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University Students' Perceptions of the B-Learning Methodology

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The times of the last pandemic that plagued humanity challenged educators to find alternatives to face-to-face teaching, which arose through technological applications. Based on the symbiosis between face-to-face teaching and distance learning, this study seeks to gain insight into the perceptions of Mathematics and Biomedical Sciences students at a Portuguese public university regarding the b-learning methodology, as well as to identify the underlying factors that determine these perceptions, through their responses to an online survey. Adopting a quantitative approach, this study describes the students' perceptions of the two courses, identifying characteristics related to their role in this learning modality. An exploratory factor analysis revealed four factors: learner receptivity towards the distance component, learner-learner interaction, learner-instructor interaction and transactional distance. The present findings revealed significant differences between the two courses, particularly in relation to the first factor. Mathematics students had lower factor scores compared to Biomedical Sciences students. Spearman correlation analysis identified effective time management as a crucial work habit associated with all four factors. Regarding the availability of resources, successful adaptation to distance teaching and learning platforms emerged as the primary characteristic correlated to the four factors. Additionally, learner receptivity towards the distance component, learner-instructor interaction and transactional distance were identified as the main factors associated with student motivation towards b-learning. This study suggests that while the b-learning approach proves to be suitable in terms of facilitating dialogue, the distance component has revealed its weakness, especially posing greater challenges for Mathematics students.

Introduction

The evolution of technology has sparked research interest in debating teaching and learning methods. In an era in which information, knowledge and skills development are not exclusive to schools, teaching and learning scenarios are emerging that go beyond the classic classroom setting, such as blended learning (Cobo & Moravec, 2011; OECD, 2016, 2022; Sheninger, 2019). The blended learning (also known as b-learning) is a mixed teaching approach that combines face-to-face and online methodologies, offering greater flexibility in the learning process (Bergamin et al., 2010). To transition back to the traditional face-to-face teaching after the period of (compulsory) distance learning imposed during the COVID-19 lockdown, many higher education institutions (HEIs) embraced the opportunity to incorporate b-learning as the primary teaching approach in several courses. Indeed, in the wake of the Covid-19 outbreak, b-learning became a highly relevant topic among scholars and a central feature of educational approaches (Ocak & Ünsal, 2021). Since then, and even prior to the pandemic era, the b-learning methodology has been emerging as an alternative to fully in-person or remote education, thus adapting to diverse educational contexts. In this setting, the teacher (or instructor) acts as both a traditional educator and as an online tutor (Bervell & Arkorful, 2020), encouraging the combination of communication technologies with guided learning development (Salas-Rueda, 2020). In a traditional face-to-face learning setting, classes are conducted entirely in the physical classroom with the presence of both the learner and the instructor. In this format, the instructor takes on an active role in guiding and facilitating the students' learning process. In the distance or remote learning known as e-learning (Nicholson, 2007), instructional materials are delivered via the Internet. In this approach, the instructor focuses on organizing and arranging online activities to enhance the learning process.

The integration of online distance education components into the learning process has prompted to investigations into theoretical frameworks such as transactional distance (Moore, 1993), as well as various forms of interaction among educational stakeholders, including learner-learner interaction (LLI) and learner-instructor interaction (LII) (Kuo et al., 2014) on online learning modalities. The Transactional Distance Theory, as described by Moore (1989), focuses on interactions within educational settings. Moore proposed that distance is a pedagogical concept that includes the strategies used by teachers, learners and institutions to bridge geographical gaps. This theory considers the dynamic relationships between environments, individuals and behaviours. Transactional Distance (TD) is present in all educational contexts, whether face-to-face or remote. Wherever there is a learner, a teacher and a communication channel, there is some degree of TD.

Building on Moore's model, forms of interaction in online learning as LLI and LII have been proposed. LLI refers to bidirectional communication between or among learners discussing and exchanging information about course content, and LII refers to two-way communication between learners and the instructor of a course with discussion prompts and timely responses. In distance learning, LLI and LII differ substantially from traditional face-to-face classrooms due to the absence of a shared physical space, resulting in a clearer distinction between instructors (teachers) and learners (students). This leads to a heightened sense of distance between learners as well as between learners and the instructor, impacting communication and psychological aspects of the teaching-learning process (Rahman et al., 2022). Consequently, both instructors and learners are affected by their experiences and interactions within the educational context.

Inspired by the transition to a b-learning methodology during the COVID-19 pandemic and aligned with the framework of LII and LLI, this study seeks to gain insight into the perceptions of Mathematics (Math) and Biomedical Sciences (BS) students at a Portuguese public university regarding b-learning, as well as to identify the underlying factors that determine these perceptions. The courses were chosen for convenience. The focus is on interpreting and comparing students' perceptions, grounded in the LII and LLI framework, exploring their experiences in b-learning in relation to these factors, and identifying key characteristics linked to their roles as learners in the b-learning context. Alongside the established dimensions LLI, LII, and TD, an integrated factor—'Student Receptivity to the Distance Component' (LRDC)—emerges in this study, encompassing various issues connected to the interaction patterns described by LII and LLI.

Student characteristics are taken into account, as they are identified in the literature as potentially having an impact on engagement with distance learning, including the physical learning environment and work habits (Zhao et al., 2021; Freitas et al., 2020), technological ability (Bawaneh, 2021; Christensen et al., 2001), and motivation (e.g., Mahande & Akram, 2021; Sarıtepeci & Çakır, 2015; Freitas et al., 2020). Therefore, with reference to empirical data obtained from an online survey, the following research questions are discussed:

Q1: Which factors determine the perceptions of Math and BS students regarding the b-learning methodology?

