Hybrid blended learning solutions in a STEM teaching of the degree course in Computer Engineering

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Abstract
The case study reports the implementation of Hybrid Blended Learning solutions in the teaching of Fundamentals of Analysis and Probability in the Computer Engineering Degree Course at the University of Padua. The teaching organization and methodology have been revised in a transformative perspective, using innovative STEM and digitally integrated approaches in blended learning mode (Ministerial Decree 289/2021). The context of the study is a cohort of 200 students, divided into two groups for organizational issues. The study analyzed data collected with different instruments: a survey administered by the lecturer and the course evaluation questionnaire required by university quality assurance standards, focusing on overall satisfaction, organizational and teaching aspects and perceived workload. In addition, data on final examination assessment were taken into account.

Keywords*:* Higher education, Blended Learning, Teaching methods, Educational technology, STEM.

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Hybrid Blended Learning Solutions

With the development of information and communication technologies, the way of teaching, especially in higher education, has gradually shifted from the

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traditional face-to-face learning experience to the more efficient blended learning approach. Many researchers and institutions have begun to thoroughly investigate the principles and models of this unconventional learning method, given its flexibility (Bernard et al., 2014; Gaebel et al., 2021). According to data from the European University Education (Gaebel & Morrisroe, 2023), over the past decade, blended learning mode is much more accepted and used throughout the European Higher Education Area (EHEA).

Currently, blended learning is an increasingly popular innovative mode of educational delivery: on average, it is used in 75 % of EHEA institutions, whether in some courses or University-wide (Gaebel & Morrisroe, 2023). Especially following the response to the Covid-19 emergency, some institutions have begun to provide hybrid learning and teaching, that is, courses that can be taken both physically and virtually (Megahed & Ghoneim, 2022). However, a paradigm shift in instructional design is needed to achieve effectiveness in teaching-learning processes.

For example, McGee and Reis (2012) identified common errors that occur in the design of blended courses, including a lack of consistency between online and face-to-face modes and attempted direct conversion from one mode to the other. Other studies have identified guidelines for blended design and teaching to ensure that this approach achieves maximum effectiveness (Reeves & Reeves, 2012; Sancassani et al., 2023). These include the importance of addressing content-related methodological issues ahead of technology; constructive alignment of course content; building cognitive, social, and instructional presences; selective adoption of new social media tools; and commitment to systematic formative assessment. They suggested that a well-planned online and blended learning environment should be geared toward pedagogical-technology integration, beginning by reviewing the core components of the discipline before considering which technologies can be used; aligning the instructional context constructively with the expected learning outcomes; using constructive and collaborative learning theory within the framework of the community of inquiry to maintain effective levels of cognitive, social and instructional presence; taking into consideration different age groups and potential pedagogical effectiveness in selecting the adoption of new technologies; engaging in formative assessment for the continuous improvement of existing blended subjects.

All this requires solid design skills on the part of teachers, specifically in the ability to integrate different types of knowledge: disciplinary content expertise, knowledge of appropriate methodological approaches and the pedagogical possibilities of digital tools. This unique amalgam of expertise has been framed in research as the Technological Pedagogical Content Knowledge (TPCK) (De Rossi & Trevisan, 2018; Mishra & Koehler, 2006; Angeli & Valanides, 2009)

framework. Hybrid blended learning modes have been extensively studied over the past two decades, highlighting a paradigm shift in education geared toward promoting innovative teaching-learning processes (Graham & Dziuban, 2008; Torrisi-Steele & Drew, 2013). The literature has shown that the reasoned use of ICT promotes flexibility of space and time through learner-centered approaches (Philipsen et al., 2019).

Moreover, with the advent and consolidation of ICT use in the synergy between formal, non formal, and informal learning contexts, new models of integrated teaching, known as hybrid instructional solutions, have become widespread and continue to be refined. The term "hybrid solution" encompasses a variety of instructional formats, including blended learning (Kaleta et al., 2007). The literature interprets the hybrid education approach basically as a combination of face-to-face and distance learning activities that are technologically integrated (Graham, 2006). Indeed, the implementation of hybrid educational solutions can take many forms: among others, the integration of technology into face-to-face teaching in a fluid dynamic (Trentin, 2015), the use of multiple methodological approaches, tools, and instructional formats between presence and distance (Bruggeman et al., 2021; Philipsen et al., 2019). The educational quality of hybrid solutions is based on their ability to foster active learning, support collaborative and student-centered instruction, and enable sustainability processes from a work-life balance perspective (De Rossi & Trevisan, 2023; Bruggeman et al., 2021).

Education supported by hybrid blended learning solutions (HBLS) can be developed with different approaches in organizing learning processes. For example, adding online activities to traditional in-person classes, designing blended learning paths with flexible spatial/temporal distribution of activities between presence and distance, setting up specific platforms as integrated learning environments (Alammary, 2014).

