2. A Student's Perspective

A natural complement to the cooperation with students during this special period was to conduct a survey after the end of the semester, regarding their impressions, opinions and comments. Since the DL approach is directly related to the availability and reliability of the technical staff (computers, tablets, smartphones) network infrastructure (bandwidth and stability of the Internet connection), the first very important question in this survey was: "What system platform did you use for on-line communication (e.g., PC. Windows, PC Linux, iOS, macOS, Android, etc.)—enter the name:". At first glance, the Windows operating system dominated the responses, but other platforms also appeared. In the summed-up responses for both groups of students mentioned in the paper, for the total number of 90 people, as many as 85 indicated the Windows operating system as the primary environment, and then other options of the system platform appeared: Android for 16 and iOS for 3 people. The results clearly show the dominance of the Windows operating system. Therefore, the teacher organizing the subject and selecting remote work tools, can confidently assume that they should be compatible first of all with this system to ensure the widest reception among participants of the classes and conflict-free operation. Considering the use of mobile applications in some activities, which is happening increasingly often, they should be available primarily for Android and secondly for iOS but preferably for both of these platforms.

Due to the large variety of teaching and learning forms and activities introduced during the summer semester of 2019/2020 academic year, the summary survey included questions related to them to collect feedback and comments from students. The first question concerned the forms of remote teaching methods and DL tools and was: "Which form of activity during the classes and lectures encouraged active participation and acquiring knowledge, which of them did you like the most?" The distribution of answers is shown in Figure 5.

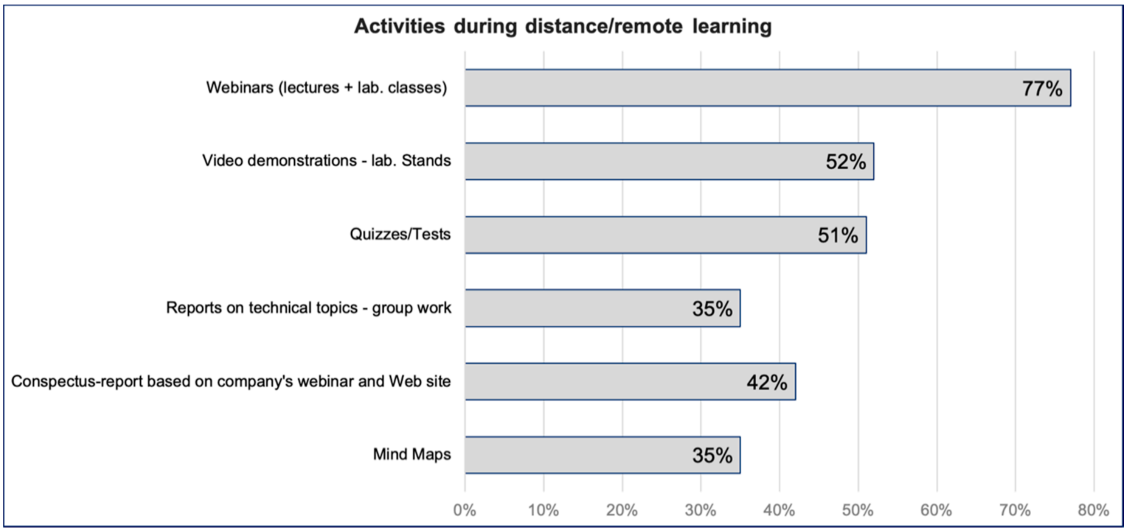


Figure 5. Students' opinions and reflections on the various forms of activities in distance learning (DL) and remote synchronous and asynchronous communication introduced during the COVID-19 lockdown.

There is no single dominant form indicated by students. As a good, effective form of activity, as many as 69 people out of the total of 90 indicated lecture and laboratory webinars (77% of respondents), and 47 people (52% of respondents) indicated laboratory webinars with accompanying video demonstrations from laboratory stands. A very similar percentage (51%—46 students) of responses with a positive assessment was obtained for all forms tests and quizzes carried out remotely using the platform and the Quizizz tool. Other forms of activity such as MMs and the work of student groups on technical topics were less appreciated. They were indicated by approximately 35% of the surveyed students as attractive and actually activating.

Another question was about the several proposed forms of synchronous work and online contact. The question was: "Which of the forms of online contacts and online synchronous activities were better and interesting for laboratory classes in DL mode?" Results for this question are presented in Figure 6.

