Exploring blended learning tools to transform a laboratory course unit in engineering: challenges, setbacks and rewards

Maria Olívia Pereira[1,2], Luciana Peixoto[1], Tatiana Vilaça[2,3], Fernanda Gomes[1], Pilar Teixeira[1]

[1] Centre of Biological Engineering, Department of Biological Engineering, School of Engineering, University of Minho, Braga, Portugal
[2] Department of Biological Engineering, School of Engineering, University of Minho, Braga, Portugal
[3] GAEB - Gabinete de Alunos de Engenharia Biomédica, University of Minho, Braga, Portugal

Email: mopereira@deb.uminho.pt, luciana.peixoto@deb.uminho.pt, tatianavilaca00@gmail.com, fernandaisabel@ceb.uminho.pt, pilar@ceb.uminho.pt

DOI: https://doi.org/10.5281/zenodo.5098351

Abstract

To boost students' engagement on learning outcomes, promote active peer learning, and adopt more dynamic teaching practices, a module of a laboratory course unit (TPL) in engineering was reformulated exploring blended learning. This reformulation was even more challenging than initially anticipated as it was implemented during the Covid-19 pandemic. As TPL learning practises are based on the operation of laboratory modules mimicking heat and mass transfer phenomena, asynchronous and on-line synchronous learning classes and face-to-face laboratory classes were outlined. To promote the asynchronous learning, a full script of TPL and pitch and longer videos presenting, respectively, each work and its practical operation process were formerly prepared and available online. Students were required to work in group to define the variables and conditions to be evaluated in each laboratory module, organize and plan the experimental activities, create data recording documents, and later present and argue their options in virtual synchronous classes. In the face-to-face classes, different activities were performed in a rotating system, scheduled and tuned in the online classes. It was also aimed in-situ promoting peer discussion of the data and reports elaboration, goals not attained due to the pandemic restrictions, as only two students of each group were present in each hands-on class and in sequential times. TPL reformulation was a tough and time-consuming task since 73 students were enrolled, divided into 3 shifts, each one with 5 groups of five students. Students individual learning evolution was inferred through online quizzes that were periodically made available. A final inquiry, launched to obtain students` opinion about this transformation endeavour highlighted the script, videos, and the prompt teachers' feedback on the reports as the most fruitful and important aspects for students' engagement and guide their learning pathway. The rationale behind this paper was to disclose this transformation experience and share information and strategies that can be used in the teaching/learning of laboratory classes.

Keywords: Blended Learning; Engineering Laboratory Courses; Pitch videos; Collaborative learning

1 Introduction

Laboratory classes provide students with a first-hand experience within the concepts of the theoretical lectures and the opportunity to explore the methods used by scientists in that courses. Therefore, the laboratory is as important as the theoretical and conceptual knowledge. In the engineering lab classes, students deepen scientific subjects in an effective way; apply concepts learned in class to new hypotheses, learn to use scientific devices, learn to estimate statistical errors and recognize systematic errors. In addition, it improves students' work skills, such as reporting skills (written and oral), skills in collecting, analysing, interpreting and presenting findings and data, the development of critical and quantitative thinking; the learn to work in group, and allows to exercise curiosity and creativity when designing a procedure to test a hypothesis (National Research Council, 1997). For this, the students define the variables and conditions to be evaluated, organize and plan the experimental activity, create data recording documents, then perform the experiments according to a laboratory protocol, and, at the end, analyse the data and interpret the results. Thus, the laboratory classes play a fundamental role in teaching engineering as they provide a valuable opportunity to understand, apply and investigate theoretical concepts, practise a wide range of personal and transferable skills, such as problem solving, team working, observing and following protocols, and the development of several individual competencies. It also helps students to work more effectively and safely in a laboratory space understanding the storage and handling of hazardous materials, safety guidelines and safety labels (Artdej, 2012).

