Journal of Engineering Education Transformations ,
Volume 36 , No. 4 , April 2023 , ISSN 2349-2473, eISSN 2394-1707

10.16920/jeet/2023/v36i4/23126

Online learning environments for the promotion of undergraduate research in pandemic times: A case study in an engineering program

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Abstract : This case study explores the use of online learning environments as an alternative tool for the promotion of undergraduate research culture within an engineering program during the COVID-19 pandemic times. This context entailed the transition from face-to-face to online learning environments, which was taken as an opportunity for the diffusion and socialization of outstanding research projects developed by undergraduate students within the classroom, through the launching of an online event and a virtual permanent exhibition. The results of this case study were measured through quantitative indicators related to the number of research projects submitted by the students for participating in this exhibition, the number of courses participating through these projects, and the number of professors involved. Participation of students and professors increased by 85% and 90%, respectively, comparing the online environment to the previous face-to-face one. Consequently, it was concluded that the use of online learning environments supports the promotion of undergraduate research culture, by increasing the interest of students for the socialization of their research results.

Keywords: Engineering education; Lifelong learning; Online learning environments; Research competencies; Research culture; COVID-19.

1. Introduction

Currently, training processes within higher education institutions are centered on the development of competencies through competency-based curricula, as they prepare students to live under variable circumstances while building knowledge and easily adapting to changes of the professional and personal environment (Ruiz 2009). Moreover, competency-based curricula focus on integral performances, while developing learning strategies such as self-regulation, autonomy, leadership, teamwork, problem solving, critical thinking, among others (Tobón 2013). In this context, educational tendencies distinguish among two main types that must be addressed in this level: generic and specific (Tobón 2013; Proyecto Alfa Tuning 2013). Among generic competencies, which are the most highly demanded by organizations since they permit greater adaptability to change and a better predisposition for lifelong learning (LL) (Del Savio et al. 2022) and

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professional development (Waite and Davis 2006; Tobón, 2017; Yarullin et al. 2015; Knight and Novoselich 2017), research competencies need to be emphasized, as they encourage "learning to learn" allowing knowledge building, which means that they support the development of autonomy in learning (González et al. 2004; Ro et al. 2015). This has led to their integration, throughout the curriculum, as part of the training process of professionals of different fields (Stanford et al. 2015; John and Creighton 2011; Wiedenbeck and Scholtz 1995).

In 2020, the transition to online learning environments, because of the global health emergency due to the COVID-19 pandemic, led to challenges, and learning has yet to be aliened to this situation. Face-to-face events for the diffusion of research projects were postponed or cancelled. This case study describes the transition of an academic face-to-face event to promote undergraduate research culture to an online learning environment during the pandemic. The event, which in its beginnings was held on the campus of a university, found itself faced with the dare of adapting.

This research shows a case study within an undergraduate engineering program that deals with this challenge as an opportunity to improve the indicators related to the assessment of a research competencies program (Del Savio et al. 2021), which ultimately focuses on promoting undergraduate research culture. In this sense, it was expected that the transition of the face-to-face event, called Research Expo, to an online learning environment would increase the participation of students and professors, promoting undergraduate research culture among both.

To this day, the literature focuses on how online environments can strengthen collaborative learning (Vartiainen et al. 2020), ultimately leading to its improvement (Lacka and Wong 2019; Al-rahmil et al. 2015). However, even though it states the benefits of developing undergraduate research in various disciplines (Stanford et al. 2015; Ishiyama 2002; Lopatto 2004), there are no reports that relate the contribution of online learning environments to the promotion of undergraduate research culture. Similarly, there is a gap regarding these environments and the acquisition and reinforcement of research competencies through accurate pedagogical design, social activities, and technology (Kang and Zhang, 2020). Furthermore, it is suggested that there is scope for developing innovative student research projects to engage undergraduates in research actively (Vereijken et al. 2018).

Therefore, this study focuses on using an online environment to motivate and involve digital natives, whose population this case study belongs to, in undergraduate research, consequently leading to the promotion of undergraduate research culture. Furthermore, online environments allow for increasing the visibility of undergraduate research projects. The following question is proposed: How to promote undergraduate research culture to increase students' interest in the socialization of their research projects?