However, the preparation of teaching staff and institutions for the integration of digital tools in teaching has not always produced quality results, and this critical issue became particularly clear when the Covid-19 pandemic forced the online transition (De Rossi & Trevisan, 2022; Trevisan et al., 2021; Trevisan & De Rossi, 2022; Zhang et al., 2022).

The challenge has been taken up in 2021-22 by the University of Padua as part of the *Teaching4Learning@Unipd*® (T4L) Project, which has as its main objective the improvement and innovation of university teaching through faculty professional development (De Rossi & Trevisan, 2022). An extensive program has been initiated to disseminate blended learning mode (upon faculty adherence, with the coordination of course chairs) to implement online lesson delivery for up to 10% of lecture hours (Ministerial Decree 289/21).

Research Questions and Instruments

The research was realized as a case study (Yin, 2009), guided by the following research question:

- how do students perceive the efficacy of a HBLS course in the STEM area?
- how do they perceive the teaching modalities?
- how do they perceive the different assessment methods?

Its context was the course of Fundamentals of Analysis and Probability (Computer Engineering curriculum) at the university of Padova, in the academic year 2022-2023. This context was deemed relevant to the research question because this was the first time the course implemented HBLS consistently.

A total of 200 students enrolled in the course were selected as participants for the case study, through a conventional sampling technique. The students were adequately informed of the means and scope of the research.

Further, the cohort of students was divided in two groups, namely A (n = 100) and B (n = 100). This was due to the classroom capacity, not research design. The two groups were divided according to their matriculation number but no differences whatsoever occurred in their education. The same face-to-face and online activities were realized in both groups, with the same percentage (1/3 online and 2/3 face-to-face), the same organization of the space on the Moodle platform and support materials.

The two groups had the following demographic characteristics: students in their first year of higher education, mostly male (85%) and with an average age of 20.

The course

The HBLS design of the course aimed to integrate the contents of the Mathematics discipline with those of Technology through the use of digital resources, while activating collaborative and reflective processes in students between presence and distance, using the MOODLE platform. The teaching approach was that of the STEM disciplines, which is based on an interdisciplinary design and methodological orientation that stimulates the integrated development of disciplinary and transversal skills required by the labor market (Kennedy & Odell, 2014). The STEM teaching method encompasses an innovative teaching method aimed at enhancing the connections between the disciplines (i.e., mathematics and technology as a transversal skill), enabling the student to have a critical reading of everyday events, to improve their cognitive reasoning and problem solving processes, and to have a greater capacity for communication (Ortiz-Revilla, 2022).

Several conditions can favor the effectiveness of STEM teaching, such as the use of technologies as a support to teaching (not as a substitute for the teacher); the integration of approaches typical of direct instruction and of collaborative instruction (especially if based on structured meta-cognitive strategies and based on pair-work or small group work); the valorization of teacher-student and peer feedback with a formative function (Allan et al., 2019). However, Evidence Based Education research data show that it is not technologies that are the main factor affecting the quality of teaching, but rather teaching strategies and methods (Hattie, 2009, 2012; Calvani, 2014).

For this reason, special attention was paid in this course to the instructional design for both groups A and B. Maximum consistency was sought between in-presence (2/3 of tot hours) and distance activities (1/3 of tot hours); the diversification of teaching formats suited to the different training objectives (frontal lessons and workshops for group work), of teaching resources and strategies (Mariconda, 2023), MOOCs for flipped classroom experiences (Mariconda, 2020); Perusall for the creation of peer review strategies; ChatGPT and in general Artificial Intelligence to generate tasks to be carried out autonomously.

Two assessment strategies were used:

- for attending students: formative assessment through weekly quizzes, shared comments (using Perusall), peer review and summative test at the end of the course;
- for non-attending students: a summative assessment in the institutionally mandated exams sessions.

It should be noted that attendance to class (either face-to-face or online) was not mandatory, and students attending the HBLS activities were 128.

The course quality was monitored through two instruments: a Wooclap survey on the MOODLE platform, administered by the lecturer at the end of the course to the attending students, to record: participation in the distance activities; students' perceptions of teaching methodologies and assessment strategies proposed in HBLS modality; students' perceived effectiveness of the course on their learning. The second instrument was the institutionally-mandated questionnaire, to be filled in before enrolling for the final exam, of which we will consider the items relating to overall satisfaction, HBLS organization, perceptions of the lecturer's action, contents and program offered, and the perceived workload.

In addition, the pass rate of the final examination at the end of the course was considered, distinguishing between the results of the attending students (i.e. who benefitted from formative assessment) and those not attending. Such final examinations consisted in solving mathematical and engineering exercises, applying the theoretical knowledge addressed during the course.

The passing rate was considered relevant to the research question because it indicates the effectiveness of the course in fostering learning in the students.