Laboratories of Transport Phenomena and Materials (TPL) is a course unit offered to the third year students within the Integrated Master in Biomedical Engineering, University of Minho. This laboratory course intends to provide to the students' capacities to understand and perform laboratory work in the areas of fluid mechanics and heat and mass transfer. In the 1st semester, this course unit comprises two laboratory modules, each one under the responsibility of different departments of the School of Engineering of University of Minho. One of the modules, under the responsibility of the Department of Biological Engineering (DEB) addresses a series of practical works covering heat and mass transfer-related phenomena. The main theoretical fundamentals, concepts and knowledge base were previously presented to the students in the scope of other course units.

In recent years, with the advent of integrative technologies, it has been reported that the capacity to support effective laboratory preparation can be more readily implemented allowing students to prepare lab classes in their own space and time. Indeed, it is now well-assumed that this approach often builds in students a greater capacity to address pedagogical learning diversity (Patterson, 2011; Jones & Edwards, 2010; Di Trapani & Gregory, 2009; Chittleborough et al, 2007). With this kind of approaches, it is expected to make learning more attractive and that students will have a greater commitment and obtain a better performance. With these new educational concepts in mind, the idea of reformulating the DEB module of this laboratory course unit in engineering grew and took shape by exploring these new integrative forms of learning. Amid the reformulation, Covid-19 emerged worldwide bringing with it some new and unexpected setbacks that forced to speed up the process of transformation and include some new teaching and learning practices, to face the restrictions dictated by the pandemic situation. As initially delineated, the traditional classes were converted in to face-to-face and online formats (Oyedotun, 2020) exploring blended learning tools.

The Covid-19, an infectious disease caused by the SARS-CoV-2 virus, was firstly identified in China, in the beginning of 2020, but rapidly spread all over the world, with the World Health Organization declaring it as a global pandemic. Covid-19 had and continues to have a negative impact on many sectors including health, industry, trading, agriculture, education, among others (Oyedotun, 2020). In addition to the impact caused by coronavirus pandemic in people's normal lifestyle, it had a profound effect in education forcing the suspension of in-class activities, the quick adaptation to non-face-to-face classes and the use of technology (Jain et al., 2021; Oyedotun, 2020) to support the continuity of teaching and learning. Indeed, the Covid-19 impact in Education resulted in the closure of schools and educational facilities, affecting over 900 million of students worldwide (Unesco 2020). All these measures were adopted aiming the prevention of the spread of the disease (Lockee, 2021). E-learning has thus become the rule of the covid-19 outbreak (Karp and Mc-Gowan, 2020).

As a great number of universities worldwide, University of Minho, in the context of Covid-19 pandemic, was forced to interrupt its normal teaching activities and move towards, in a first stage, to totally non-face-to-face, classes, and later to hybrid teaching models. Accordingly, the entire laboratory classes were transformed into online and blended classes.

Therefore, this paper aims to share to teachers and students and discuss some measures and strategies adopted in the scope of the reformulation of TPL, a laboratory course unit in engineering, exploring more dynamic teaching practices attempting to engage students in the learning outcomes and improve active peer learning. This transformation was even more challenging as its implementation took place coincidentally during the Covid-19 pandemic. Hence, the rationale behind TPL transformation and their advantages, limitations and recommendations are highlighted, as well as the feedback of students regarding this transformation endeavour.

2 Blended learning tools

A module of a laboratory course unit of engineering, TPL, was reformulated exploring blended learning strategies. Blended learning is highlighted throughout the educational resources as a major curriculum design method for improving students' motivation and the acquisition of knowledge via a student-centred approach (Benn, 2019). Blended learning tools combines both real-time in-class (and/or in-lab) activities and online ways of teaching. The latter can be accomplished in asynchronous and synchronous learning classes. In the TPL reformulation, asynchronous classes were implemented to allow students, in their own space, time and pace, to gain knowledge about the works to be later developed and prepare the lab classes by reading the TPL script (containing the description of the laboratory works, their theoretical fundamentals and practical aspects), visualization of pitch videos (2 min) and longer videos (10 min) presenting, respectively, each laboratory work and its practical operation process. These educational materials were formerly prepared and made available online for student's timely access. Indeed, pitch videos disclose a general explanation of each laboratory module mimicking heat and mass transfer phenomena (e.g. different types of heat exchangers) and a brief description of how they work. Longer videos exemplify the practical operation of each laboratory work that students will run into, calling attention to the particularities of each work and the possible conditions for analysis. After the individual examination of the educational materials, students were required to interact with each other in team work in order to share their own knowledge and interpretation of the information provided, define the variables and conditions to be evaluated in each laboratory module, organize and plan the experimental activities, create data recording documents, and later present and argue their options in virtual synchronous classes. The synchronous sessions, scheduled through Blackboard and Colibri Zoom platforms, also allowed the close contact and interaction between teachers and students and also served to clarify any doubts, namely, those regarding the laboratory modules, the theoretical concepts supporting each work and the pre-prepared documents to collect the experimental data and discuss with teachers and colleagues the variables to be studied to attain the goals defined for each laboratory work. Extra synchronous classes were held whenever requested by students.