2. Conceptual Frameworks

The case study method has been used in various contexts to observe and analyze the nexus between teaching and research processes, fundamental pillars in contemporary higher education (Hattie and Marsh 2004). This method has been used for two main aspects: assessment techniques and instruments to verify the validity of proposed concepts; and in field studies, to assess students' performance in specific scenarios (Ambrosini and Bowman 2010; Booth et al. 2000; Healey 2005; Mesny 2013).

In a parallel scenario, there are still unanalyzed gaps in the relationship between the integration of the teaching-learning processes and research culture within the undergraduate curriculum and its evolution. Even though the integration of teaching processes and research is an issue within contemporary higher education, authors report difficulty establishing a direct relationship between them, given the wide range of contexts that correspond to undergraduate programs (Geschwing and Brostrom 2015). In contrast, the literature reports evidence about establishing connections between learning processes and research culture (Wilson et al. 2017).

Within this frame of reference, this case study looks forward to filling in the blanks about the interaction between the teaching-learning processes and undergraduate research culture using online environments to strengthen this interaction. Research culture can be defined as an environment of interpersonal encouragement and collaboration, where colleagues demonstrate shared affinity about the value of research (Hesli and Lee 2011). Research

culture can be, therefore, equally promoted among students and professors.

In this context, the undergraduate engineering program to which this case study belongs is focused on blurring the boundaries between the teaching-learning processes and research. To achieve this goal, gradual synergy is established between the curricular contents and research training exercises, which results in the development and reinforcement of research competencies in students. This synergy encourages professor-researchers to make the most of the curricular content and promote research among their students. As a result, academic productivity is benefited and the institutional performance indicators are bolstered (Jenkins and Healey 2004; Jenkins et al. 2007; Thornton et al. 2018).

Within this framework, undergraduate research experiences embedded throughout the curriculum have been proven to be a convenient tool for the successful conduction of the teaching-learning processes since they encourage knowledge construction. Undergraduate research, understood as the type of research that is guided by professors as part of their teaching role and where research agents are active subjects in training (Walther et al. 2011), allows students to be engaged with the content, processes, challenges, and problems of their discipline (Healey 2005). Consequently, students become involved with high-impact experiential learning, enriching undergraduate research educationally (Zimbardi and Myatt 2014). This is the first step to enable future autonomous learning in students, which leads to lifelong learning (LL) (Tobón 2013).

Specifically, undergraduate research involves several activities that students must perform such as conducting observations, proposing questions, examining information sources, planning, using, and developing tools for data collection, analysing and interpreting data, discussing and socializing results (González, Galindo, Galindo and Gold 2004).

In a parallel scenario, Information and Communications Technologies (ICT) are a fundamental pillar within the higher education student experience, since the new generation of higher education students are digital natives, which means that it is innate for them to communicate using technologies. In fact, ICT are related to the success of the teaching-learning processes including benefits such as flexibility (Smedley, 2010), interactivity (Leszczyński et al. 2018; Wagner et al. 2008), personalization of the learning processes (Amer 2007) and easier access and share of the information (Jones et al. 2005). Furthermore, online learning environments have been proven to have a positive impact on learning behavior, which is related to learning cognition (Zhu et al 2022). An online, or virtual, learning environment can be defined as an electronically designed scenario which supports the teaching-learning processes (UNESCO, 2023). ICT, and specifically online learning environments, are an integral component of the learning experiences, so they must be considered for the teaching process (Henderson et al. 2015).

As a matter of fact, several design models are currently available to help professors integrate ICT into the curriculum. Every model must consider three (3) elements: pedagogy, social interaction, and technology, as every educational system combines these (Kirschner et al. 2004). The first one refers to the teaching and learning strategies and should involve using resources and activities to support knowledge construction (Chen 2003); the second one is centered in the design of learning environments that provide a comfortable space so that learners are willing to share information with others; and the third one focuses on the availability and easy access as requirements for the success of the learning processes (Wang 2008).

To the date of this study, there are few reports on how technology, such as an online learning environment, can promote research culture within undergraduate students. Literature focuses on how technological tools strengthen collaborative work, which ultimately leads to the improvement of learning processes (Lacka and Wong 2019; Al-rahmil, Othman, Yusof and Musa 2015). Therefore, this study focuses on using an online learning environment to increase the visibility of undergraduate research projects, motivate, involve, and generate impact among digital natives, whose population this case study belongs to, and, consequently, stimulate undergraduate research culture.

