Blended learning in the engineering field: A systematic literature review

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Blended learning in the engineering field: A systematic literature review

Roberto Sala[1] | **Antonio Maffei**[2] | **Fabiana Pirola**[1] | **Fredrik Enoksson**[2] | **Sandi Ljubić**[3] | **Arian Skoki**[3] | **Joseph P. Zammit**[4] | **Amberlynn Bonello**[4] | **Primož Podržaj**[5] | **Tena Žužek**[5] | **Paolo C. Priarone**[6] | **Dario Antonelli**[6] | **Giuditta Pezzotta**[1]

[1]Department of Management, Information and Production Engineering, University of Bergamo, Dalmine, Italy

[2]Department of Production Engineering, KTH Royal Institute of Technology, Stockholm, Sweden

[3]University of Rijeka, Faculty of Engineering, Department of Computer Engineering, Rijeka, Croatia

[4]CERU, Department of Industrial and Manufacturing Engineering, University of Malta, Msida, Malta

[5]Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia

[6]Department of Management and Production Engineering, Politecnico di Torino, Torino, Italy

Correspondence
Roberto Sala, Department of Management, Information and Production Engineering, University of Bergamo, Viale Marconi, 5, Dalmine (BG), 24044, Italy.
Email: roberto.sala@unibg.it

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Abstract

Blended Learning (BL) is defined as a combination of face-to-face and digital activities that, in recent years, has been adopted more and more frequently by Higher Educational Institutions (HEIs). In the engineering field, the adoption of BL allows creating challenging situations for students with industry-like problems to foster the acquisition of advanced problem-solving skills. Thus, it can be used to enhance traditional learning by enriching it with new aspects, allowing to update the Intended Learning Outcomes traditionally defined by teachers. Although prior coronavirus disease 2019 (COVID-19) teachers had the time to prepare and programme the transition to BL, during the pandemic they had to abruptly move to the full digital delivery of the content, requiring technological and organizational adaptation, as well as change in the content teaching and assessment methods. Through a systematic literature review, this paper aims to understand how BL has been implemented in the engineering field by HEIs, discussing if and how the learning expectations of teachers (evaluated through Bloom's Taxonomy) change when using different mixes of face-to-face and digital activities and when the target audience changes. More specifically, the investigation addresses how content and learning expectations are split and set in face-to-face and digital settings. Additionally, the interest is towards understanding how COVID-19 impacted the adoption of BL, not only during the pandemic but also after.

KEYWORDS
blended learning, Bloom's taxonomy, constructive alignment, COVID-19, Engineering

1 | INTRODUCTION

Higher Educational Institutions (HEIs) are expected to give their students the competencies, skills and knowledge to address the new problems raised in the current always-changing industrial environment, allowing them to adapt to the new problems and necessities that industries must face to remain competitive. It is difficult to tackle the challenges of modern HE through traditional pedagogy: i.e., approaches still anchored to teacher-centred methodologies and that do not exploit new technologies to support the learning experience [108]. The modern student-centred pedagogy and the introduction of digital technology in engineering education can leverage active learning and consequently increase the effectiveness and efficiency of the learning processes [3].

Modern pedagogy has moved away from the transmissive approach and embraced constructivism as a prominent approach to learner-centred education. In this context, the notion of Blended Learning (BL), as combination face-to-face and digital activities emerged in the late 1990s when personal computers entered the classroom. However, as Hrastinski [49] pointed out the related body of literature is scattered and diverging: a unified definition is still elusive. In addition to that, the current available classification are based on the mechanisms of integration of the digital technology (what is BL? and how can we implement it?) rather than on the role they have in the achievement of the learning outcome (what are BL specific embodiments good for?). This has so far hindered a systematic incremental contribution to the knowledge in the discipline [77].

Two of the most cited and established definitions are suggested by [38, 40]. Graham gives the definition 'BL systems combine face-to-face instruction with computer-mediated instruction', [40] whereas [38] defines it as 'the thoughtful integration of classroom face-to-face learning experiences with online learning experiences'. Although Graham's definition [40] focus on instructions, Garrison and Kanuka [38] instead use the wider term learning experiences. In addition to that, Garrison and Kanuka [38] hints also at the quality aspect by including the expression thoughtful integration. This means that the aforementioned integration should be aimed at, among other things: increasing teaching and learning effectiveness by enabling a wider spectrum of learning experiences and educational opportunities, as well as making course communication and management more efficient.

The adoption of BL strategies has always been regarded as a critical upgrade of education, and during the recent coronavirus disease 2019 (COVID-19) pandemic its relevance has been highlighted as fundamental to ensure residence of the educational offer. When the virus hit our society, the courses that had been designed with a thoughtful integration of face-to-face and online experiences often proved more resilient to the required changes: those courses did not have to resort to Emergency Remote Teaching [48]. The COVID-19 experience has been an unwanted, yet useful stress test for the HE systems: in this sense it forced HEI to experiment with on-line learning. The notable report on the impact of COVID-19 on engineering education by Graham [41] has identified a set of perceived benefits and drawbacks of online and BL. The result is based on a large number of interviews of people at Higher Education institutions across the world with a focus on in Engineering Education. The outstanding conclusions of the report is that 'the online pivot both validated the benefits of BL and enabled its acceptance across the academic community'. The main future drivers found in the report, is the possibility to emphasize authentic and collaborative learning on campus, based on well-crafted learning resources available online. Finally, the report also indicates that students now are more vocal about wanting the teachers to use online learning to a larger extent.

Summarizing, the thoughtful digitalization of learning, coupled with modern outcome-based and student-centred pedagogy, is the key to a successful future for higher education. This paper aims at investigating how BL strategies have been utilized in engineering courses before and during the pandemic. In addition to that, this analysis is set to contribute to identify and classify the BL example according to their respective learning outcome. The following Section 2 contextualizes the research providing an overview of the literature on the topic.

2 | LITERATURE CONTEXT

Modern pedagogical research in the domain of BL builds upon constructivist theory of learning: that is, through reflection and subsequent abstraction of fundamental principles, individuals construct knowledge from their experiences. The acquisition of new knowledge involves two processes: assimilation and accommodation. Assimilation entails integrating new knowledge into pre-existing frameworks, which can potentially lead to misconceptions when individuals attempt to fit new concepts into inadequate pre-existing knowledge. On the other hand, accommodation involves reframing pre-existing knowledge based on new information, allowing for a more accurate understanding of the subject matter [81]. Consequently, the learning process relies not only on the words spoken by teachers but mainly on the actions taken by students. In contrast to traditional transmissive pedagogy, the key focus of an efficient and effective pedagogy should be on the learner's evolving perception rather than on the teacher's activities. Therefore, the fundamental role of the teacher is to facilitate the proper evolution of the student's understanding and perception of the subject matter.

Building upon the constructivist theory of learning, John Biggs proposed Constructive Alignment (CA) as an approach to design educational units. [11]. In detail, CA aims at delivering a learning experience that activate the constructivist understanding of the learning process and it is based on the principle of an aligned and outcome-based curricula design [11]. The salient aspects of the CA have been recently extracted and classified in a comprehensive taxonomy, called the Constructive Alignment (CONALI) ontology [69]. In Practice, implementing CA means devising Intended Learning Outcomes (ILOs) featuring a specific expected action of the learner that is described through an Educational Goal Verb (EGV). That is, the EGV refers to the action the learners are expected to learn after completion of the educational unit. The ILO, and related EGV, are then enacted through Teaching and Learning Activities (TLAs) and verified through Assessment Tasks (ATs). The alignment between ILOs, TLAs and ATs is achieved by using the same action, that is, EGV [67, 68].

The central role of the EGV in this pedagogical approach, reflects the focus on the students' actions and, in turn, to the level of knowledge and skills they acquire. The EGV can be classified according to these levels using the fundamental modified Bloom Taxonomy [5]. In this conceptualization, six different, increasingly sophisticated, levels of understanding are identified. Each level is then populated with a set of verbs that represents the associated learning actions. In detail:

- Level 1: Remembering (recall and recognition) verbs: Define, duplicate, list, memorize, repeat, state. Description: At this level, learners recall and recognize information without necessarily understanding its meaning. They can define terms, reproduce facts, or list items from memory.
- Level 2: Understanding (comprehension) verbs: Classify, describe, discuss, explain, identify, locate, recognize, report, select, translate. Description: Learners grasp the meaning of information and can explain it in their own words. They are able to classify, describe, or identify concepts and ideas.
- Level 3: Applying (application) verbs: Execute, implement, solve, use, demonstrate, interpret, operate, schedule, sketch. Description: At this level, learners use their acquired knowledge to solve problems or apply concepts in real-world situations. They can demonstrate skills and implement solutions.
- Level 4: Analysing (analysis) verbs: Differentiate, organize, relate, compare, contrast, distinguish, examine, experiment, question, test. Description: Learners break down information into its components, identify patterns and make connections. They can analyse and evaluate relationships between different elements.
- Level 5: Evaluating (evaluation) verbs: Appraise, argue, defend, judge, select, support, value, critique, weigh. Description: At this level, learners make judgments about the value, validity, or quality of information. They can argue a point of view, support their opinions and critically assess ideas.
- Level 6: Creating (synthesis) verbs: Design, assemble, construct, conjecture, develop, formulate, author, investigate. Description: The highest level of Bloom's Taxonomy, learners generate new ideas, concepts, or products. They can design solutions, create hypotheses and contribute to new developments.