In the face-to-face in-lab classes, 5 different laboratory activities (equal to the number of groups enrolled in each shift) were performed on a rotating basis, scheduled and tuned in the online classes. Due to laboratory space limitations and to comply with the guidelines of the World Health Organization and the good safety rules imposed by the Covid-19 pandemic crisis, the number of students attending the practical classes at the same time had to be drastically reduced which led that, in each in-lab class, only two elements of each group, in sequential times, operated alone the laboratory modules. Consequently, each student only executed, in person, two of the five practical works proposed in the DEB module. Even though, it must be highlighted that with the rotating system for carrying out the different works, all the students had the opportunity to have contact with the laboratory facilities and the lab modules mimicking the heat and mass transfer phenomena. Even operating the lab works individually, all students were encouraged to work in group when performing the treatment and analysis of the experimental data and the discussion of all proposed works, being mandatory to do, weekly, a mini-report, containing the following sections: abstract, main results presentation, data discussion and main conclusions. Teachers feedback on these results reports was communicated to students in the face-to-face class immediately after the practical work class. With this effort of timely reading and critical analysis of the reports, teachers attempted that the weaknesses and the less well achieved aspects, both in terms of form and content, could be improved and the constructive suggestions included in the following mini-reports. Additionally, in scheduled synchronous extra classes some quizzes were available for students individual learning self-diagnosis.

After running into all the laboratory activities, all groups were required to do a whole report about one of the laboratory modules carried out along this course unit, encompassing data collected by all the groups in each shift in order to stimulate knowledge sharing between groups and allowing the discussion of a wider range of variables and conditions. This strategy was an attempt to overcome the lack of sharing and discussion of information initially expected to occur among students during the face-to-face in-lab classes. Teachers opinion about the whole reports was also communicated to students.

At the end of the semester, a final in-class written evaluation test covering all the subjects explored in each of the laboratory works performed throughout the PTL course unit was carried out. In addition to all the aforementioned elements of evaluation, the students interest, preparation and performance in the face-to-face in-lab classes were also registered and appreciated by teachers.

3 Challenges, setbacks and rewards

The migration to partial online pedagogy entailed many challenges and setbacks but also brought some rewards. As mentioned before, TPL is a course unit in the Biomedical Engineering course at the University of Minho. This course unit is exclusively laboratorial, which in itself made the transition to blended learning here proposed even more challenging and which ended up being applied during the pandemic situation experienced recently.

This transformation endeavour was a tough and time-consuming task, requiring great flexibility and availability of the teaching staff and therefore a great and well-coordinated teamwork. The videos had to be prepared in advance to be timely provided to the students in order to give them the possibility to clarify any doubt in the synchronous classes scheduled for this purpose. Moreover, these videos aimed to familiarize and prepare students for the work to be carried out in the lab environment. Since each student only attended two in-lab classes due to the pandemic constraints and, therefore, operated two of the five proposed works, these videos acquired special importance since they allowed students had a closer and informative view about the installations and operating modes of the laboratory works not carried out by themselves. These videos and all the TPL supporting documents were published on the e-learning platform Blackboard, a digital space aimed at the University of Minho's students, providing them with access to the contents of their course units. It must be also stressed that students were also notified by email whenever any information or class support document is posted.