3. Materials And Methods

3.1. Context

The study was carried out within an engineering program of a Peruvian higher education institution. Among the didactical tools used to promote undergraduate research culture, this program

organizes Research Expo, a semi-annual event meant for the diffusion and socialization of the best research projects developed by the students within the classrooms. The projects are addressed as research exercises, in teams of two to five students, throughout the curriculum and the five-year training process. Research Expo is an event to display the final results of these exercises, which are held throughout the different courses.

To the date of this study, Research Expo has had four editions. The first one was held during 2018, while the second and third in 2019. All of them were developed in a traditional face-to-face format in the university facilities, which this case study belongs to. D uring 2020, a single edition of Research Expo was conducted virtually using an online environment (https://www.expocicul.com/). The event was redesigned and, with the aim of motivating competitiveness between students, an additional innovation was implemented: Research Expo was launched, for the first time, as a voluntary academic contest.

3.2. Purpose of the study

The purpose of this case study is to show that using an online environment is an alternative tool for the promotion of undergraduate research culture. This objective was addressed measuring the participation of

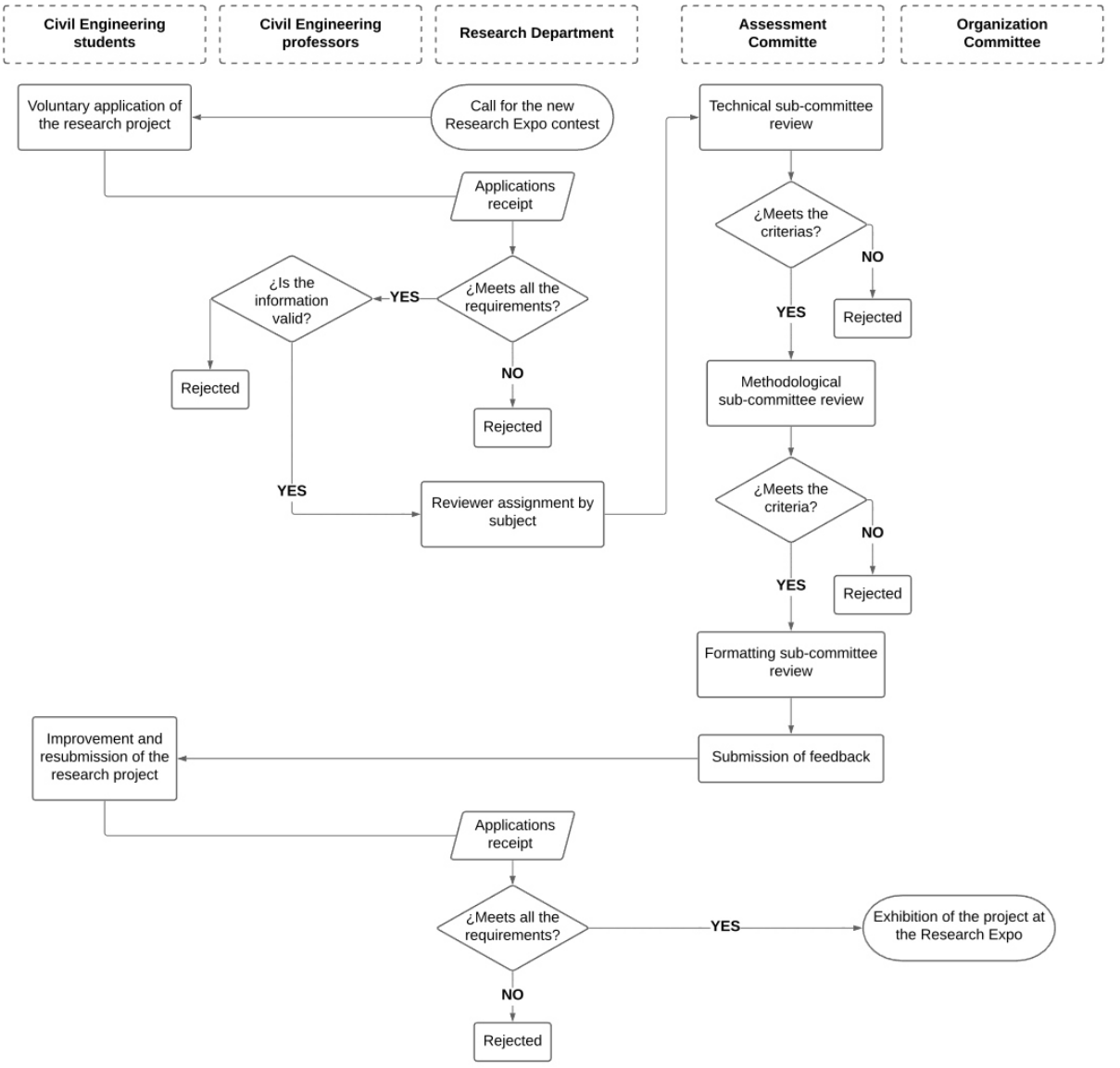

Fig. 1 : Workflow for selecting projects at the Research Expo.

students and professors in Research Expo. This can is considered an indicator of their interest for the socialization of research projects.

Once reckoning the opportunity that the transition from a face-to-face to an online environment represented, an entirely new workflow for Research Expo was developed. This workflow is used for the assessment, selection, and organization of the projects to exhibit at Research Expo. As shown in Fig. 1, it includes different stages, which involve the active engagement of the engineering program community: students, professors, Research Department, Assessment Committee and Organization Committee.

New strategies for the selection and the assessment of the research projects involved in the process were designed, according to the new needs produced by the virtual context, and taking into consideration the improvement opportunities identified, after the feedback provided by students and professors.