Research literature reports on BL as an effective approach to teaching and learning, see, for example, [4, 8, 38, 57]. Even though the concept for BL seems to be both easy to comprehend and well established, it is still an open question on how it should be framed. This could be due to new technology being developed, opening up for new possibilities for teaching and learning. Hrastinski [49] brings up five main conceptualizations of BL, that while not being mutually exclusive serves as a way to categorize either in what way or for what reason that BL is utilized. The conceptualizations are summarized below:

1. The inclusive conceptualization: BL should be considered in an inclusive fashion, making any type of teaching and learning processes included if it contains one or more element that can be carried out online.
2. The quality conceptualization: Considers improvement of quality in the teaching and learning processes and emphasizing that online and face-to-face learning are integrated in a thoughtful way.
3. The quantity conceptualization: Considers the quantity of online and face-to-face learning. That is, how much time is spent by the student in the different activities.
4. The synchronous conceptualization: Emphasizing teaching and learning that occur in real-time, for example, a seminar, which include participation both online and on campus.
5. The digital classroom conceptualization: Focus on online technologies in the classroom. That is, BL is described via activities carried out online but dependent on the physical location of the classroom.

From a teacher/instructor perspective BL is to be seen as course design, thus a question on which teaching and learning activities to include. Although a multitude of BL approaches to course design can be found, Alammary et al. [3] set out to make an inventory of BL designs to guide teacher on which BL approach to choose. This resulted in the following classification:

1. Low-impact blend: Adding extra activities to an existing course—basically adding activities that are mediated online. Commonly done by the inexperienced teacher who are reluctant to change their course too much. This approach contains little or low risk.
2. Medium-impact blend: Replacing activities in an existing course—taking existing face to face activities and replacing them with activities that can be carried out online. An approach feasible for the teacher not yet confident to redesign the full course. Here the parts of a course that don't work well could be considered a good candidate to blend.
3. High-impact blend: Building the blended course from scratch—this approach allows the teacher to take full advantage of BL

To analyse this domain, it is necessary to consider the practical embodiment of BL in education. Among the many descriptive contributions found in literature, the prominent Staker and Horn [103] and Friesen [36] converge in the six models of BL (2011), which introduces a taxonomy of possible implementations that is generic enough to capture the different ways practitioners have approached BL. In detail, the following six categories have been characterized:

1. Face-to-face driver: Most of the teaching is done in a face-to-face setting, but the teacher can choose to augment with digital tools. This would most often correspond to a low-impact blend.
2. Rotation: The students go through a set of thoughtfully sequenced learning activity, both face-to-face and online. This would most often correspond to either a medium- or high-impact blend
3. Flex: The course is offered to the student via a digital platform. Teachers are available for face-to-face consultation when needed.
4. Labs: The course is offered to the student via a digital platform, which is only available from campus. This would often correspond to the digital classroom conceptualization.
5. Self-blend: Students are given options to augment their physical learning with online course work. This would often correspond to low-impact blend.
6. Online driver: Students complete the course on an online platform. Face-to-face meetings can be included as optional or required.

Given these premises, the paper wants to address the following research challenges and related question (RQs):

- Lack of studies specific for engineering education (RQ1): How BL has been used for teaching engineering courses?
- Impact of the pandemic on BL literature (RQ2): How has the COVID-19 pandemic impacted the adoption of BL teaching approaches?
- Dimension identifies as relevant, BL strategies and level of understanding (RQ3): How is BL used for in the different levels of Bloom's taxonomy?

To do so, the authors used a systematic literature review approach. The paper is structured as follows: Section 3 describes the methodological steps followed to conduct the research. Section 4 presents the results of the analysis while Section 5 discusses them, answering the three RQs and providing suggestions on how some of the problems encountered during the analysis were overcome. Section 6 concludes the paper by summarizing the results and delineating future research.

3 | METHODOLOGY

The paper adopted a systematic literature review methodology to run the research. The authors, following the identification of the main research topic, defined a query to be run into Scopus, selected as a research database for the presence of peer-reviewed documents. A PRISMA-like approach has been adopted to conduct the initial search and execute the filtering. More specifically, a research query aimed at returning the papers dealing with BL in the engineering field has been defined. To be ensure a higher soundness of the results, the authors decided to keep only journal articles in the sample, limiting the subject area to Engineering. The query used to run the search in Scopus is the following:

"TITLE-ABS-KEY ((“blend* learn*“) AND “engineer*“) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (SUBJAREA, “ENGI”))”.

As of the beginning of 2023, the query returned 206 results, exported in the form of a .csv file. No duplicates were found in the .csv, as a single query was run. A screening of the title and abstract allowed excluding the papers not coherent with the scope of the search, mainly due to the perspective adopted (i.e., not focused on explaining the evolution of the learning or teaching methodologies following the implementation of BL). Thanks to this first screening, 48 papers were removed, leaving 158 papers in the sample. A second screening, based on the content of the full texts, was carried out. More specifically, this allowed researchers to (a) double-check the coherence of the papers with the scope of the research and (b) provide studies with a first classification in terms of learning approach (e.g., Face-to-Face, Flex, Rotation). Thanks to this screening, 55 papers were excluded, leaving the final sample for analysis to 103 papers. The methodology is summarized in Figure 1.

Following the identification of the final sample of papers for the analysis, the papers were split into the six models of BL previously explained.

Each research unit was responsible for one BL model and took care of reading the related studies to (a) check whether the initial classification was correct (e.g., a Face-to-Face study was actually describing a Face-to-Face BL setting), incorrect, or needed additional information (e.g., a Face-to-Face paper discussed also Rotation aspects) and (b) extract the information used for the analysis that will be shown in the next section.

The classification criteria were identified based on the scope of the research mixing some general information (e.g., location of the study, publishing source), with other specific information needed to support the analysis (e.g., degree level of the participants, learning approach, Bloom's taxonomy level). When explicitly stated, researchers extracted the information from the paper. Otherwise, assumptions based on the general description were made to execute the classification. Of course, assumptions were made only when the description was informative to make them. While doing the classification, researchers also chose to split the classification of Bloom's taxonomy level in terms of 'in place' and 'remote' activities, which means that the idea was to understand how, in the described setting, in-place and remote activities were run and to what they were aimed to. For instance, in some cases, in a Rotation setting, the in place activities were aimed at developing higher levels of Bloom's taxonomy (e.g., Analysis), whereas the remote activities were aimed to strengthen basic knowledge of a topic (e.g., addressing the Remember, Understand or Apply levels). This division allowed the researchers to better frame the way BL possibilities are used in the teaching and learning activities.

In general, researchers decided to collect information on the degree level, year and type, the technology type and name used in the applications, the results discussed by the papers, whether the papers explicitly refer to studies done during or following the COVID-19 pandemic, the learning approach and the