Q2: Are there significant differences in the perceptions between Math and BS students?

Q3: Are there significant associations between students' perceptions on b-learning methodology and digital instruments and technological conditions available to the students?

Q4: Are there significant associations between students' perceptions on b-learning methodology and their work habits?

Q5: Are there significant associations between students' perceptions on b-learning methodology and their motivation for b-learning?

Theoretical Framework

Networks of computers interconnected on a global scale have led to the appearance of new communication tools, such as email, forums, blogs and communication platforms, such as Moodle, Zoom and Teams. These tools have become efficient and fast, capable of being processed synchronously and/or asynchronously. One-to-one communication, as expected in the interactions LII and LLI, as well as group communication that emphasizes social interaction in the construction of knowledge (Wenger, 1998), have challenged the role of both learners and instructors within online learning systems insofar as both communication formats involve technology as a mediator for the interactions LII, LLI, and sharing of knowledge between instructors and learner (Garrison &Vaughan, 2008). With the advent of information and communication technologies (ICT), online learning emerges reconciled with e-learning and b-learning models.

A growing number of articles in the scientific literature considers e-learning as a form of distance learning. According to Lencastre and Coutinho (2015), e-learning can have different meanings: some emphasize its capacity of obtaining information via the Internet or to learn through multimedia tools; while others define it as a pedagogical approach that fosters communication, collaboration and cooperation in a virtual space. E-learning enables the personalization of the learning experience by allowing for: (1) an increase in LII; (2) bilateral communication; (3) synchronous and asynchronous communication; (4) the inclusion of collaborative strategies; (5) learning mediated by materials and strategies that encourage students to process information autonomously; (6) a systematic collection of data; and, (7) an update of relevant information in real time.

B-learning has two distinct interpretations that are not mutually exclusive: (1) the information is disseminated and becomes accessible only through technological communication tools as a complement to the on-site communication; (2) the information is diffused, and the participants are spatially distributed. According to Lencastre and Coutinho (2015), although the concept of b-learning has historically aligned more closely with the distance learning model, face-to-face classes have evolved into a learning approach enhanced by ICT. Based on this perspective, the teacher is not expected to interfere in the several assignments during the face-to-face session, allowing students to be more independent in certain activities, while recommending different tasks using ICT, beyond the moments dedicated to the classroom participation.

Researchers have explored the connection between b-learning and sustainable development, which has contributed to the emergence of innovative pedagogies (Caird & Roy, 2019), even before the COVID-19 crisis. Graham (2006) notes that, initially, b-learning was also used as a bridge between classroom-based and computer-mediated distance learning. More recently, with the proliferation of the Internet and learning management systems, the concept of b-learning expanded to include various combinations of online and face-to-face instruction.

As referred by Lencastre and Coutinho (2015), b-learning can also be analysed through the concepts of synchronous and/or asynchronous learning. Synchronous learning occurs for all students that attend the same classes at the same time as if they were in a physical classroom.

However, they are in a virtual classroom accessible via the Internet. In this context, communication may occur through text-based tools, such as instant messaging, or through audio and video channels. Conversely, asynchronous learning takes place at different timetables for each student, taking into account their own schedule and needs. Examples of asynchronous activities are forums and email. When both synchronous and asynchronous learning are used, a b-learning approach emerges, allowing learning to take place anywhere and at any time, using any kind of electronic device (e.g., computer, smartphone, tablet, and so on).

The transactional distance (TD), developed by Moore (1993) and discussed in both the context of e-learning and b-learning (Ekwunife-Orakwue & Teng, 2014), can be categorized into different dimensions: physical space (referring to the observable separation between learners and between learner and teacher), communication space (in the sense that it could be more difficult to clarify misunderstanding) and a psychological space (relating to the feeling of isolation).

In remote education, the separation between teachers and learners, either physically or virtually, requires the use of ICT. The interaction between behaviour patterns resulting from this gap plays a significant role in the learning experience. The theory of TD has extensively examined this interplay. The three dimensions explored in transactional distance are dialogue, encompassing both LII and LLI, course structure and learning environment flexibility, and student autonomy for self-learning (Moore, 1993). A decrease in the frequency of dialogues between students and teachers (LII) and among students (LLI) leads to higher levels of TD. Dialogue, promoting knowledge among students, is an active pattern of behaviour in the teaching and learning process. Additionally, students perceive higher TD when the course structure is rigid, or the learning environment lacks flexibility (Karaoglan-Yilmaz et al., 2022). According with Moore (1993), and as highlighted by Karaoglan-Yilmaz et al. (2022), both interactions LII and LLI play a key role in the learning process, but LII is more valued in a learning environment depending on students' motivation, satisfaction, interest and teacher's guidance, feedback and encouragement (Kuo et al., 2014). Nevertheless, in the recent pandemic context, analysing the perceptions of 56 Math students regarding online distance learning during the first wave of the COVID-19 crise, Freitas el at. (2020) found that, although the majority (62.5%) preferred predominantly face-to-face instruction, the expected LII was less effective while the LLI, promoted by group activities among learners, was a positive aspect highlighted in the distance learning among students.