Moreover, to familiarize students with the dynamics involved in the publication of scientific papers and, in that way, reinforce undergraduate research culture, the Assessment Committee was reorganized, to make the selection process more rigorous and structured, like a double-blind peer review process. Three sub-committees were distinguished to address different issues regarding the research projects: Technical, Methodological and Formatting. These were the ones who helped throughout the assessment and selection processes, which determined what projects were suitable to be exhibited.

3.3. Universe and sample

This case study was carried out in an engineering program at a Peruvian higher education institution. Students are enrolled in different years of the program, while professors, are in different courses regarding several engineering knowledge areas. This favored the heterogeneity of the sample, which supports the results' validity. The engineering program has more than 638 students, divided according to the curriculum, into five years of studies. The staff of professors is made up of 33 people, including full and part time professors, and teaching assistants. As for the sample, 21 professors and 208 students, who participated throughout 52 different research projects, were involved.

Note that students from the second to the fifth year of the curriculum can apply for Research Expo, as they take part in the research competencies program. In the first year of studies, engineering students share courses with students from other professional programs, hence the mentioned program is not applied. Additionally, it must be emphasized that the scope of the research projects varies, according to the year of the curriculum in which the students are. Therefore, second-year students develop exploratory research; third-year, descriptive; and fourth and fifth, explanatory (Del Savio et al. 2021).

Regarding the timing, the implementation of the new format of Research Expo was conducted from April until November of 2020. The involvement in this case study was voluntary, for both students and professors. Even though the research projects are developed within the courses of the engineering program, as part of the contents addressed throughout the curriculum, participating in Research Expo meant dedicating extra time to perform the different tasks involved in the process previously described.

3.4. Data collection techniques and instruments

To measure the promotion of undergraduate research culture using an online learning environment, representative indicators were identified. A raise in their numerical values was expected, and this increase was sought to indicate the progress in the promotion of undergraduate research culture, which includes students' increasing interest for the socialization of research projects. Below, Table 1 addresses the main indicators chosen, as well as their description.