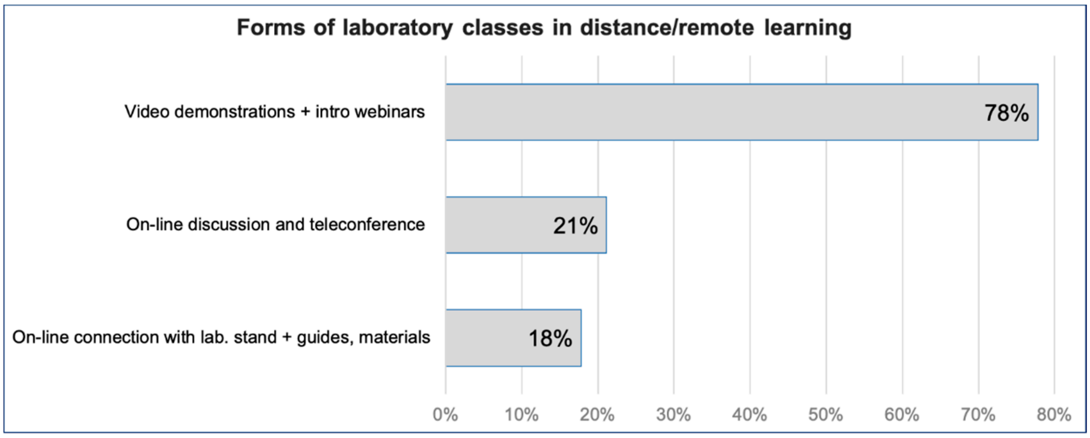


Figure 6. Students' answers for the question: "Which of the forms of online contacts and online synchronous activities were better and interesting for laboratory classes in DL mode?".

The vast majority of the 90 respondents indicated webinars again in conjunction with asynchronous recording of laboratory stand demonstrations as the preferred and satisfactory solution. Such an answer was given by 70 people. Other proposed forms were less favored by the students, respectively—teleconference meetings and technical discussions—indicated by 19 people, or finally online direct connections with the laboratory stands, along with the availability of instructions and materials (i.e., virtualization of lab stands)—indicated as positive by 16 students.

Summarizing, the results and the answers to these few questions indicate more favorable opinions of students towards more "passive" tools and activities from their point of view—such as webinars, presentations and stand demonstrations. Perhaps this is due to the fact that the preparation of good, highly-active forms for classes requires better and thus time-consuming preparation. Meanwhile, in the extraordinary period described in this paper, decisions regarding the selection of tools, methods and areas of their use were made quickly, with very superficial preparation. Therefore, the results of the survey should not be treated arbitrarily, pointing to the marginalization of active discussions, synchronous work, laboratory virtualization or group work with technical materials. As shown by practical observations of students' work during the semester, these forms also work well and mobilize students to work and study. However, in order to be recognized by a wider group of them, they must be refined and well prepared.

5. Conclusions and Future Works

In spite of the prevailing opinions that COVID-19 lockdown and its restrictions brought only negative effects, it is also necessary to clearly indicate the positive consequences of the closure of institutions, schools, universities and social isolation. New reality and unprecedented circumstances forced a radical need to rapidly introduce and use all the available technologies and tools for remote, distance work and communication, not only at universities. The pandemic of COVID-19 has pushed the policy makers and university authorities to search for alternatives to the traditionally based learning system with classrooms, halls and laboratories [60,61]. More importantly, it caused a discussion on the need to modernize teaching methods with new technologies and tools as well as to develop completely new organizational concepts for various types of classes and student activities. It only remains to hope that this evolutionary and even revolutionary trend towards changes in the forms of organization of work with students, especially at technical universities, will be continued in the coming years, regardless of changing circumstances and easing restrictions. Those changes bring many benefits, both for the students themselves, who have grown up surrounded by technological innovations, especially mobile devices that they have been using daily, as well as for the teachers for whom new and better electronic tools and systems, LMS and other software platforms are being developed. All of them allow the introduction of new forms of activity and methods of teaching and learning in more interesting, attractive and effective formulas, staying in line with the contemporary, dynamically changing reality. This is of particular importance in the context of the need to present the latest technologies in technical studies, along with developing students' skills to work with mobile devices and technical information available on the web [7,60,62].

Bearing in mind all the benefits of the modified BL approach described with the case study and discussed in Section 4, in future work, the author will improve the already developed methods of remote and hybrid work, using primarily the BL approach. According to Alqahtani et al. [13], the BL is one of the most popular and preferred e-learning models among lecturers, teachers and students. In addition, due to prolongation of the COVID-19 limitations for the next 2020/2021 academic year (new guidelines from the Ministry of Science and Higher Education and the AGH-UST rector available in fall 2020), the author will take on new organizational challenges, in particular in the field of hybrid work with students—with some stationary and some remote classes. Moreover, extended and more detail surveys for students' feedback will also be carried out to collect their opinion and reflections related to blended and hybrid learning approaches.

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