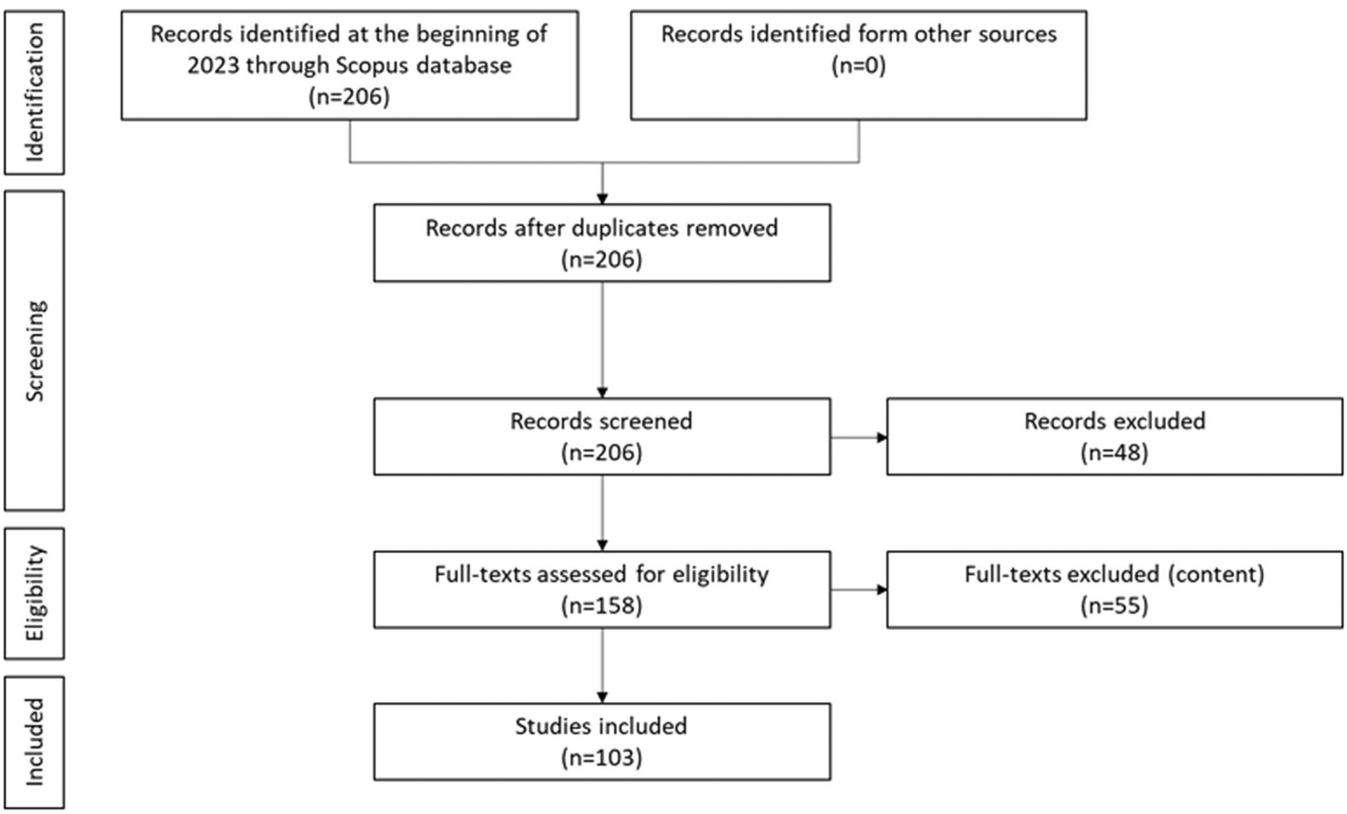

FIGURE 1 Methodology applied to identify the final sample of analysis.

Bloom's taxonomy level for in place and remote settings.

In the next section, the results of the classification phase are presented.

4 | ANALYSIS

Although the previous section presented the methodology used for the retrieval and classification of the papers, this section focuses on the analysis of the accepted papers.

4.1 | Time trend

Figure 2 shows the trend behaviour of the papers published on the topic of engineering and BL over the last 15 years. The time series clearly shows an increasing number of publications with a peak in 2020. Although the general trend is increasing, on average, by a couple of papers per year, in the period between 2018 and 2020 the increase is significant. The downfall in terms of results happening in 2021 can be explained by the necessity of teachers to adapt the teaching methodologies to the COVID-19 context and the necessity to have time to evaluate the effectiveness of the new proposal, which may cause a delay in the publications. The low number of publications for 2022 can be justified by the fact that, since the query was run at the early beginning of 2023, not all the studies were yet present in the database.

4.2 | Country distribution

Figure 3 summarizes the distribution of the papers according to the country of application reported in the papers. What emerges, from the chart is that the country with the highest number of studies is Spain (14), followed by Australia (9), the United States (8), India (6) and others. If we consider a continental perspective, Europe is the one with the highest number of studies on the topic.

4.3 | Learning approaches

Figures 4 and 5 provide an overview of the distribution of learning approaches in the sample of analysis. Specifically, Figure 4 shows the count of papers in which each learning approach appears classifying papers in two manners. On the one hand, the number of times a paper appears singularly in a paper is proposed. The chart shows that Rotation is the learning approach that is most frequently discussed by itself, followed by the Face-to-Face learning approach. On the other hand, Figure 4 also shows the number of times a learning approach has been analysed in combination with other ones. As in the previous case, Rotation is the one that is most frequently considered in combination with other learning approaches. It is interesting to notice that the Flex learning approach is the only one that has never been analysed in combination with other approaches. In general, what emerges is that usually authors publish with the intention of discussing a single learning approach, whereas the proposal or comparison of multiple learning approaches is rare. This might be due to the difficulty of organizing courses in a way that allows experiencing the learning phase in different ways.

Another perspective that has been considered in the analysis of the learning approaches is the time-based one. Specifically, Figure 5 shows the trend of publication for the different learning approaches. What emerges is that Rotation is the learning approach that, over the years, gained the highest attention, especially in 2020. Also, learning

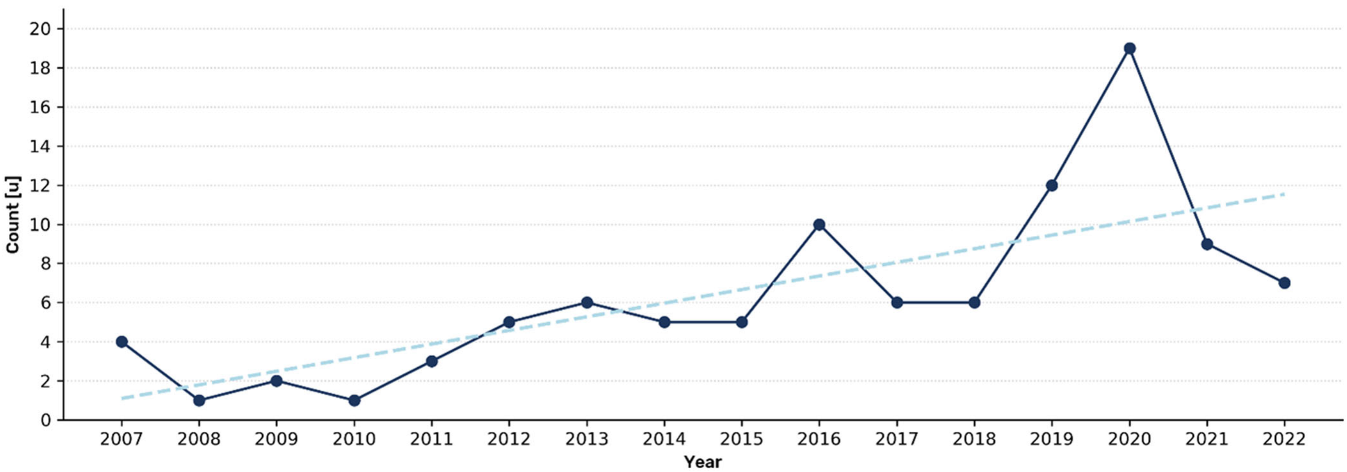

FIGURE 2 Time trend series of analysed publications.

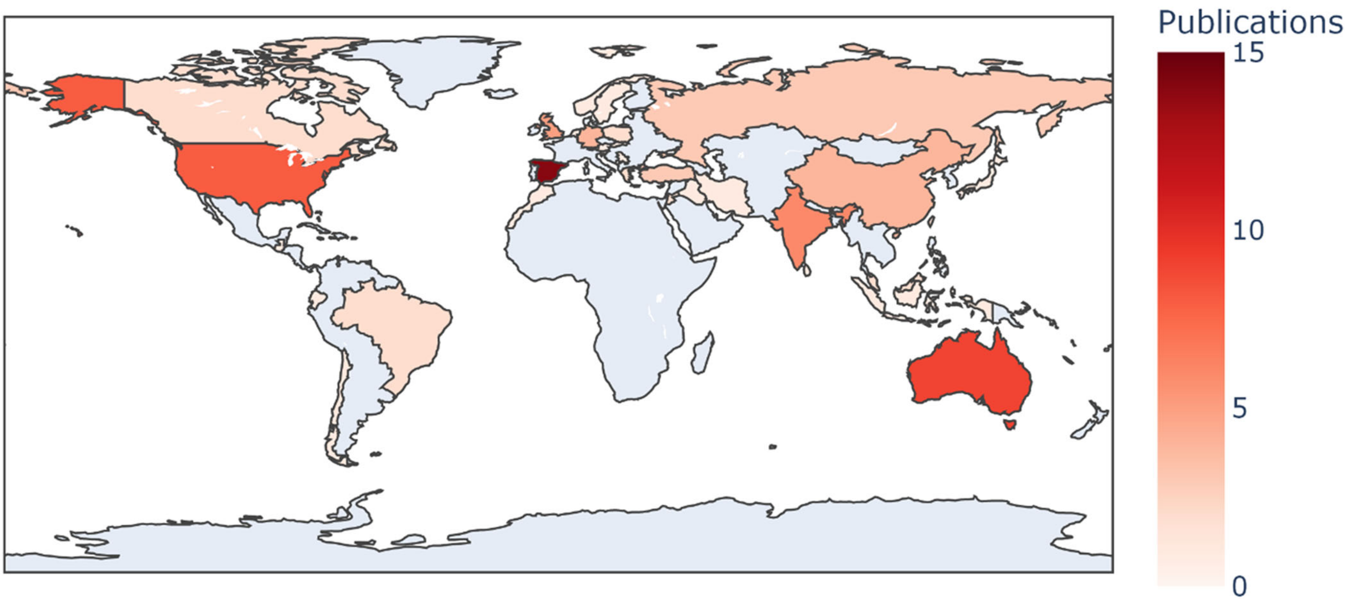

FIGURE 3 Country distribution of published papers.