Several studies have showed that LII is a significant predictor of student satisfaction (e.g., Kuo et al, 2014; Bağrıacık Yılmaz, 2023). Therefore, understanding that student characteristics which may influence this satisfaction and their engagement with distance learning is essential for developing strategies that enhance student experience and motivation within the b-learning methodology (Sarıtepeci & Çakır, 2015). Perceptions of physical learning environment have been shown to impact students' distance learning experience. Zhao et al. (2021), in a study of 406 students during the COVID-19 pandemic, found that environmental comfort played a substantial role. Good physical conditions not only support physical health and enhance motivation but can also alleviate negative emotions such as anxiety and isolation. Technical support also emerges as a significant determinant of student satisfaction in distance learning. Christensen et al. (2001), in a study involving 399 undergraduate and graduate students enrolled in online courses, and so expectably more receptive to that kind of learning environment, emphasized the relative importance of perceived technological usefulness. The authors argue that providing a technology-mediated distance learning environment is not, by itself, sufficient for students to regard this modality as viable. Instead, it must be accompanied by a strong

perception of the usefulness of the technology involved. Communicating both the utility and the demonstrable outcomes of these technologies can help foster greater receptivity among current and future distance learners. Additionally, Al-Rawashdeh et al. (2021) reported that insufficient support for students in e-learning environments limits their effectiveness, particularly in enabling social interaction with peers and instructors.

The success of b-learning depends on multiple factors. Min and Yu (2023) identified six critical areas for its effectiveness: student profile, teacher training, course design, technological infrastructure, institutional support and learning environment. In this work, student characteristics will be analysed within the frameworks of LII and LLI, situated within the broader TD theory, aiming to explore the correlations among these elements.

Method

The current study followed a quantitative paradigm in order to identify patterns, test relationships, and compare results (Creswell, 2012). To identify factors related to b-learning method, an Exploratory Factor Analysis (EFA) (Hair et al., 2010) is carried out. Since b-learning often involves many interrelated factors, it is crucial to understand how these elements are associated. Correlational research methods (Gall et al., 2003) based on Pearson's correlation are used to examine linear relationships among the estimated score factors. To explore associations between these factors and students' key conditions reported on b-learning context, correlational methods based on rank-order Spearman's correlation are applied, as the items related to these conditions were measured using Likert scales.

Participants

By convenience of the authors, this study was carried out with Mathematics (Math) and Biomedical Sciences (BS) undergraduate students enrolled at a Portuguese university in the academic year 2020/2021, when the b-learning methodology was widely applied as consequence of COVID-19 pandemic crisis. A total of 179 undergraduate students (54 from Math and 125 from BS) provided complete responses to the questionnaire. The difference in group sizes (Math vs. BS) proportionally reflects the total number of students enrolled in each course in 2020/2021 (Math=117; BS=255). Although the proportions observed in the sample closely mirror those in the population –with Math representing approximately 31% (117/(117+225)) of the population and 30% (54/(54+125)) of the sample, and BS accounting for the complementary proportions–, no stratification was applied by design. This indicates that the distribution of the sample is proportionally consistent across both courses, despite being randomly determined.

Most of the participants were female (82.7%), aged in the range of 20–23 years old (54.7%), and affirmed to spend more than 50% of their online time working on their undergraduate degree (68.7%). Almost half (49.7%) of the respondents indicated that they were able to manage their time efficiently. When asked about their preferred learning method, among the three already experienced before and during the COVID-19 pandemic crisis (b-learning, e-learning, face-to-face), although there were 16.8% and 12.8% who opted for e-learning and face-to-face methods, respectively, most participants (70.4%) indicated to prefer the b-learning method. Nevertheless, just over a third of the students (38.0%) indicated to be motivated to learn in a b-learning environment. Among those who expressed a preference for the b-learning method, 42.9% indicated a preference for having more face-to-face classes than online classes, while

25.4% stated a preference for having more online classes than face-to-face classes. The remaining students indicated that the experienced b-learning method was suitable for their needs. Regarding student conditions, most of the participants reported having adequate digital equipment (97.2%), access to an Internet connection (81.0%), gathering conditions that provide space, comfort, and tranquility (82.1%) and easy adapting to teaching platforms and online learning tools such as Moodle and MS Teams (88.8%). Interestingly, around 75.0% of the students expressed a sense of increased autonomy in their work rate within a b-learning environment.

Instrument

To further comparative studies between e-learning and b-learning, the questionnaire developed in Freitas et al. (2020) on student's perception of e-learning was adequately adapted for the current study. The adapted questionnaire contained five questions associated with the interest of the present research about b-learning. These five questions were named q3, q4, q5, q8 and q9 (see in Appendix) and were conceptualized in four statement main groups: demographic features (gender, age) and weekly online time dedicated to their course (q3–q5); learning resources and behaviours (q8); and issues concerning b-learning methodology (q9)

Each item in q8–q9 was rated on a 5-points Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Thirteen items in q8 were split into two parts: first part, with items 1.1–1.4, referred to learning resources, including the physical learning environment and technological skills, while the second part, with items 2.1–2.9, addressed learning behaviours, specifically work habits and motivation. These items were adapted from the following studies on distance learning by slight modifications for fitting to the context of the b-learning environment: items 2, 5–10 from Freitas et al. (2020), item 4 from Bawaneh (2021), items 1, 3 from Zhao et al. (2021), and items 11–13 from Mahande and Akram (2021). In summary, items 1–3 pertain to the technological and spatial comfort conditions of the student in their physical learning environment. Item 4 is focused on the student's adaptability to platforms used in distance education. Items 5–8 address the student's work habits, while items 9–13 are associated with the student's motivation for studying in a blended learning environment. Regarding q9, item 15 is about autonomy in the b-learning environment, and it is based on Mahande and Akram (2021). The other items, 1–14, are related to b-learning methodology and were adapted from Freitas et al. (2020). It is worth noting that items 2–7 and 8–12 correspond to statements related to LII and LLI, respectively, as proposed by Kuo et al. (2014) but adapted to b-learning context. Additionally, items 1, 13, and 14 are associated with motivation in distance education, as suggested by Freitas et al. (2020).