As for the selection of the addressed indicators, among students, their participation in research is a key factor to measure their perception about it, as participation relates directly with motivation for research (Vereijken et al. 2018). A positive perception

Table 1. : Workflow For The Selection of the Projects To Exhibit At The Research Expo

Indicator	Explanation
Courses	Number of courses participating with submitted research projects to Research Expo
Research projects	Number of research projects submitted to Research Expo
Advisor professors	Number of professors involved as advisors for the students
Assessment Committee	Number of professors involved asmembers of the Assessment Committee

helps with the improvement of the related learning outcomes which, in this case study, are research competencies. Moreover, motivation for research promotes positive student beliefs about its value, which is also related to student achievement (Breen and Lindsay, 1999). Finally, the involvement of professors in research is also important to support undergraduate research (Prosser and Trigwell, 2014). Therefore, it can be assumed that the selected indicators allow for measuring the promotion of undergraduate research.

Finally, the selected indicators were established in accordance with the institutional strategic plan of the university. In fact, one of its four main lines of action is Research, as its mission focuses on the development of high impact research, considering this a fundamental issue for university international world rankings (Deem et al. 2008). Furthermore, the institution's strategic objectives are strengthening research, producing relevant research, and communicating the research results. Therefore, one of the main indicators is the number of undergraduate students participating in research projects (Universidad de Lima, 2016).

4. Results And Discussion

The analysis of this case study shows that the use of online environments is an alternative tool for the promotion of undergraduate research culture, as it has helped increase students' interest in the socialization of their research projects. Indeed, it effectively combines the indispensable elements for ICT integration into the curriculum: pedagogy, social interaction, and technology (Kirschner et al. 2004), which results in a resourceful, comfortable, and accessible learning environment (Wang 2008). Moreover, it is an innovative tool for actively engaging undergraduates in research (Vereijken et al. 2018). Furthermore, online environments seek to mitigate two major challenges of promoting research culture online: the involvement of the professor staff within it and the lack of incentives among students to participate.

To measure and quantify the previous statement, the values obtained for the proposed indicators are shown in Table 2. Their fluctuation over the four editions is revealed in Fig. 2 and discussed below. The virtual proposal of the Research Expo has had a major welcome from the institutional community. The positively increasing trends revealed in Table 2 and Fig. 2 signify that Research Expo is contributing to the promotion of undergraduate research culture, as it is strengthening. It is expected that these trends will continue over the next few years.

Regarding the number of courses participating in submitted research projects to the Research Expo, Table 2 and Fig. 2 reveal that this number has increased by more than 170%. This translates into 12 additional courses participating in the 2020 edition of the Research Expo, comparing it to the previous one. This fact remarks three ideas: first, more professors have included the development of research projects as part of the methodological strategies applied for the teaching-learning processes within their courses (Falcone et al. 2019; Wilson et al. 2017). Second, students are more willing to participate in Research Expo as they are becoming aware of the importance that research has for their training process as engineers (Vereijken et al. 2018). Third, the virtual voluntary academic contest format stimulates competitiveness between students, which leads to higher levels of motivation and, as a result, a better quality is displayed in the research projects (Deem et al. 2008; Vereijken et al. 2020).

According to the number of courses participating with submitted research projects, the number of research projects submitted to Research Expo has also risen, as shown in Table 2 and Fig. 2. The number of submissions has grown more than 85%, which means 24 more research projects, comparing this last edition, in the new virtual format, with the two preceding ones, held in 2019 (Henderson et al. 2015; Wang 2008). As the research projects submitted result from teamwork, it can be concluded that more students are participating in this event.

Concerning this point, for this edition, students are the ones that have led the submission processes for their respective research projects. This activity was non-compulsory, and, despite this fact, students have

Table 2 : Growth For Research Expo Indicators Comparing the First Virtual With the Previous edition

Indicator	Value
Courses	171,43%
Research projects	85,71%
Advisor professors	90%
Assessment Committee	133,33%

demonstrated their interest and commitment to the entire submission process (Vereijken et al. 2018). This motivation for research shown by students is necessary to promote positive student beliefs about its value, related to student achievement (Breen and Lindsay 1999), in this case, development and reinforcement of research competencies.

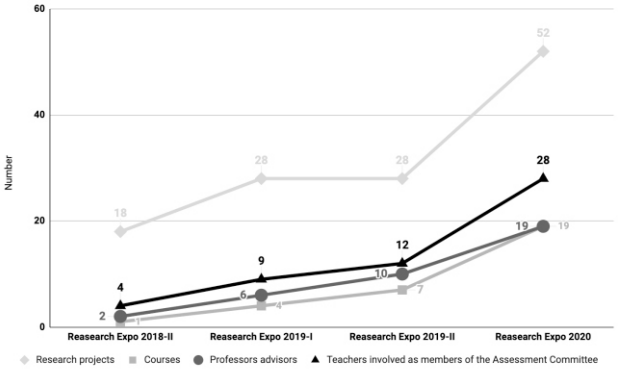

Fig. 2 : Values for Research Expo indicators over its four editions.