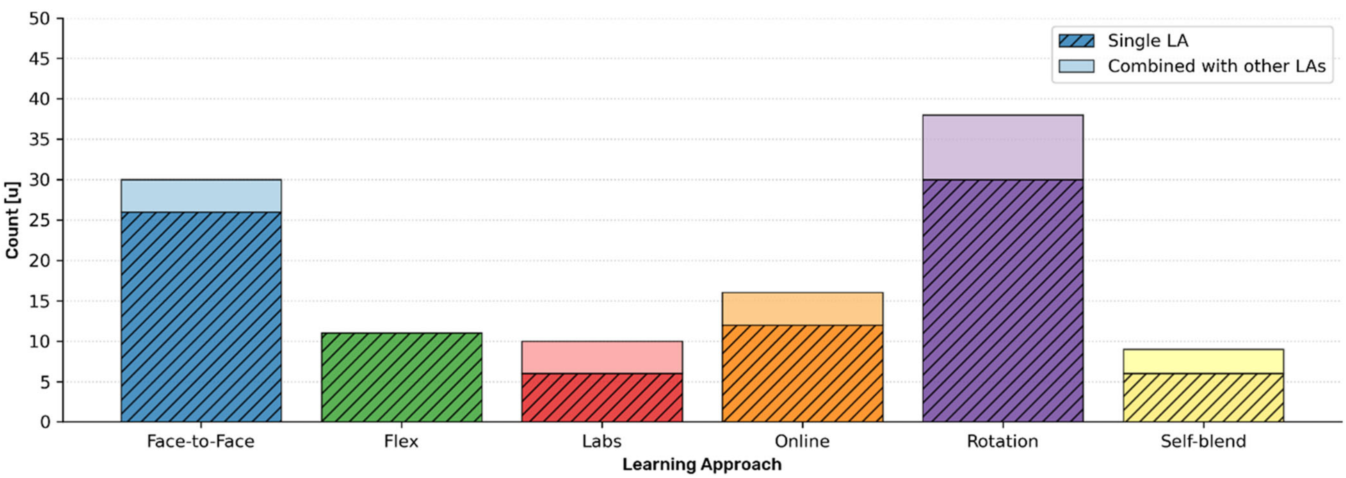

FIGURE 4 Learning approach count.

approaches such as Face-to-Face, Online and Flex have been frequently discussed, whereas Labs and Self-blend learning received less attention in the literature. This might be due to the typology of content taught or, recently for the Labs case, due to the limitations imposed by the COVID-19 pandemic and because the trend of publications on this learning approach started increasing from 2012 on. In addition to the single behaviour, for each chart, Figure 5 shows the trend line created using Figure 2 data to allow a comparison between the time behaviour of each learning approach and the general trend.

4.4 | Source

Table 1 show the most frequent source for the papers in the analysed sample. As is can be clearly seen, the *Computer Applications in Engineering Education* journal is the most frequent source, with 14 publications out of the 103 papers present in the sample of analysis. Coherently with the research query, the target journal of the papers analysed deals with engineering education, confirming the correctness of the filtering activity and the query used for the research.

4.5 | Degree type

Figure 6 shows the degree course used as setting for the BL activities. As shown, the major part of the papers discuss the application on a general level, without disclosing the except engineering course chosen. Following, a great number of applications in Mechanical Engineering, Computer Science and Electrical

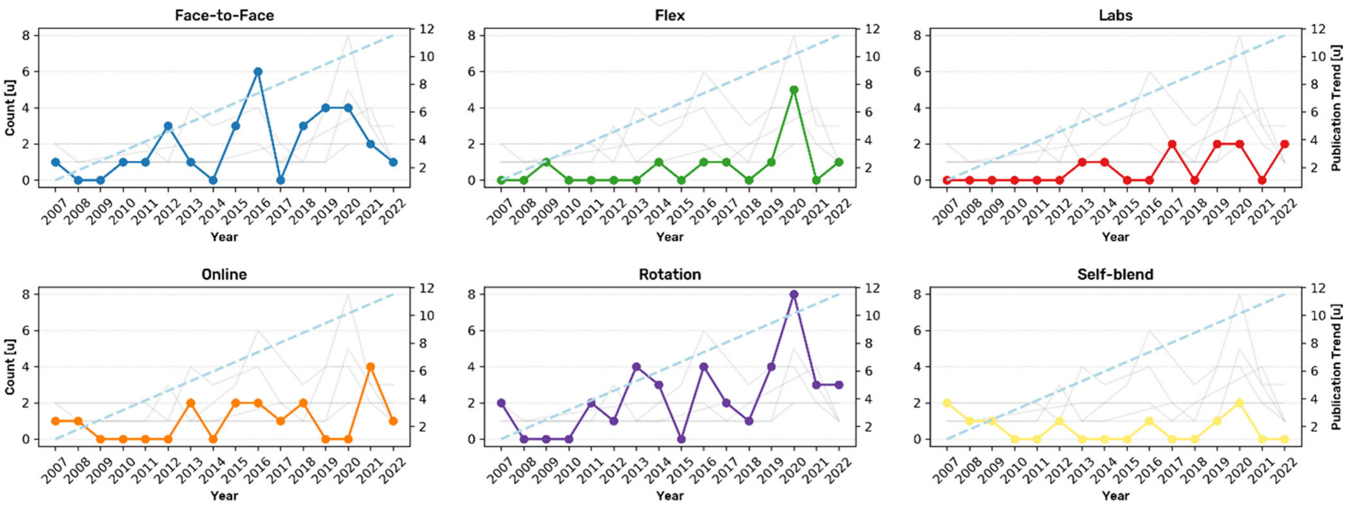

FIGURE 5 Learning approach trend.

TABLE 1 Publication source.

Journal	Papers [u]	References
Computer Applications in Engineering Education	14	[21, 27, 43, 58, 66, 70, 73, 80, 86, 87, 95, 117–119]
European Journal of Engineering Education	8	[10, 20, 32, 35, 39, 46, 85, 112]
IEEE Transactions on Education	8	[4, 37, 42, 47, 62, 72, 101, 113]
International Journal of Engineering Education	8	[12, 17, 31, 55, 56, 78, 107, 115]
Advances in Engineering Education	5	[19, 22, 30, 44, 105]
Journal of Engineering Education Transformations	4	[9, 24, 60, 93]
International Journal of Emerging Technologies in Learning	4	[13, 59, 89, 91]
International Journal of Electrical Education Transformations	3	[1, 23, 83]
International Journal of Continuing Engineering Education and Life-Long Learning	3	[102, 110, 111]
Educational Technology and Society	3	[7, 26, 53]
Others	41	[2, 6, 14–16, 18, 25, 28, 29, 33, 34, 45, 50–52, 54, 61, 63–65, 71, 74–76, 79, 82, 84, 88, 90, 92, 94, 96–100, 104, 106, 109, 114, 116, 120]

Engineering courses are discussed. What emerges, is that BL has been applied and tested in various settings, demonstrating the usefulness of the approach in various settings. In Figure 6, only the top 10 degree types are reported.

4.6 | Degree level

Figure 7 shows the degree level of the students or participants to the BL activities in the analysed samples. As expected, a major part of the papers deals with Bachelor and Master students, with a strong preference towards Bachelor students. Instead, only with few papers dealing with PhD students, middle school scholars and faculty level participants. The sum of the percentages values is higher than 100%, as, in a few cases, papers contemporary dealt with multiple degree level participants.

4.7 | Bloom's taxonomy classification for in place versus remote activities

Figures 8 and 9 discuss the distribution of the in place and remote activities on the levels of the Bloom's

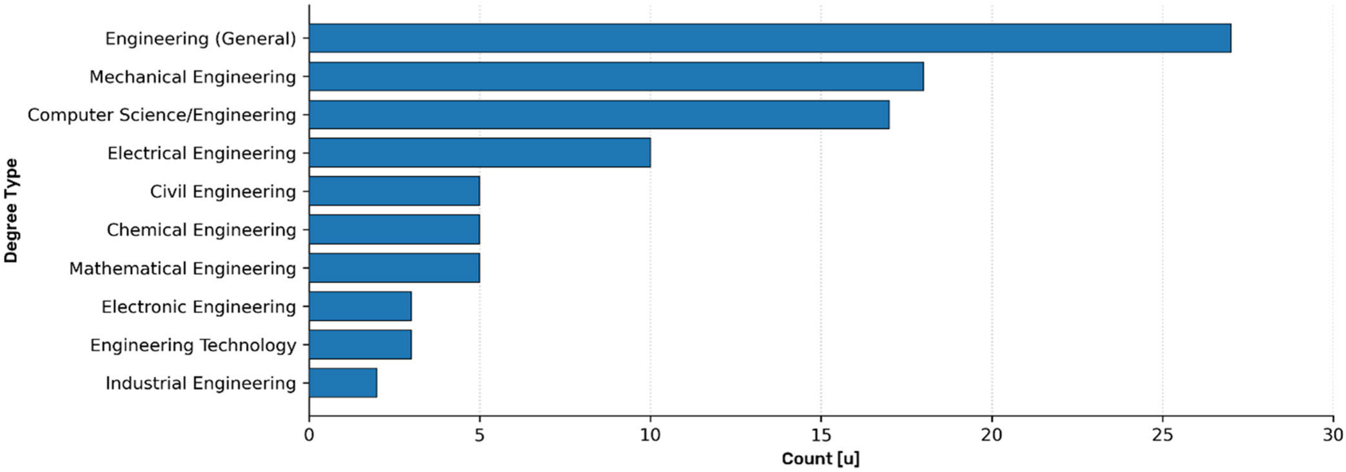

FIGURE 6 Degree type discussed in the paper.