One of the hurdles of this reformulation was the high number of students enrolled in the course unit (seventy-three), which reduced the possibility of a more active and personal learning and teaching dynamics. The class size and the safety rules imposed by the Covid-19 pandemic also impaired students' attendance to all the face-to-face classes (in the rotating system) and consequently the continuous contact with the laboratory facility and the laboratorial modules of all the works programmed in TPL. Although it was mandatory for the entire group to elaborate the mini-report regardless of the student who performed the work in the laboratory, it was difficult to scrutinize whether the mini-repots resulted from teamwork, involving the participation of all the elements, in a cooperative effort, or individually work. However, this is a doubt that occurs in any work performed in group and not directly related to the fact that only two students in the group have attended each practical class. Even so, it is credible to assume that, for most groups, intra-group work management has been done according to the practical work performed. This meant that the two students that carried out the practical work were the ones designated by the whole group to elaborate the correspondent mini-report. This setback could have been partially solved through intragroup evaluation, aspect not taken into consideration when preparing the evaluation methodology for this course. However, to be reliable, students would have to make it seriously and conscientiously. The number of students in each shift also made difficult to reliably define the individual evaluation of each student since the majority of the evaluation components were accomplished in group. The most trustworthy individual assessment components were obtained in face-face classes such as the final written evaluation test and the teachers' appreciation on the participation, interest and performance of the work done by the students in the in-lab classes. This last aspect was facilitated by the small number of students present in each in-lab class. Although not foreseen, as it was dictated by the pandemia crisis, the reduced number of students in each in-lab class also allowed for a closer and, therefore, more profitable and constructive interaction between students and teachers. This close teacher-student relationship also increased the assumption of responsibility of each student in carrying out the work since, at that moment in the class, he was fully responsible for the good laboratory performance and the experimental data his group would obtain. These findings emphasised the importance of the balanced number of students in each class for the success of teaching-learning strategies.

Another setback of this mode of learning is related with the quizzes launched along the semester. These quizzes were created aiming to allow teachers and students to make a diagnosis of the previous and acquired knowledge by students. However, as they were on-line carried out, it was very easy for students to share answers knowing there's nobody is watching and, thus, biased the final scores.

Despite the challenges and setbacks previously mentioned, this blended teaching/learning practice also had some rewards. The positive feedback acknowledged by students and the good marks attained by them, as well as the fulfilment of the TPL program and the achievement of the proposed objectives were some of them. From the teachers' point of view, this transformation effort in engineering education allowed teaching staff to apply and thus learn more about blended learning practice. This knowledge and acquired experience will for sure assist teachers in new challenges of transformation of other curricular units the teacher staff will embrace for.

4 Study design and data collection

Regarding students, a survey, filled at the end of the module of TPL, was the method used to explore, gather, process and evaluate the student's opinions about the reformulation of this module of the TPL classes. This survey was a valuable source of feedbacks for teachers and self-reflection for students and will support the planning of future classes and improve the teaching and learning methods. Students were asked to complete a questionnaire whose questions are presented in Table 1. Of the seventy-three students enrolled in this course unit, thirty-five responded to the proposed survey, corresponding to approximately 50% of the students. Students' participation was voluntary and anonymous.

Table 1- Survey questions asked to students at the end of the module.

Survey questions
1- In general, in this contingency situation, how do you evaluate the organization of TPL classes?
2- The previous availability of the teaching materials (videos, manuals and protocols) was relevant and useful for the programming of group work?
3- From the pedagogical materials available (videos, protocols, course unit manual), which one (s) was (were) the most relevant and useful for the preparation and programming of the works and understanding of the objectives of the experimental activities?
4- The feedback that the teachers communicated in each class regarding the work done in the previous class was useful and relevant for the following works?
5- Did the elaboration of the mini-reports contribute to the understanding of the theoretical foundations underlying each work and to the achievement of the learning objectives?
6- Indicate suggestions for improving the functioning and teaching / learning of this course unit.
7- Indicate the least successful aspects in the functioning of this course unit.
8- Give general feedback on LFTM.