Data collection

Data were collected through an online questionnaire at the end of the second academic semester. The selection of participating students was not conducted through random sampling. The unique circumstances created by the pandemic allowed a larger number of students to experience the b-learning methodology. Although the collected responses may represent students with diverse characteristics, it is important to note that all participants experienced the same type of teaching environment, thus minimizing potential biases in data collection (Cavanaugh et al., 2023).

Data analysis

Based on the complete questionnaire responses, factors related to b-learning methodology were exploited using, firstly, Confirmatory Factor Analysis (CFA), and then Exploratory Factor Analysis (EFA). Interrelationships were examined using association statistical tests based on Pearson and Spearman correlation coefficients.

At the beginning, item 1 in q9 was reversed to a positive statement, where higher scores indicate better agreement. Median and interquartile range (IQR) were calculated for qualitative (ordinal) data collected in q9. Since items 1–14 in q9 were assigned to LII, LLI, and Motivation, as mentioned above, a similar 3-factor structure was explored for b-learning using CFA. The quality of the factor model fitting to the data was assessed by computing fit indices, namely the chi-square to degrees of freedom ratio (χ^2/df), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA). The following values were obtained: χ^2/df=3.07, CFI=0.832, TLI=0.785, RMSEA=0.108. According to widely accepted criteria (e.g., Hair et al, 2010), χ^2/df values slightly exceeding the commonly accepted threshold of 3 still fall within the broader acceptable range (i.e., below 5), suggesting a reasonable, though not optimal, model fit. Nevertheless, CFI and TLI values below 0.90 indicate inadequate model fit. Regarding RMSEA, values above 0.10 reflect poor fit. Therefore, the 3-factor structure (LII, LLI and Motivation) for q9 (restricted to items 1–14) does not adequately fit the data in the b-learning context.

An EFA including all items in q9 was conducted to comprehensively address research question Q1. Firstly, Bartlet's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were applied to evaluate the adequacy of a factor structure for the fifteen items in q9 concerning students' perceptions of the b-learning methodology. Once the structure was validated, the Principal Component method was applied to extract the factors. For a better interpretation of the factors, the loadings in the factor model were established using oblique rotation (direct oblimin). Oblique rotation was chosen over orthogonal rotation because it allows for inter-factor correlations (Costello & Osborne, 2005), providing a more realistic and interpretable factor structure in contexts where factors are conceptually related (such as LII and LLI within the b-learning context; e.g., Yu, 2022), or where potential features could be associated with different theoretical dimensions (e.g., LII and TD; see Table 1 in Results).

Student's t-distribution was used to test the significance of Pearson's correlation. The number of retained factors in the final factor model was based on Kaiser-Guttman rule. For the labelling of the retained factors in the final model, only loadings greater than 0.3 and item communalities exceeding 0.5 were considered (Hair et al., 2010). The reliability of the developed questionnaire on b-learning methodology and the identified factors were assessed by calculating Cronbach's alpha coefficient as a measure of internal consistency. The polychoric correlation matrix was used due to the ordinal nature of the items.

Once each factor has been identified, its score is estimated by averaging the scores of the items considered to describe the factor. In cases where a factor exhibits negative loadings, the corresponding items were reverse-coded. To address research questions Q1 and Q2, the normality of estimated scores for each factor was evaluated using the Shapiro-Wilk test. If the scores were normally distributed, a t-test was conducted. Otherwise, the sign test and Wilcoxon-Mann-Whitney test were performed for one-sample (Q1) and two-samples (Q2) cases, respectively.

To answer the last three research questions (Q3-Q5), factors and issues in q8 (related to students' available conditions, work habits, and motivation for the b-learning methodology) were first crossed. Then, for each factor-issue pair, two simultaneous Spearman's coefficient correlation tests were performed to test the existence of significant association per course. Bonferroni's method was applied to calculate the adjusted p-values in multiple tests.

For inferential analyses, a significance threshold p=0.05 was established. All statistical analyses were conducted using R software (R Core Team, 2021). The following packages were used: DescTools (Signorell, 2024), lavaan (Rosseel, 2012), nortest (Gross & Ligges, 2015), polycor (Fox, 2022), psych (Revelle, 2024).

Results

Most students expressed disagreement with statements related to the motivation for the b-learning methodology. Conversely, most students agreed with statements related to LII, LLI, and autonomy in the b-learning methodology. Evaluating the KMO's adequacy measure, it reports an overall value of 0.77, above the threshold of 0.7 (Kaiser and Rice, 1974). Bartlett's test (χ^2=1250.979, p-value<0.00005) pointed to the presence of statistically significant correlations between items. Therefore, both results support the factorability of the data set.

According to the Kaiser-Guttman criterion, four factors are considered. For the construction of a 4-factor model using EFA, the items 6 ("I reply to teacher messages when requested") and 12 ("Group activities provide opportunities to interact with other colleagues") from q9 were removed since they exhibited communalities very low (both around 0.35). Results of the EFA with direct oblimin rotation are depicted in Table 1.

Table 1. Factor loadings, communalities and explained variance by factor.