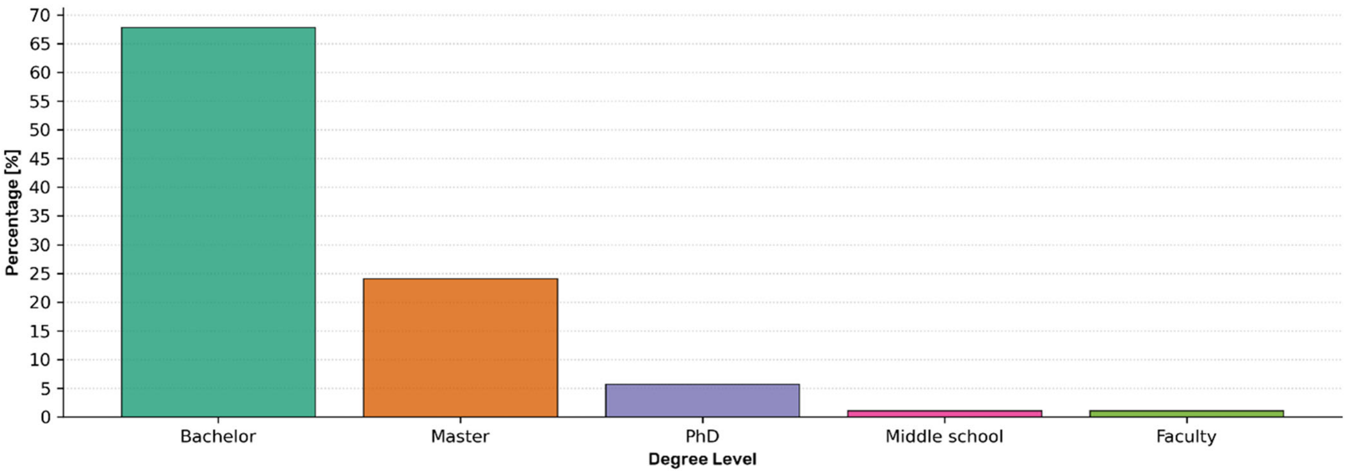

FIGURE 7 Degree level of participants discussed in the paper.

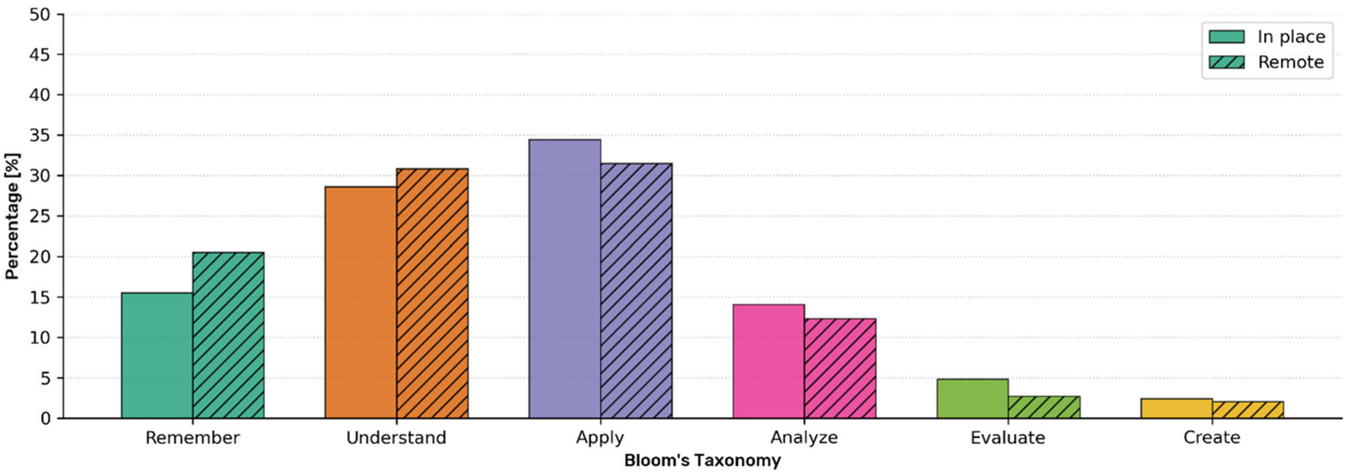

FIGURE 8 Bloom's taxonomy distribution on in place and remote activities.

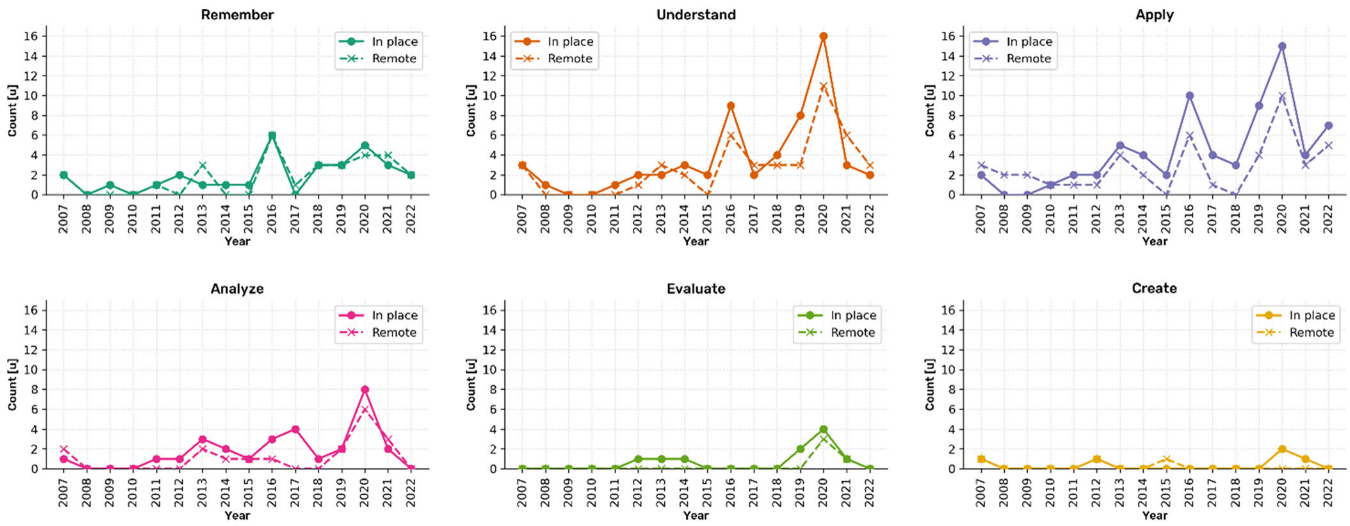

FIGURE 9 Bloom's taxonomy trend for the in place and remote learning approaches.

taxonomy. This comparison aims at identifying specific clusters when setting the learning objectives in the in place or remote activity. To create the chart shown in Figure 8, the learning process described in each paper was clustered into in place and remote sub-activities and then classified according to Bloom's Taxonomy. According to the results shown in Figure 8, there is no clear preference in terms of learning objectives between when doing in place or remote activities.

On the other hand, Figure 9 provides a trend perspective on the topic, allowing noticing, also in this case, a similar distribution for the in place and remote activities in the various levels of the Bloom's taxonomy. While the research related to the lower levels of Bloom's taxonomy has grown over the years, the number of papers dealing with the Evaluate and Create levels remained constant with only a few studies per year—or none. In accordance with Figure 8, also Figure 9 shows an increasing number of papers related to the lower-central levels of Bloom's taxonomy, with a common peak in 2020. Also, the Remember level showed a slight increase in the number of publications in 2016 but remained stable, with no significant variation.

Out of the total sample of analysed papers, only seven specifically deal with the COVID-19 setting, considerably limiting the possibility of making deep discussion on the impact of COVID-19 on BL. Figure 10 filters the results shown in Figure 8 to the sample dealing with COVID-19. The first thing that can be noticed is the absence of the Evaluate and Create levels of Bloom's taxonomy, probably due to the difficulty of transposing such learning objectives in remote form and executing them in place part during the COVID-19 pandemic. Another interesting aspect is related to the fact that, at least in the analysed sample, the in place activities reached the Apply level of Bloom's taxonomy, whereas the remote setting also considered the Analyse level.