5 Results and Discussion

The responses to the questionnaire were on a five-point rating scale from (1) through (5). In the first question 1 corresponds to "bad" and 5 to "excellent", and in the other questions 1 corresponds to "No" and 5 to "Fundamental".

Considering question 1, none of the students considered that the classes were poorly organized and most students think that the classes were well organized, with around 17% even considering the organization of the classes excellent.

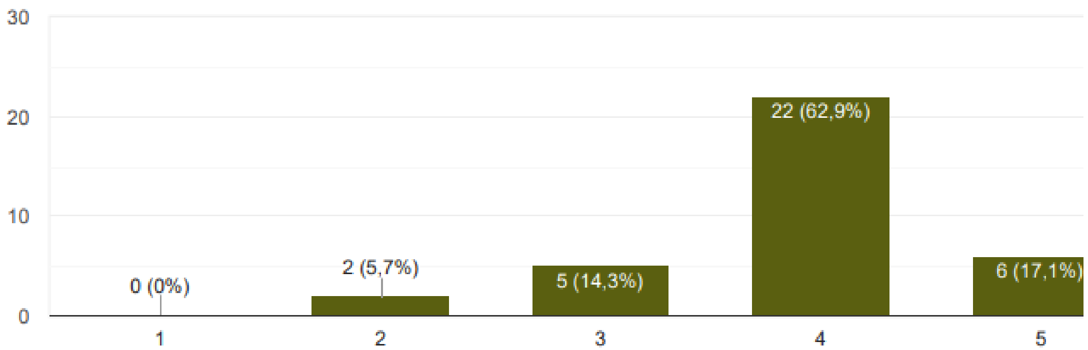

Figure 1 – Student's responses to the question evaluating the organization of the classes.

When asked about the offer and the usefulness of the previous availability of the pedagogical materials (videos, manuals and protocols) for the programming and management of the group work (Question 2), only two students considered that the availability of the supporting material was not relevant and useful for the organization of the teamwork. On the other hand, 60% of the responding students considered as fundamental the provided pedagogical materials (Figure 2).

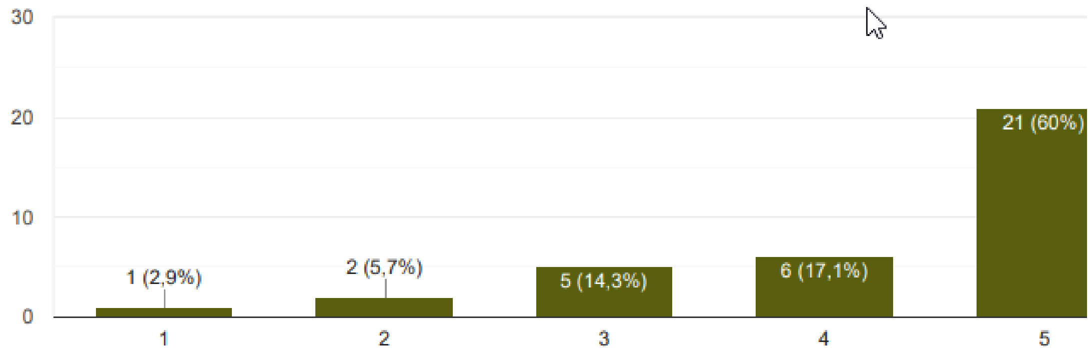

Figure 2 – Student's responses to the question evaluating the utility of the availability of teaching material (videos, manuals and protocols) for the programming of group work.

More than 50% of the students who answered the third question mentioned that both protocols and videos were the most relevant and useful materials to the preparation, programming and understanding of the laboratory modules proposed in TPL. About 25% of answers were attributed to protocols or to videos individually.

Regarding the question about whether the feedback that the teachers communicated in each class regarding the work done in the previous in-lab class was useful and relevant for the following works (question 4), only two students considered as non-fundamental. About 47% of the respondent students recognized teachers' feedback on mini-reports extremely important and crucial for the following works (Figure 3).