Items	F1	F2	F3	F4	Com.
1. In distance learning I miss contact with the teacher and colleagues*	**0.877**	-0.167	-0.133	0.019	0.685
2. It promotes interaction between teacher and students	**0.807**	0.058	0.107	-0.097	0.731
3. Provides convenient tools to communicate with other colleagues	**0.722**	0.248	0.058	-0.078	0.694
4. I can easily communicate with the teacher through different electronic means (email, zoom, ms teams, facebook, etc)	**0.322**	0.283	**0.408**	0.272	0.657
5. The teacher regularly poses questions for students to discuss outside of class	0.201	-0.084	**0.765**	**-0.354**	0.787
7. I receive timely feedback from the teacher whenever I need it	-0.136	0.008	**0.928**	0.189	0.840
8. With some frequency I interact with my colleagues about class contents	0.037	**0.864**	-0.101	0.094	0.754
9. I communicate with my colleagues through various electronic means (email, zoom, ms teams, facebook, etc.)	-0.124	**0.812**	-0.002	0.230	0.710
10. I share my ideas or reflections with other colleagues on topics presented in class	-0.001	**0.910**	0.030	-0.084	0.817
11. I comment on the other classmates' ideas or reasoning during class	0.154	**0.662**	0.120	**-0.474**	0.713
13. Learning in a b-learning environment is more motivating than through face-to-face classroom	0.**693**	0.022	0.090	**0.406**	0.787
14. A complete course can be taught without difficulty using b-learning	**0.483**	0.063	0.039	**0.574**	0.686
15. Strengthens the ability to perform tasks autonomously	0.162	0.216	0.137	**0.640**	0.611
Proportion of explained variance	0.239	0.231	0.141	0.118	---

**Reversed item. Com.=Communalities. Loadings higher than 0.3 in absolute value are indicated as bold.*

The final model resulted in four factors (F1, F2, F3, F4) capturing 66.2% of the data's variability. Focusing on higher loadings (i.e., higher correlations between items and factors), each factor can be interpreted. The factor F1, capturing 23.9% of the total variance, addresses students' feelings toward the b-learning methodology, capturing not only technological issues related to the development of communication with peers and teachers due to physical distance, but also the student's perception of their motivation for distance learning processes, the emotional gap created by the lack of contact with the instructor and their perceived difficulties in remotely delivered courses. This integrated factor resonates with Christensen et al. (2001), who addressed a range of interconnected elements related to distance learning receptivity, such as technological, reputational, and constraint-related issues, as well as learning preference. In this manner, F1 can be interpreted as student's receptivity to the distance component of the b-learning methodology and then it will be called Learner Receptivity towards the Distance Component (LRDC). It is worth noting that motivation (reflected by item 13) is positively and then intrinsically associated with this factor.

Factor F2, which explains 23.1% of the total variance, corresponds to the LLI dimension of the b-learning methodology, specifically focusing on student communication. Factor F3, explaining 14.1% of the total variance, captures the LII dimension of the b-learning methodology; this dimension encompasses items associated with communication between teachers and students, such as the frequency of teachers posting questions for discussion outside of class and students promptly responding to teachers' messages when needed. Factor F4, which accounts for 11.8% of the total variance, encompasses negative aspects associated with both LII and LLI dimensions (items 5, 11), while positively reflecting characteristics related to course structure (e.g., perceived difficulty, item 14), the learning environment (e.g., student motivation for this type of learning, item 13), and student autonomy (item 15). These positive and negative interplay patterns of F4 with the two dimensions of dialogue (LII and LLI), course structure and learning environment flexibility, and student autonomy reflect the behavioural patterns of the TD, in line with Moore's theory. Indeed, a higher score in F4 is associated with lower levels of LII and LLI. Additionally, a decrease in LII is associated with an increase in self-learning, leading to a greater likelihood of students engaging in autonomous study. Furthermore, a higher score in F4 is expected when students show a higher level of agreement regarding the flexibility of the course structure or the learning environment within a b-learning context. These patterns support the identification of F4 as representing TD.

Cronbach's alpha estimates a good global consistency internal of the survey (α=0.86) and for the four factors varying between moderately reliable (F3: α=0.69; F4: α=0.65) and highly reliable (F1: α=0.85; F2: α=0.84). It is worth mentioning that 5-dimensional factor models were also examined for the fifteen initial items. Although the inclusion of a fifth factor would allow the increase of the communalities of the items 6 and 12 from 0.35 to 0.64 and 0.74, respectively, the increase in the percentage of explained total variance is negligible, from 74.7% to 74.9%. Furthermore, the fifth factor, which was more correlated with items 6, 11, and 12, proved difficult to interpret and exhibited low internal consistency internal consistency, with a coefficient alpha (α) of only 0.52. Significant correlations were observed between LRDC, LII and LLI (Table 2).

The distributions of the estimated scores of the four factors are visually depicted in Figure 1. Levels of receptivity towards the distance component of b-learning were significantly negative, and levels of perception towards dialogue with teachers and peers were significantly positive (p-values<0.001). Transaction space or gap (TD) were not significantly perceived by the students in both courses (i.e., median did not differ from the neutral position 3; p-values>0.170).

Table 2 – Pearson's correlation values between factors

	F2 (LLI)	F3 (LII)	F4 (TD)
F1 (LRDC)	0.251**	0.310**	0.146
F2 (LLI)		0.254**	0.109
F3 (LII)			0.020

p-value <0.05; p-value<0.01***

When comparing the two courses, the data suggests that Math students experienced statistically significantly lower receptiveness towards b-learning (p-value=0.009, medianBS=2.50, medianMa=2.17) than BS students.