4.8 | Bloom's taxonomy classification according to the learning approach for in place and remote activities

Figure 11 provides an overview of the number of papers clustered according to the Bloom's taxonomy and learning approach they have been assigned also considering the division into in place and remote activities. Analysing Figure 11a, what emerges is that Face-to-Face and Rotation were the most common learning approaches, with Face-to-Face approaches being the most used for the Remember task while Rotation being used as most common approach for the other levels of Bloom's taxonomy. This is coherent with the analysis conducted so far, which also demonstrated the strong focus on the mid-lower levels of Bloom's taxonomy. The same can be said for Figure 11b, with Rotation being the most used learning approach across a major part of Bloom's taxonomy levels. While the sample available for the Create level is quite low in both Figure 11a,b, it should be noticed the adoption, in both, of the Self-blend learning approach for the Create level of Bloom's taxonomy. Other applications are carried out through Rotation, Face-to-Face and Online approaches. Still, the sample of papers dealing with the top levels of Bloom's taxonomy is quite poor, requiring discussing if this is due to the impossibility of reaching such a level through these approaches or simply due to the lack of publications.

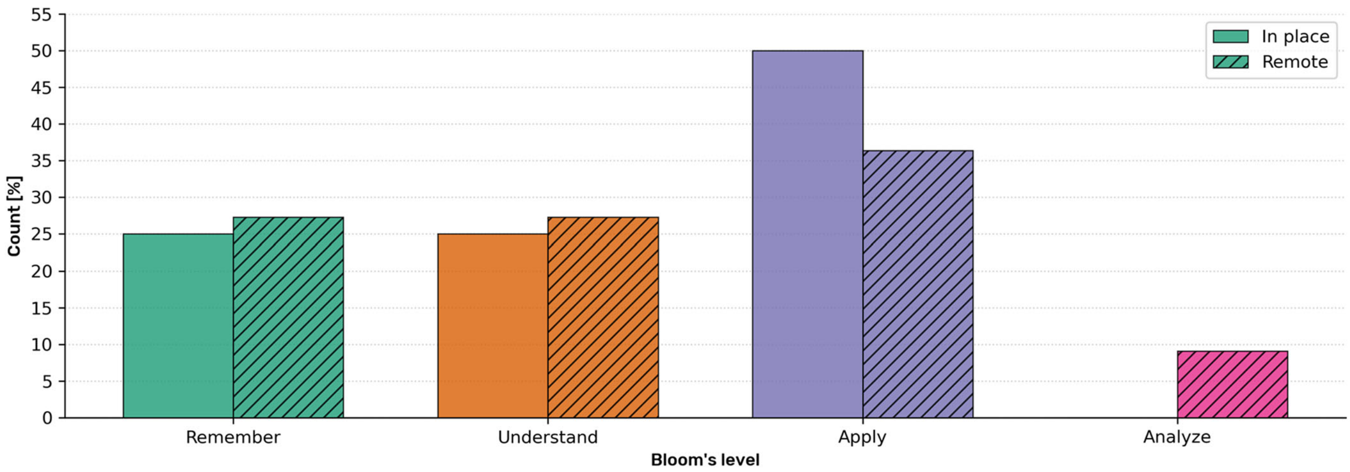

FIGURE 10 Bloom's taxonomy distribution on in place and remote learning approaches for coronavirus disease-2019-related papers.

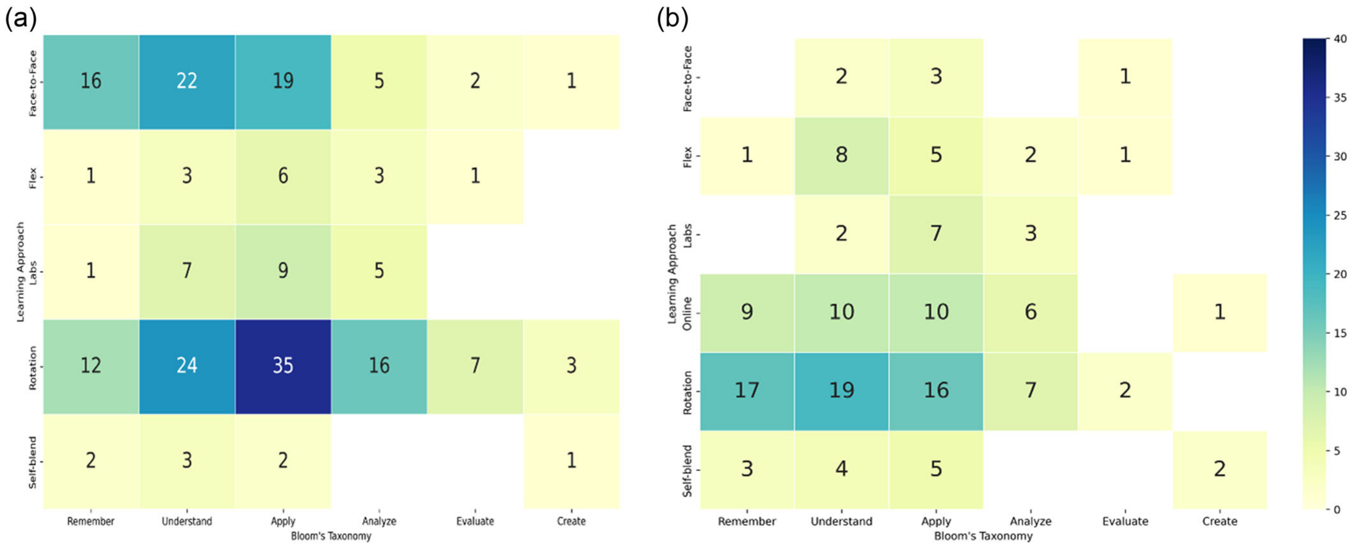

FIGURE 11 (a) Count of papers for Bloom's taxonomy level and learning approach for in place activities and (b) count of papers for Bloom's taxonomy level and learning approach for remote activities.

4.9 | Bloom's taxonomy classification according to the degree level for the in place and remote activities

Figure 12 uses the same approach of Figure 11 but analyses the problem considering the Degree Level of the participants. As in the previous case, many papers focus on the lower levels of the Bloom's taxonomy both in the in place and remote settings. In Figure 12a,b, in the PhD subsample, despite the higher autonomy expected from these students, only 1 paper deals with the Create level limiting the learning outcome to the lower level of Bloom's taxonomy. The same goes for the Faculty, which reaches the Apply level as the most discussed level.

5 | DISCUSSION

The previous section provides an overview of the content of the papers according to the classification categories. Three main research questions mean to be addressed by the researchers in this work. This section will be divided accordingly, with an additional subsection aimed at discussing the difficulties that the researchers had to address during the classification process.

5.1 | How BL has been used for teaching engineering courses?

In general, what emerges from the previous section, is that the interest towards BL increased over the years.

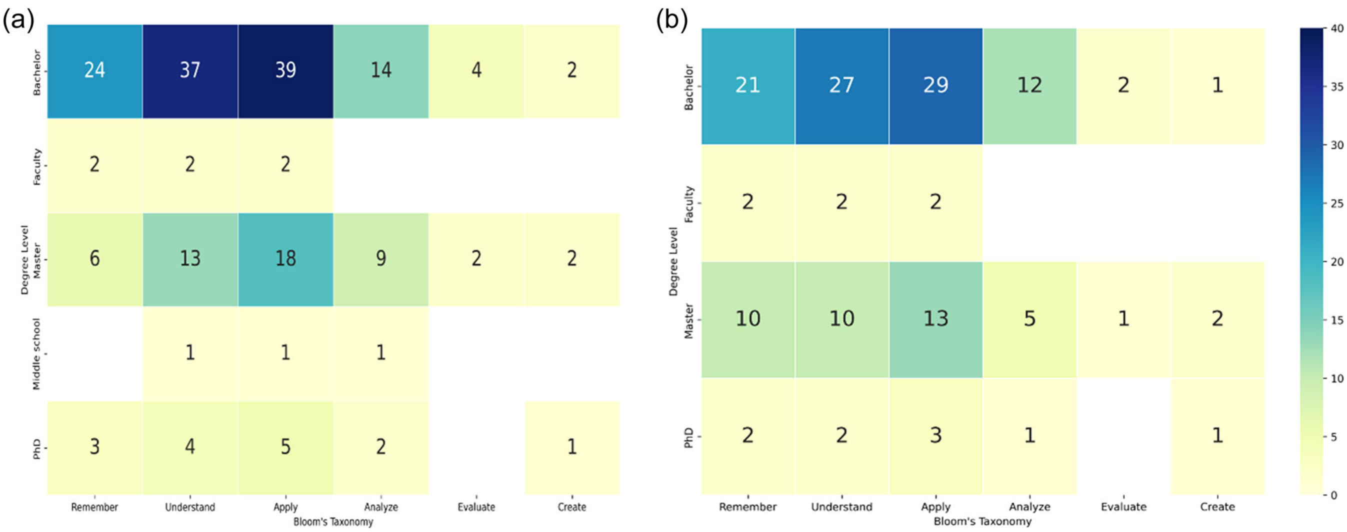

FIGURE 12 (a) Count of papers for Bloom's Taxonomy Level and Degree Level for in place activities and (b) count of papers for Bloom's Taxonomy Level and Degree Level for remote activities.