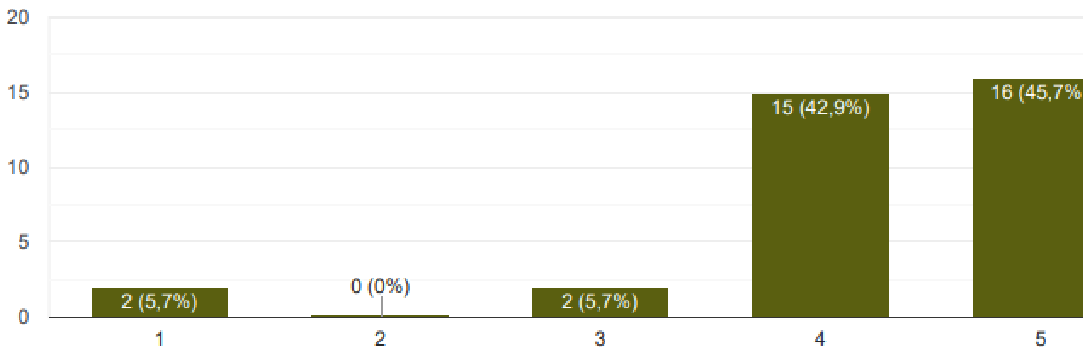

Figure 3 - Student's responses to the question evaluating the feedback given by the teachers about the previous work.

To question 5, "Did the elaboration of the mini-reports contribute to the understanding of the theoretical fundamentals underlying each work and to the achievement of the learning objectives", all students considered the elaboration of the mini-reports relevant to TPL classes/works comprehension and to consolidate previous knowledge and to, consequently, attain the learning objectives, of which 31.4% answered 5 (extremely fundamental) (Figure 4).

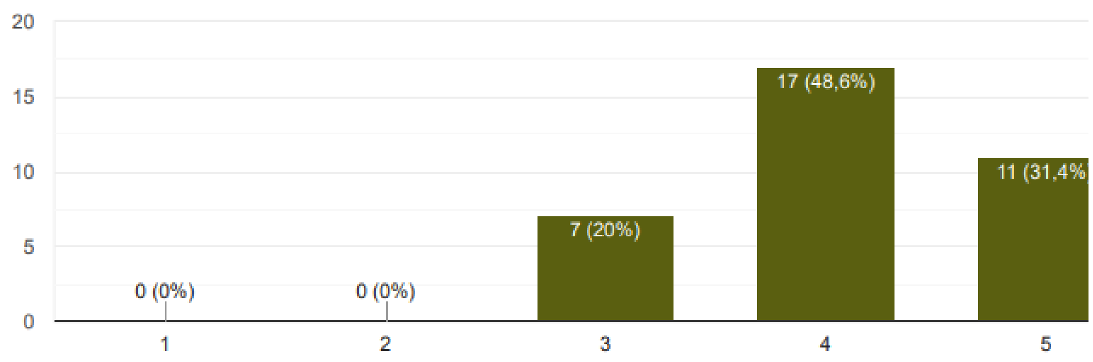

Figure 4 - Student's responses to the question evaluating the utility of the elaboration of mini-reports.

For improving the functioning and teaching/learning practices of this course unit, several relevant suggestions were given by the students, namely: intragroup evaluation; the communication of grades along the semester and not just at the end for students to be aware of their evolution throughout the course; more lab shifts (if possible) and launching quizzes before each laboratorial activity. These suggestions seem to be a sign of students' growing willingness to be involved in the TPL learning outcomes.

Regarding the less well achieved aspects in the functioning of this laboratory course unit, fourteen students gave their personal opinion. The mainly observations are related with the non-communication of quantitative grades during the performance of the different evaluation components, reinforcing the need of intragroup evaluation. They also pointed the various sections of the mini-reports as too extensive, and, in their opinion, the final written evaluation was needless.