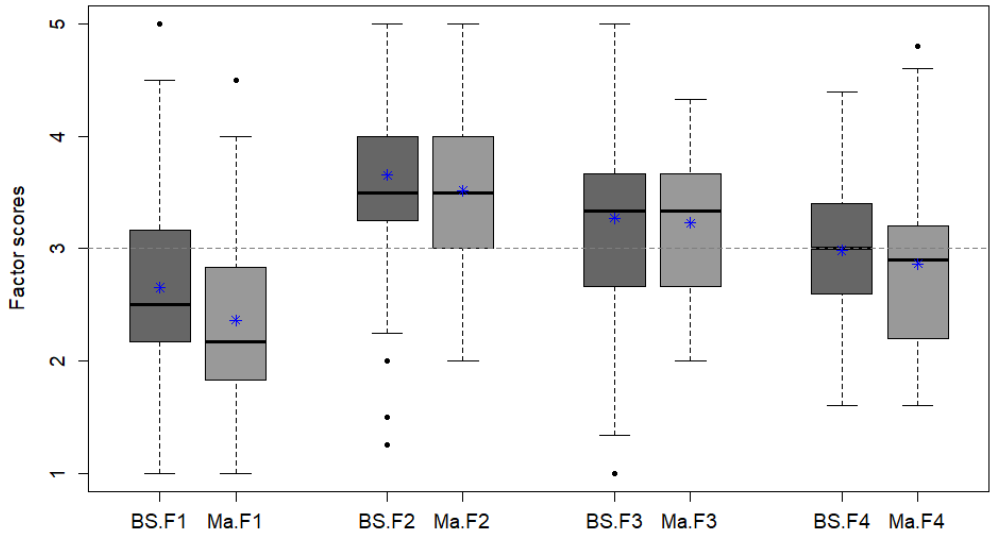

Figure 1. Comparative boxplots by degree and factor. The observed means are in *. The dot line is the neutral position.

(BS – Biomedical Science; Ma – Mathematics; Factors: F1, F2, F3, F4)

Spearman's correlation values between the four factors and student conditions are presented in Table 3. Regarding LRDC, in both courses, students who found it easier to adapt to distance learning/teaching platforms demonstrated greater receptivity towards the distance component of b-learning (corBS=0.27, corMa=0.41). However, notable differences in association patterns were evident when examining the relationship between LRDC of the b-learning approach and students' work habits. Specifically, among BS students, a positive correlation was identified between receptivity and their ability to effectively manage time (corBS=0.33), as well as their enjoyment of working independently (corBS=0.23). Conversely, for Math students, greater receptivity was solely associated with a higher level of comfort in searching for online information (corMa=0.31). Regarding LII and LLI, in both courses, the ability to manage time effectively is significantly relevant in establishing dialogue among students (corBS=0.22, corMa=0.44), and between teacher and students (corBS=0.33, corMa=0.41). In addition, the interaction between teacher and students is positively significantly correlated with ease of adaptation to online platforms for Math students (corMa=0.35), and with performance in both individual work (corBS=0.24) and group work (corBS=0.27) for BS students. Both BS and Math students are expected to experience greater TD when they find it easier to adapt to distance teaching and learning platforms (corBS=0.32, corMa=0.35). Furthermore, greater TD is expected among BS students who feel (i) more confident in their access to adequate equipment (corBS=0.22), (ii) more capable of managing their time effectively (corBS=0.25), and (iii) better adapted to working independently (corBS=0.30) and autonomously (corBS=0.26). On

the other hand, Math students who experience greater enjoyment from group work perceive a smaller TD (corMa=−0.43).

Table 3 – Spearman correlation between students' perceptions of the b-learning methodology and the available conditions and work habits of students (for details of each item see Appendix)

		Item in question q8 in the questionnaire								
Factor	**Course**	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**2.4**	**2.7**
LRDC	**BS**	0.08	0.05	0.05	0.27*	**0.33***	0.23*	0.02	0.19	0.01
	Math	0.18	0.23	0.21	0.41**	0.29	0.10	-0.26	0.31*	0.07
LLI	**BS**	0.02	0.05	0.13	0.05	0.22*	0.12	0.17	0.15	-0.02
	Math	-0.01	0.03	-0.04	0.09	**0.44****	0.06	0.27	0.23	0.01
LII	**BS**	0.09	0.15	-0.07	0.17	**0.33***	0.24*	0.06	0.27*	-0.07
	Math	0.29	0.20	0.15	0.35*	0.41**	-0.02	0.05	0.24*	0.08
TD	**BS**	0.22*	0.05	0.15	0.32*	0.25*	0.30*	-0.09	0.06*	0.26**
	Math	0.04	0.17	0.19	0.35*	0.12	0.23	**-0.43****	0.24	0.15

Adjusted p-value <0.05, <0.01**. Statistically significant extreme values by course are in bold.*

Spearman's correlation values between each factor and students' motivation for the b-learning methodology are shown in Table 4. For both courses, the greater the motivation for the b-learning methodology, the greater the LRDC of b-learning (corBS=0.64, corMa=0.73). Furthermore, students with greater receptivity are more open to carrying out activities using the Internet (corBS=0.30, corMa=0.49) and show increased interest in participating in extracurricular activities that foster their ongoing learning process (0.22≤corBS≤0.25, 0.33≤corMa≤0.44).