Researchers mainly focused on mixed settings, where in place and remote activities are mixed, in the scope of providing students with learning outcomes usually on the low or medium levels of Bloom's taxonomy. The most interesting aspect is related to the fact that there is no clear distinction between the selection of in place or remote activities scopes according to Bloom's taxonomy classification. All the levels of the Bloom's taxonomy equally distribute the in place and remote activities in each level, not providing any clear indication on the preference of an in place or remote setting to achieve a specific learning outcome (e.g., in place activities for Rotation useful for the Create level while remote activities used for Understand). Moreover, there is no consistency in the description provided by the authors, with the same learning approach used to achieve different learning outcomes. What can be noted instead, is the preference towards the low and medium levels in the Bloom's taxonomy (i.e., Remember, Understand, Apply, Analyse) instead of the high ones (i.e., Evaluate and Create).

5.2 | How has the COVID-19 pandemic impacted the adoption of BL teaching approaches?

What emerged from the analysis of the data set, is that only a minor part of the papers dealt with the COVID-19 pandemic in a direct way. The publication trend did not suffer any peak in relation to the necessity of publishing COVID-19 related articles. The same can be said for what concerns the Online publications that followed the usual trend.

Out of the total 103 articles, only a subsample of seven papers explicitly dealt with the COVID-19 pandemic situation, using it as a motif for experimenting in the BL field.

In this sample, the papers [6, 24, 66] deal with the online setting, covering the Remember, Understand, Apply and Analyze levels of the Bloom's taxonomy for remote activities, in accordance with the Figure 10. Instead, [58] and [62] focus on the Rotation learning approach, while [70] and [62] focus on the Labs. Martín-Lara and Rico [74] is the only one focusing on the Face-to-Face setting.

A reason for this can be found in the short time that researchers had to think and implement new Online-based teaching and learning methodologies and contents, which limited the possibility of setting testbeds to measure the effectiveness of the change. Another reason might be found in the support that BL scholars had to provide to the other scholars not used to work in blended settings in structuring courses, learning and assessment activities. This is also explained by the number of the papers in this subsample, where it is possible to notice that publications got an increase in 2022 (four papers) compared with the ones in 2020 (one paper) and 2021 (two papers). This can be explained both by the necessity of undergo the revision process but, most importantly, by the time it took to scholars to develop BL courses and implement them.

Another interesting hint confirming this explanation is given by the research gap addressed by these papers, with the ones written in 2020 and 2021 more focused on the understanding of the development process for BL material in the new setting with the ones published in

2022 more focused on evaluating the effectiveness of the BL strategies applied.

5.3 | How is BL used for in the different levels of Bloom's taxonomy?

According to the results of the analysis, the BL approaches discusses in the literature for engineering learning mainly focus on the medium and lower levels of Bloom's taxonomy. In particular, the two highest levels of Bloom's taxonomy (i.e., Evaluate and Create), are only touched by circa the 7% and 3% of papers in the analysed sample when it comes to in place activities. The same situation happens with remote activities, where the Evaluate level is used in around 4.5% of the papers and the Create in around 2.5% of the papers, showing even lower adoption compared to the in place setting. On the other hand, the medium and low levels of Bloom's taxonomy are used in around 45% of papers each. For the medium level, according to Figure 8, it is possible to notice an average use of in place and remote setting of 33% for the Apply level and 10% for the Analyse level. The same goes for the low levels, with an average presence of circa 30% for the Understand level and around 16% for the Remember level.

From these percentages, it emerges that authors are more prone to publish about learning settings where the learning outcome is not linked to the highest levels of Bloom's taxonomy. This might be due to create settings for such accomplishments or to the difficulty in measuring such outcomes in the engineering field.

Surprisingly, the PhD course resulted to be consistent with the courses offered to Bachelor and Master's courses, focusing on the medium and low levels of Bloom's taxonomy instead of the highest ones. Given the typology courses attended by PhD students and their role, authors expected to find, in the papers related to them, courses structured towards higher levels of Bloom's taxonomy. Motivations for this should be studied more in detail to understand to what kind of limitations or decisions this is due.

5.4 | Difficulties in the classification of papers according to Bloom's taxonomy

Despite the useful results that emerged from the analysis, the classification task was not straightforward for the researchers, which encountered some difficulties during the process.

First, Bloom's taxonomy is not always used in the paper, which makes it difficult (especially for non-experts) to identify in an easy and reliable way the aim of the learning phase. To overcome this problem, researchers relied first on the description provided in the papers, trying to identify the main verbs used for the description of the learning activity and, thus, identify Bloom's level. When not possible, researchers made assumptions that were then discussed with the whole research team, exchanging ideas and interpretations to reach a common agreement. In addition, a shared document with a short description and indications of what to look for in the papers was shared among the team. The document is summarized in Table 2. Through this, a common understanding guiding the classification phase was reached and additional discussions, for the most complicated cases, were carried out.

Other assumptions were made in relation to the type of activity that students had to make during the courses. For instance, all papers where students were required to write some code or create simulation models/use simulation software were classified as Apply instead of Create, as the idea underneath the request was to apply specific knowledge learnt from previous classes to a specific case under established guidelines. This is also the reason why only a few papers dealing with the highest level of Bloom's taxonomy appeared in the analysed sample.

Another issue was related to the terminology used for the classification. Specifically, many papers in the literature, and in the database, indicated as learning approach Flipped classroom, which did not belong in the researchers' classification. The reason for the choice of not using the term Flipped classroom can be retraced in the fact that authors might define a Flipped classroom setting in different ways (e.g., situations in which the students are teaching other students, situations in which the learning process alternates class presence to remote learning). For this reason, researchers decided to not consider the Flipped classroom classification and rely on the ones discussed in the paper choosing, depending on the paper content and course description, the most appropriate classification. As for Bloom's taxonomy classification, also in this case the classification process required multiple internal discussions, mainly because course descriptions were not clear, or a course used a mix of approaches. Following this, researchers decided to use, when needed, multiple approaches for the classification, or select only one after discussing in detail the case in doubt.

5.5 | Recommendations for teachers in engineering courses

Important and interesting commonalities emerge among the papers analysed. From these, some recommendations

TABLE 2 Bloom's taxonomy classification guidelines.

Bloom's level	Short description	What to look for. Screening questions
Face-to-Face	The teacher drives the instruction and augments with digital tool.	Are students required to attend physical meetings with teachers? Are teachers using digital tools to enhance learning?
Rotation	Students cycle through a schedule of independent online study and Face-to-Face classroom time.	Does the course design establish BOTH online moments and digital moments in a sequential way?
Flex	Most of the curriculum is delivered via a digital platform and teachers are available for Face-to-Face consultation and support.	Does the course design allow student to work entirely in a digital way and go see the teacher ONLY if they need help?
Labs	All the curriculum is delivered via a digital platform but in a consistent physical location. Students usually take physical classes in this model as well.	Do students study in a physical lab using digital tools?
Self-Blend	Students choose to augment their physical learning with online course work.	Are the digital parts only for optional self-study?
Online	Students complete an entire course through an online platform with possible teacher check-ins. All curriculum and teaching is delivered via a digital platform and face-to-face meetings are scheduled or made available if necessary.	Can students complete ALL the activities online? Do teachers have possibility to check in digitally? Optional: face-to face meeting?

for teachers interested in adopting BL for their engineering courses can be extracted:

- A Learning Management System (LMS) should be identified and used as a repository for the material. The LMS can also be used for other purposes, such as redirecting to additional sources that interested students could use to deepen a specific topic if interested, or as a platform to practice theoretical concept and assess their learning.
- The content on the LMS should be properly organized and teachers should explain, since the beginning, the structure of the course and the aim of the activities, as well as the milestones in the course. This would allow students to understand the learning path that the professor defined and simplify finding the needed material on the LMS.
- The use of LMS should not be seen as a substitute for the F2F learning. Instead, a mix of the two should be used to provide students with practical experiences that can be then replicated remotely to evaluate their comprehension. In case students cannot participate in person to practical classes, it is useful to use the LMS to share recording of the practical session that can be viewed by students.
- After each milestone in the class, self-assessment quiz and/or exercise should be made available to allow students understanding their competence level and work to cover gaps and difficulties. Moreover, discussion forums should be made available to allow students to exchange opinions and help other students in solving their doubts. Also teachers should contribute to the forum helping students. Feedback on the learning process should be provided by the professor through the self-assessment quiz, targeting students to the learning resources required to cover the gaps.
- The learning path should be structured with a controlled increasing difficulty, allowing students to secure the achievement of a concept before moving to the following one.
- Group work and problem solving/case-based exercises should be adopted to allow students practice what they learned and challenge them in further elaborating the content of the practice lectures. The group work should be designed to be as close as possible to a real situation, allowing student to comprehend the difficulties and challenges of real-world problems. The group work should be targeted at favouring the discussion in between the students of the group but also with the teachers, which should be available to guide students when needed.
- When video are used to support or complement the learning phase, their length should be under or equal to 10 min. Additionally, when multiple videos need to be watched, quizzes should be used in between a video and the following one to maintain a certain level of attention.
- Teachers should collect feedback from the students on the quality and usefulness of the material provided, so that, if necessary, it can be improved.