In turn, thirteen students expressed their general feedback on TPL classes highlighting the following positive aspects: the availability of the teaching staff; the good organization and support of the laboratorial activities, the stimulus for the discussion and practical analysis of the contents of the theoretical classes (heat and mass transfer phenomena) underlying this course unit, being reported as an excellent complement to this; and the constant development of knowledge throughout the progress of the lab works included in this course unit. Aligned to the least successful aspects previously mentioned, as negative feedback, students highlight the excessive work involved in this course unit and, once again, the non-need of the written test; the need for more face-to-face in-lab classes, although they aware that this event was due to the restrictions inherent to the current pandemic situation. In general, the respondents considered that TPL classes "went well".

6 Conclusion

The TPL pre-programmed reformulation and coincidentally the challenging time resulting from the covid-19 pandemic obliged to a sudden transition, partial or total, to online pedagogy education and to a different teaching and learning dynamics. This task, although hard and time consuming, inherent to any course transformation and more challenging and exhaustive due to the Covid-19 situation, was considered successful. Despite the challenges and setbacks, inherent to the program and objectives of a laboratory course in engineering, the goal of transformation of TPL has been fulfilled and, in general, the students involved in this new blended learning practice acknowledge as very positive this endeavour.

Suggestions and recommendations are mentioned in this paper aiming at a broader applicability in related course units and demonstrating the effectiveness and success of the blended learning tools in the complement of the traditional face-to-face learning. In addition, teachers felt that this transformation endeavour provided them with knowledge, experience and new learning skills that will help, not only to consolidate the TPL transformation, refining the less well achieved aspects, but also to have the willingness to expand and strengthen those competences in the transformation of other curricular units.

7 References

Artdej, R. (2012). Investigating Undergraduate Students' Scientific Understanding of Laboratory Safety, Procedia - Social and Behavioral Sciences, 46, 5058-5062.

Benn A. (2019) Pedagogic Practice in Blended-Learning. In: Cheung S., Lee LK., Simonova I., Kozel T., Kwok LF. (eds) Blended Learning: Educational Innovation for Personalized Learning. ICBL 2019. *Lecture Notes in Computer Science*, vol 11546. Springer, Cham. https://doi.org/10.1007/978-3-030-21562-0_1

Chittleborough, G. , Mocerino, M., Treagust, D. (2007). Achieving Greater Feedback and Flexibility Using Online Pre-Laboratory Exercises with Non-Major Chemistry Students. *Journal of Chemical Education*, 84(5), 884-888.

Di Trapani, G. , Gregory, (2009). Laboratory practical experience: an innovative and distinctive approach to student learning. Proceedings of the Motivating Science Undergraduates: Ideas and Intervention

Jain, S., Lall, M., & Singh, A. (2021). Teachers' voices on the impact of COVID-19 on school education: Are ed-tech companies really the panacea? *Contemporary Education Dialogue*, *18*(1), 58-59. https://doi.org/10.1177/0973184920976433

Jones, A., Edwards, S. (2010). Online pre-laboratory exercises enhance student preparedness for first year biology practical classes. *Computer Science*, 18(2), 1-9.

Karp, P., & McGowan, M. (2020). Clear as mud': Schools ask for online learning help as coronavirus policy confusion persists. *The Guardian*, 261–307.

Lockee, B. Online education in the post-COVID era. Nature Electronics, 4, 5-6. https://doi.org/10.1038/s41928-020-00534-

National Research Council. 1997. Science Teaching Reconsidered: A Handbook. Washington, DC: The National Academies Press. https://doi.org/10.17226/5287.Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-Based Learning in Post-Secondary Education - Theory, Practice and Rubber Sling Shots. Higher Education, 51(2), 287-314.

Oyedotun, T. (2020). Sudden change of pedagogy in education driven by COVID-19: Perspectives and evaluation from a developing country. *Research in Globalization*, *2*, 100029. https://doi.org/10.1016/j.resglo.2020.100029

Patterson, D. (2011). Impact of a multimedia laboratory manual: Investigating the influence of student learning styles on laboratory preparation and performance over one semester. *Education for Chemichal Engineers*, 6, e10-e30.

UNESCO. (2020). COVID-19 Educational Disruption and Response. https://en.unesco.org/covid19/educationresponse/.