Table 4 – Spearman correlation between students' perceptions of the b-learning methodology and their motivation for b-learning. (for details of each item see Appendix)

		Item in question q8 in the questionnaire			
Factor	**Course**	**2.5**	**2.6**	**2.8**	**2.9**
LRDC	**BS**	0.30*	**0.64***	0.22*	0.25*
	Math	0.49**	**0.73****	0.33*	0.44**
LLI	**BS**	0.15	0.16	0.24*	0.26*
	Math	0.27	0.16	0.23	0.02
LII	**BS**	0.27*	0.31*	0.22*	0.23*
	Math	0.39**	0.35*	0.18	0.23
TD	**BS**	0.17	0.49*	0.03	0.12
	Math	0.31*	0.53**	0.27*	0.39**

Adjusted p-value <0.05, <0.01**. Statistically significant extreme values by course are in bold.*

Regarding LLI, more interactions among BS students are expected when there is greater motivation to engage in extracurricular activities that provide a break from their studies and encourage them to continue their learning process (0.24≤corBS≤0.26). Regarding LII, more interactions between teacher and student are expected in both courses when students are more motivated to engage in activities using the Internet (corBS=0.27, corMa=0.39) and to learn in a b-learning environment (corBS=0.31, corMa=0.35). Additionally, BS students tend to interact with their teachers when they take breaks from studying by participating in extracurricular activities that motivate them to continue their learning process (0.22≤corBS≤0.23).

For both courses, as the students show higher motivation to learn in a b-learning environment, TD increases (corBS=0.49, corMa=0.53). Among Math students, a stronger perception of TD is associated with higher motivation to (i) work using the Internet (corMa=0.31), and (ii) engage in extracurricular activities that foster their ongoing learning process ($0.27 \leq corMa \leq 0.39$).

Discussion

In response to research question Q1, the analysis revealed four factors. Interaction factors inherent to different teaching-learning methodologies, such as LLI and LII, were perceived positively by the students in the b-learning system. On the other hand, statistically significant low levels of receptivity to the distance component of the b-learning approach (LRDC) were detected. Indeed, the factor scores of LRDC predominantly showed negative estimates. Christensen et al. (2001) show that students enrolled in online courses display a slightly positive receptivity toward distance learning, which the authors attribute to a broader trend of increased comfort with technology and technological change among that cohort of students. However, the authors initially hypothesised that students would exhibit a more negative than positive attitude toward distance learning. One of their key arguments was that fear of the unknown might influence students' perceptions, particularly given that distance learning was at a relatively early stage at the time and was supported by a limited number of instructors and students experienced in online courses. A similar situation occurred during the pandemic crisis with the introduction of a b-learning environment, where both instructors and learners were, in general, unprepared. These circumstances likely contributed to lower levels of receptivity among learners accustomed to traditional educational settings.

Among the four factors identified, the correlation values are generally not strong, with the highest correlations observed between LII, LLI, and LRDC, all of which are significantly positive. The comparatively stronger associations between LRDC and both LII and LLI indicate that these interactions are particularly pertinent to receptivity, thereby corroborating the findings of Kuo et al. (2014), who highlighted the importance of these types of interaction in a learning environment, particularly the LII. Although the level of receptiveness may be low, students with more interaction with their teacher were likely to demonstrate greater receptiveness to the distance component of b-learning. In fact, in b-learning, the use of more interactive tools, such as videoconferencing and chat rooms, is more common in communication between learners and teachers.

Comparing the perceptions of Math and BS students and addressing research question Q2, statistically significantly differences were detected for LRDC, with Math students exhibiting lower perception. This may be attributed to the lower mathematics self-concept among online learners, as highlighted by Bringula et al. (2021). Mathematics self-concept refers to an individual's perception and understanding of their abilities and competence in mathematics. It includes beliefs, feelings, and thoughts about one's mathematical skills. In this context, a student with a negative mathematics self-concept may doubt their abilities, feel anxious about mathematical tasks, and generally hold a low opinion of their competence in the subject. Conversely, BS students demonstrate a higher self-concept, as noted by Regmi et al. (2024).

Concerning research question Q3, in Zhao et al. (2021) it is reported spatial comfort as one of the elements that best explains satisfaction regarding b-learning. However, one year after the sudden and unexpected shift to e-learning experienced during the first waves of the COVID-19 pandemic, results showed that the adequacy of students' workspaces is no longer a significant constraint for the distance component of the b-learning methodology. In fact, most students

claimed to have an adequate workplace with conditions that facilitate study and learning (q8 item 1.3: median=4, IQR= [4,5]). Therefore, it is expected that a better workspace will correspond to producing little impact. Surprisingly, students' perceptions of b-learning did not seem to be significantly influenced by the quality of their Internet connection. The shift to b-learning resulted in students adapting to online teaching platforms due to the reduced physical contact. Many students, being digital natives, possess the necessary digital skills to effectively utilize digital resources (Mpungose, 2020). In this study, students' ease of adaptation to computer applications and online platforms, which is influenced by their computer skills, was found to be positively related to transactional distance and receptivity towards b-learning. This aligns with previous research (e.g., see Kintu & Zhu (2016) and Lin & Vassar (2009)), which emphasizes the importance of learners' ability to handle technical difficulties and possess computer skills for successful b-learning. Experience with Internet use and computer applications has also been identified as a crucial factor for b-learning success (Picciano & Seaman, 2007).

Regarding students' work habits and answering the research question Q4, the results revealed that Math students who enjoy group work tend to perceive the distance transactional feature as less relevant. This aligns with findings from studies on LLI, which emphasize the importance of collaborative learning in reducing perceived distance (Achuthan et al., 2024). On the other hand, the students' ability to manage their time effectively tends to improve their interaction with peers and instructors in a b-learning environment. This is supported by literature indicating that time management skills are crucial for successful LII and overall student success in distance education. Moreover, BS students with better time management skills demonstrated greater receptivity to the distance component of b-learning. Kintu and Zhu (2016) reported a significant association between time management skills and motivation for b-learning, a finding echoed by other researchers (e.g., Rovai, 2003; Selim, 2007; Song et al., 2004).