As for the professors involved as advisors for the students, Table 2 and Fig. 2 indicate that the number in the last edition has also increased by 90%, 9 more professors, comparing the 2020 edition to the ones held in 2019. This indicator directly correlates with the increment of the number of courses participating in submitted research projects. Furthermore, it must be noted that not only the professors are engaged with Research Expo, but also the teaching assistants, who formerly did not figure as an important resource for the successful conduction of these projects (Collins et al. 2021). As previously stated, the participation of professors in research projects is key to promoting student motivation (Prosser and Trigwell 2014).

About the professors involved as members of the Assessment Committee, the results reveal that this indicator has grown more than 130% in the 2020 edition, a satisfactory outcome compared to editions held in 2019, as shown in Table 2 and Fig. 2. This is translated into 16 new members of the Assessment Committee. The role of this Committee is relevant for the virtual and voluntary academic contest success, as it is expected to give guidance and orientation to the entire submission process carried out by the students (Prosser and Trigwell 2014; Vereijken et al. 2018). Its support through its members' tasks is key to assure scientific rigor, which is fundamental in developing and reinforcing research competencies (Khoukhi 2013).

Therefore, the four proposed indicators reveal that using an online environment is an effective tool to increase the interest of undergraduate students in the socialization of research results developed within the classroom context. This tool has positively incised in the promotion of undergraduate research culture.

5. Conclusions

Before drawing general conclusions, it is essential to acknowledge some limitations of this research. The observation period was rather short, as data collected corresponds to four editions of the Research Expo of which only the last one has had a virtual voluntary academic contest format. More information will be gathered with future editions, and trends detected are expected to continue. Further research about possible upgrades for the event is the motive for future reflections. Additionally, the authors have participated as part of the Organization Committee, turning them into observers of this study and guaranteeing the objectivity of the analysis and interpretation of the obtained results.

As for the results, the proposed indicators have shown major improvements. In this sense, the specific contextual factors of the global health emergency, which were originally seen as a problem, were rather taken as an opportunity for continuous improvement. Hence, it was possible to carry out the Research Expo with the support of technology, and, as expected, the event's transition to an online environment increased the voluntary participation of students and professors by 85% and 90%, respectively, consequently supporting the promotion of undergraduate research. This also reveals that the virtualization proposal has had a major welcome from the institutional community.

Consequently, it was concluded that the use of online learning environments is an alternative tool for promoting undergraduate research culture among professors and students. For future works, a qualitative and quantitative approach will be addressed in the following phases of the research. Data gathered from instruments such as interviews and surveys should be used to support the findings.

As for the Research Expo, the new format is expected to become a seedbed for research products within the engineering program, such as Thesis. It is contemplated that they will involve students and professors working collaboratively. Moreover, with

the aim of improving results and strengthening the research competencies program, the following activities are proposed: accompaniment and advice to students for job applications to academic events; development of research competencies that allow students to obtain their engineering degree under the modality of publication of scientific papers in indexed journals; digital monitoring of the results of the mentioned program; documentary record of the process of developing, improving and strengthening research competencies in the students of the engineering program; mapping possible research project development opportunities by areas; accompaniment to professor-researchers; diffusion through social media for the participation in initiatives to promote research culture; and strengthening motivation in students throughout the recognition and visibility guaranteed by the Research Expo.

The following three recommendations can be made from the findings to promote undergraduate research culture. Regarding institutional policy, universities should try to implement research initiatives with the support of online learning environments; regarding research, future works may explore the use of additional online learning environments different from the ones mentioned in this paper and their impact on undergraduate research culture; finally, concerning practice, the use of online learning environments requires the commitment and support of the entire academic staff.

Acknowledgment

Use the singular heading even if you have many acknowledgments. Leave this section as is for the double-blind review process.

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