6 | CONCLUSION

The adoption of BL strategies in the engineering field aims at increasing the engagement of students in the learning process, providing additional flexibility to their educational path and allowing them to acquire the necessary skills to be competitive in the job market and in the industry. This paper presented the results of a systematic literature review to understand how BL has been adopted in the engineering context, also investigating the role that the COVID-19 pandemic had on the transition.

The authors identified three main research questions to guide the research, going from a more general perspective of adoption of BL in an engineering course, evaluating the role of the COVID-19 pandemic and investigating the use of BL from Bloom's taxonomy perspective, trying to understand if and how the BL approaches suit specific levels of the Bloom's taxonomy, providing in this way an additional layer of analysis not yet provided in the literature.

What has emerged is that the interest towards BL increased in the recent decade, with an increasing trend in terms of papers published. While the peak in terms of publications in the analysed sample belongs to 2020, the presence of COVID-19-related papers constitutes only a minor part, which is explainable since no limitations were given in terms of the period of analysis and that the researchers might not have enough time to publish (e.g., due to the necessity to support other scholars or the necessity to test the new settings). Additionally, the new perspective provided by the inclusion of Bloom's taxonomy in the analysis allowed identifying a consistent number of publications discussing the medium and lower levels of Bloom's taxonomy for all the considered learning approaches, with only a minor part focused on the higher levels.

The course descriptions provided by the analysed papers were not always detailed enough to go into detail about the sub-activities composing the learning process. Many times, only general descriptions of the course were provided and only a minor part of the papers directly referred to Bloom's taxonomy levels while discussing the course structure and the intended learning outcomes. This is why, for future developments, the researchers intend to tackle the problem of the percentage of high-level activities (i.e., Evaluate and Create levels of Bloom's taxonomy) in the engineering field, understanding how it would be possible to implement them and the reasons that prevent scholars from publishing on these (e.g., difficulties in the implementation, difficulties in the evaluation).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Roberto Sala http://orcid.org/0000-0001-7671-6927
Antonio Maffei http://orcid.org/0000-0002-0723-1712
Sandi Ljubić http://orcid.org/0000-0003-3456-8369

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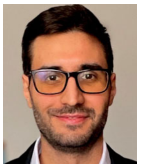
AUTHOR BIOGRAPHIES

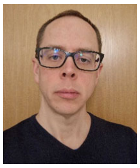


Roberto Sala is Assistant Professor at the Department of Management, Information and Production Engineering of the University of Bergamo (Italy) where he is also member of the CELS Research Group on Industrial Systems Engineering, Logistics, and Service Operations. He received his PhD in Technology, Innovation, and Management at the University of Bergamo in 2021 with a thesis on data-driven decision-making processes to improve the maintenance service delivery. His research interests gravitate around data-driven decision-making, maintenance, Industry 4.0, and product-service systems. He has participated into multiple projects at Regional, National and European level in these research areas. Email: roberto.sala@unibg.it

Antonio Maffei is an Associate Professor in production system with focus on business models at KTH, Sweden. He received his PhD in production systems from KTH (Sweden) in 2012, and MSc and BSc from the University of Pisa in Italy in 2004 and 2007 respectively. He received a second PhD degree on pedagogy for higher education from Bologna, Italy in 2021. Associate Professor Maffei has extensive international experience having been visiting researcher or teacher for a number of institutions worldwide. His research interests includes sustainable business model for novel automation technologies as well as autonomous system control, assembly systems and technology and cybersecurity. Associate Professor Maffei is also active in pedagogic research and development in the domain of constructive alignment, phenomenography and blended learning. Associate Professor Maffei has participated and often coordinated in excess of 10 national and international research projects and he has published over 80 scientific contributions in journals, books and peer-reviewed conference proceedings. Email: maffei@kth.se

Fabiana Pirola is a Associate Professor at the Department of Management, Information and Production Engineering of the University of Bergamo (Italy) and Rector delegate for international research in economic and engineering area. She holds a master's degree in Management Engineering and received her PhD in Logistics and

Supply Chain Management at University of Bergamo in 2011. She is a member of the CELS—Research Group on Industrial Engineering, Logistics, and Service Operations at the University of Bergamo. She teaches courses in Operations Management, Production Management, Healthcare Operations, and Healthcare Planning and Control at the University of Bergamo. Her research interests are Product Service Systems (PSS) engineering and operations, mainly focused on data-driven services and on decision-making processes supporting their delivery (with particular reference to maintenance service delivery), and smart manufacturing, mainly focused on modelling and simulation. Email: fabiana.pirola@unibg.it

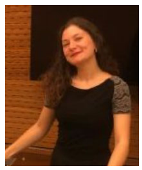


Fredrik Enoksson, PhD, is employed as a researcher at the division of digital learning at KTH Royal Institute of Technology, Stockholm, Sweden. His area of research is focused on teaching and learning in blended setting, i.e., where digital approaches are combined with campus-based approaches. He also supervises PhD students with similar research focus. Furthermore, Fredrik is responsible for a course on digital learning in Higher Education, which is offered as a part of faculty development at KTH. He also holds a central appointment at KTH to lead the group that maintain and develop the university's digital learning environment. Email: fen@kth.se

Sandi Ljubić currently holds the position of Associate Professor at the University of Rijeka, Faculty of Engineering, Croatia. He is the Head of Section of Software Engineering and leads Human-Computer Interaction Lab at AIRI: Center for Artificial Intelligence and Cybersecurity. His research interests cover a range of topics in HCI, including mobile interaction, sensor-based interaction augmentation, predictive modelling and evaluation, and text entry methods. Email: sandi.ljubic@riteh.uniri.hr

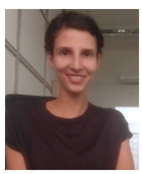
Arian Skoki is a Research and Teaching Assistant at the Faculty of Engineering, University of Rijeka. His research delves into machine learning, data analytics, and optimization methods, particularly applied to football. In addition to his academic role, he teaches computer science courses, co-leads the Riteh Web Team student organization, and passionately advocates for data science and sports popularization. Email: arian.skoki160@gmail.com

Joseph P. Zammit is Lecturer within the DIME. His research interests include; Collaborative product development, Manufacturing Information and knowledge management, Product lifecycle management (PLM), and Enterprise Engineering, publishing numerous peer-reviewed articles within these fields. His PhD research involved the development of a knowledge capturing and sharing framework using advanced ICT technologies to enable problem-solving in a social context and ensure the use of the collective company knowledge. Before joining UM, Dr Zammit worked within Industry for over 15 years in various engineering and management positions. Email: joseph.zammit@um.edu.mt



Amberlynn Bonello graduated in Mechanical Engineering (Industrial and Manufacturing) with First Class Honours from the University of Malta and is currently reaching for a PhD in Industrial Engineering. Her interests include Industry 4.0, machine learning, collaboration between man and machine, automation and sustainability. Email: amberlynn.bonello@um.edu.mt

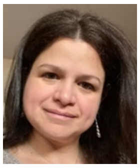
Primož Podržaj received the PhD degree from the Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia, in 2004. He is a Full Professor with the Laboratory for Mechatronics, Production Systems, and Automation (LAMPA), Faculty of Mechanical Engineering, University of Ljubljana. His research interests include control systems, artificial intelligence, and machine vision. Email: primoz.podrzaj@fs.uni-lj.si



Tena Žužek received her Ph.D. degree in mechanical engineering from the Faculty of Mechanical Engineering, University of Ljubljana in 2022. She is currently a research assistant in the Laboratory for Mechatronics, Production Systems and Automation at the University of Ljubljana. Her main research interests include autonomous mobile robots, fleet management, multi-agent simulations, and reinforcement learning. Email: tena.zuzek@fs.uni-lj.si

Paolo C. Priarone obtained a MSc degree cum laude in Mechanical Engineering and a PhD in Production Systems and Industrial Design from Politecnico di Torino. He is currently Associate Professor of Manufacturing at the Department of Management and Production Engineering of Politecnico di Torino and Associate Member of the International Academy for Production Engineering (CIRP). His research activity is mainly focused on sustainable manufacturing and development, advanced production technologies and machining of difficult-to-cut materials. Email: paoloclaudio.priarone@polito.it

Dario Antonelli is an Associate Professor at the Department of Management and Production Engineering, Politecnico di Torino (Torino, Italy). He lectures on Manufacturing Systems, Advanced Die Design and Production Technology courses. His recent research includes Human-Robot Collaboration in Assembly, Die-life Estimation through Finite Elements Simulation, Inclusive Production supported by Machine Learning and Robotics. Email: dario.antonelli@polito.it



Giuditta Pezzotta is an Associate Professor at the University of Bergamo, also serving as Vice Chancellor for Quality Assurance. She earned her PhD in Management, Economics, and Industrial Engineering from Politecnico di Milano in 2010, specializing in Service Engineering and Product Service System fields. Her research focuses on product-service systems, process modelling, and simulation for both production and service delivery. Working extensively with the University of Bergamo, she has led numerous projects in the Product-Service domain. With over 100 papers published in international and national journals and conferences, she's been actively involved in IFIP's Special Interest Group (SIG) in Service Systems Design, Engineering, and Management since 2019. Email: giuditta.pezzotta@unibg.it

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