Results

The first analyzed data come from the lecturer's survey administered to both groups at the end of the course lessons but before the final examination (January 2023). A total of 128 students took part in the survey, answering the 4 questions on:

1. attendance to peer review activities during the course;
2. preference for HBLS also in other courses – as an index of satisfaction with the teaching modalities implemented;
3. perceived effectiveness of HBLS and formative assessment for their own learning;
4. perceived effectiveness of HBLS in fostering content learning.

Table 1 synthesizes the results.

	Yes	No	Indifferent/ I don't know
1. I participated in the peer review and in at least half of the weekly quizzes.	124 96,88%	4 3,13%	0
2. I would like to attend other courses in the future with the HBLS mode used in this course.	70 54,69%	31 24,22%	27 21,09%
3. I would like in the future to attend other courses offering the type of in-progress assessment used in this course.	87 67,97%	25 19,53%	16 12,50%
4. I feel that the mode used in this teaching (HBLS + formative assessments) enabled me to learn the content better than a traditional course.	75 58,59%	25 19,53%	28 21,88%

Overall, attendance to at least half of the blended learning and peer assessment activities was at a positive level (62% out of the total of 128 students taking the survey), taking into account that attendance at lectures was not compulsory.

The answers to the next three questions (2,3,4) are affirmative for more than 50% of the respondents. In particular, with regard to the possible opportunity to be able to apply the formative assessment with diversified tests realized during the learning pathway to other subjects (67.97%).

The institutional survey was mandatory for the entire cohort (N = 200) and anonymously filled out. From the data extracted from the institutional survey (N = 200), some differences can be seen between the assessments (score 0-10) of participants.

Below we will present a summary of the results of the different sections of the questionnaire comparing the responses of the group A and B. indeed, data was gathered divided by group.

Overall satisfaction: group A recorded an average score of 6.96 out of 10 (20.2% answers with a rating lower than 6; 60.6% answers with a rating between 6-8 and 19.9 answers with a rating between 8-10). Group B, instead had an average score of 8.08 (3.9% answers with a rating lower than 6; 53.25% answers with a rating between 6-8 and 42.85% answers with a rating between 8-10).

Organization of the course: this section groups together a set of questions relating to the teacher's clarity in presenting the training objectives, the mode of assessment, the appropriateness of teaching-learning time and the teaching material. In both groups the evaluations were positive. Students in group A evaluated course organization quality with an average score of 8.56 (8.05% answers with an evaluation below 6; 26.66% of answers between 6-8; 55.56% answers with an evaluation between 8-10). Group B gave an average score of 8.74 (3.9% answers with an evaluation below 6; 53.25% answers with an evaluation between 6-8 and 42.85% answers with an evaluation between 8-10).

Teaching activity (teacher's action): this section includes questions relating to students' assessment of the teacher's actions: motivating and arousing interest in the discipline taught; clarity of presentation; willingness to provide clarifications and explanations; perceived usefulness of the workshops and other learning activities on offer. As can be seen in the table (the complete data on all questions in the section of the questionnaire on teaching activity), there are differences between the evaluations of the two groups of students. In particular, the evaluations of group B in all questions are > 8 (%) (Table 2).

Table 2 - Teaching activities data

Teaching activities	Avg (dev. St.)		< 6 (%)		6-8 (%)		>8 (%)	
	A	B	A	B	A	B	A	B
Teacher action to stimulate motivation and interest in the discipline.	6.93	8.22	19.19	5,19	51,52	42,86	29,29	51.95
Clear definition of assessment methods.	6.84	8.00	21.21	3,9	52,53	55,84	26,26	40.26
Availability of the teacher to give clarifications and explanations.	8.52	8.93	6.19	0	34,02	33,33	59,79	66.67
Perceived usefulness for learning the discipline, derived from workshops and other proposed teaching activities	7.34	8.30	14	4,92	53,52	44,26	32,04	50.82

Content and program: the section includes two questions; one on the coherence between the course syllabus and the activities carried out, and the other about student interest in the content. In group A, the average score of the two answers was 7.85 (10.13% average of answers with a rating lower than 6 in the various aspects investigated; 46.38% answers with a rating between 6-8; 43.48% answers with a rating between 8-10). In group B the average score was 8.36 (4.6% answers with a rating lower than 6; 42.72% answers with a rating between 6-8 and 52.76% answers with a rating between 8-10).

Perceived workload: this section includes one question about whether students believe they had adequate prior knowledge to understand the course topics. It also has another question regarding the perception of the appropriateness of the assigned workload, considering the amount of course credits (Table 3).

Table 3 - Perceived workload data

Perceived workload	Avg (dev. St.)		< 6 (%)		6-8 (%)		>8 (%)	
	A	B	A	B	A	B	A	B
Adequacy of prior knowledge	7.67	8.06	10.02	3,09	57,14	55,84	32,36	40.26
Adequacy of the required study load	5.22	6.84	49.49	23,38	40,04	42,86	10,11	33.76

A final reflection was conducted on the data collected through final examination results from the 2013/2014 academic year considering the methodological and evaluative transformations made to teaching over the past decade by the same lecturer.

Until 2013/14, this course was carried out exclusively in the classroom, with face-to-face lectures and traditional assessment methods (summative, with a final exam). The average pass rate was 35% in the first session after the course and 55% in the following exam sessions.

From 2014/15 to 2021/22, the course continued to be taught in the traditional mode (face-to-face only), but changing the mode of assessment. For attending students, various types of activities and assessments with feedback (formative assessment) were instituted, as well as a final examination at the end of the course. For non-attending students, only the final exam was maintained for each exam session (summative assessment). The average pass rate of the examinations for students who carried out the formative assessment activities during the course, in the years taken into consideration was: 50% pass rate in the first session after the course and 60% in the other subsequent sessions. Grades were between 18 and 26 for 57%, between 27 and 30 and Honors for 43%.

For the academic year 2022/23, the teaching was carried out using the HBLS approach and considered in this study included a formative and summative assessment. 69% of the students passed the final examination (21% with a grade between 18 and 26, 79% with a grade between 27 and 30 and Honors). 76% of the students passed the exam in the subsequent winter and summer sessions.

Conclusion

Overall, the feedback provided by students through the teacher survey showed a high percentage of participation in blended learning and formative assessment activities, out of the total number of students enrolled. The idea of extending this way of organizing the course to other disciplines was well received by most of the students involved, although for around 20% the response was negative. This can be explained by the subsequent analysis of the data from the institutional evaluation questionnaire. As can be seen from the workload perceptions, in general the lowest ratings were recorded on the adequacy of the workload required (Table 3). In fact, despite success in terms of passing exams and grades obtained, satisfaction on this dimension was lower in academic year 2022-23 than in previous years when teaching was delivered in the traditional mode. Despite adherence to the institutional load of 25 working hours per credit and the reduction of the number of lectures by a third in favor of online teaching, the amount of autonomous and group work, to be carried out at times other than lectures, was perceived as excessive. One explanation could be related to the busy academic calendar, with a few weeks of intensive coursework close to exam sessions, as opposed to more diluted periods for subsequent exam sessions. The concentration of the course in a few weeks may not be entirely adequate to support continuous formative assessment activities. A less demanding formative assessment might be more effective. The help provided by ChatGPT and generative Artificial Intelligence in homework could be more adequate if a part of the formative assessment was carried out in the classroom (Liu & Gibson, 2023).

These considerations align with the University's guidelines on blended teaching, which encourage lecturers, together with course chairs, to consider spatio-temporal organization as a crucial element of teaching quality, especially in HBLS environments.

A final interesting element is the figure that emerged in the section of the institutional questionnaire devoted to Teaching Activities. As mentioned above, the teacher, activities, time, digital resources and assessment methods were the same for both groups of students considered, however the evaluations of the various questions, although overall above sufficient, returned by the

students in group A are on average 1 point lower than those of the students in group B. This set of data aligns with the statements of Evidence Based research (Hattie, 2012) that highlight the relevance of the teacher's methodological action, rather than just the technological equipment, and the students' awareness of the changes they will have to face when faced with innovative HBLS teaching. Indeed, again according to Evidence Based literature, technological implementation in education is most effective when it is guided by active learning strategies; when multiple learning possibilities are implemented; when the student is facilitated in the autonomous use of digital resources and when peer learning and feedback are optimized (Marzano & Calvani, 2020). This requires the competence not only of the teacher, through specific training, but also of the students, so that they are effectively prepared to learn in an innovative way (Coggi & Ricchiardi, 2018).

The case considered has some limitations when considering the application of the intended STEM teaching approach, which did not span the entire curriculum with more than one course in the STEM area disciplines but was only applied to one course in which the learning objectives of mathematics and technology were integrated. However, the relevance of the study lies in the context of the bachelor's degree in Computer Engineering, which is fully within the STEM area, and in the didactic design developed that addresses the learning objectives in an interdisciplinary manner and with an active learning approach (student-centred participatory and collaborative learning) (Kennedy & Odell, 2014). This activity is part of the policies undertaken by the University of Padua to promote the STEM area. Starting from the academic year 2022-23, the university has implemented a dedicated platform that also offers postgraduate master courses in this area (e.g. Omics Data Analysis; Biostatistics for Research and Scientific Publication; Advanced Biostatistics for Clinical Research; Pharmaco-epidemiology and Evaluation of Integrated Care; Geostatistics for Human, Animal and Environmental Health; Machine Learning and Big Data in Precision Medicine and Biomedical Research; Synthesis of Empirical Evidence and Reproducibility of Research).

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