Regarding motivation for b-learning and in addressing research question Q5, the results revealed that the students' receptivity towards the distance component, LII and their perceived transactional distance significantly impact their motivation for b-learning. This is particularly evident among Math students where lower levels of motivation correspond to lower estimated factor scores for LRDC, LII and TD. Thus, given the predominantly negative and positive score estimates for LRDC and LII, respectively, these outcomes may lead to the conclusion that while LII was meaningful during the implementation of the b-learning methodology, receptivity (LRDC), and consequently, motivation for the distance component of b-learning were perhaps insufficient. This issue is particularly critical in the Math course, where there is a trend towards lower scores related to the receptivity to the distance component. Since interaction perception has been shown to be an important predictor of satisfaction in online learning environments (Bağrıacık Yılmaz, 2023), and LII is more valued in a learning environment depending on students' motivation, among other dimensions (Kuo et al., 2014; Sarıtepeci & Çakır, 2015), the present study recommends giving greater attention to this interaction type.

Conclusions

B-learning is emerging as a viable and effective alternative in contemporary education. However, its implementation requires careful planning to be truly transformative. By examining two fields — Mathematics and Biomedical Sciences — traditionally dominated by face-to-face instruction, this study expands the discussion on b-learning and investigates key student characteristics relevant to this transition, offering insights to enhance the learning experience for both educators and students.

The findings indicated both LII and LLI were positively perceived by students from both courses. This is a significant point, as strong LII has been shown to improve student satisfaction and learning outcomes (Achuthan et al., 2024; Conklin et al., 2024). Additionally, in line with TD theory, engagement and effectiveness in distance education are improved when psychological and communication gaps between learners and instructors are minimized. Furthermore, receptivity to the distance component emerged as a weakness, with negative perceptions reported in both courses — notably more pronounced among Math students. Prior research, such as Vallée et al. (2020), has demonstrated that b-learning can outperform traditional methods in health-related disciplines, especially when online content is well structured and integrated with in-person objectives. This lower receptivity among Math students towards the online component may be attributed to the particularities of mathematical language, which involves formulas, graphs and the creation of geometric constructions. These elements complicate communication in remote settings, especially when using general-purpose digital tools. Effective delivery often demands specialized software and familiarity with less universally adopted ICT resources. These findings highlight the importance of tailoring b-learning design to the specific needs and challenges of each discipline. Future research and practical implementations should focus on developing discipline-sensitive digital resources — for example, specialised mathematical tools that facilitate clearer remote communication — and on strategies to foster receptivity towards distance components.

In examining key student characteristics, the ability to manage study time effectively and adapt easily to digital learning platforms were positively associated with students' overall perceptions of their b-learning experience. Conversely, collaboration with peers — specifically group work — was negatively associated with perceived transactional distance among Math students. Future work could explore the development and evaluation of practical interventions that support students in managing their study time and engaging effectively in blended learning contexts.

Limitations

One limitation of this study concerns the small sample size requiring future research to perform CFA with an independent sample to confirm the 4-factor structure herein identified. Another limitation is the imbalance in group sizes between the Mathematics and Biomedical Sciences courses. Although the sample proportions reflect the populational student distribution, the imbalance may reduce the power of comparative analyses. Furthermore, students were exclusively recruited from a single university population. As such, the findings should be interpreted cautiously, with consideration of these limitations, to avoid overgeneralization. Future studies may benefit from employing a more balanced or stratified sampling strategy.

Declarations

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Appendix

In this study, the responses to five questions from a questionnaire on b-learning, selected from a total of nine questions, were analyzed. These five questions, labeled as q3, q4, q5, q8, and q9 in the questionnaire, are associated with the focus of the present research on b-learning. They are listed below.

Label	Question	Option of answer
q3	What is your gender?	Female Male Diverse gender I prefer not to answer
q4	What is your age (in years)?	Less than 20 Between 20 and 23 Greater than 23
q5	Of the total time you spend online each week (on the Internet),), what percentage, on average, do you spend on your course?	Less than 25% Between 25% and 50% More than 50% and up to 75% More than 75%
q8	**Part 1.** Concerning physical learning environment and technological skills: **1.1.** I have equipment (laptop or other) with sufficient requirements for my activities as a student; **1.2** I can access the Internet with a good connection; **1.3** My workplace has conditions that facilitate studying and learning (space, comfort and peace); **1.4** I find it easy to adapt to the distance teaching and learning platforms used (such as Moodle, MS Teams or others); **Part 2**. Concerning work habits and motivation: **2.1** I am able to manage my time effectively; **2.2** I like to work independently; **2.3** I enjoy working with other colleagues, in a group; **2.4** I am comfortable with searching for online information; **2.5** I feel motivated when I have to carry out an activity using the Internet. **2.6** I feel motivated to learn in a B-Learning environment. **2.7** I notice that the amount of autonomous work increases with b-learning. **2.8** When I feel unmotivated, I try an activity, such as walking, cooking or something else. **2.9** After carrying out an activity, such as walking, cooking or something else, I return with more enthusiasm and motivation to study.	Totally disagree Disagree Neither agree nor disagree I agree I totally agree
q9	**1.** In distance learning I miss contact with the teacher and colleagues **2.** It promotes interaction between teacher and students **3.** Provides convenient tools to communicate with other colleagues **4.** I can easily communicate with the teacher through different electronic means (email, zoom, ms teams, facebook, etc) **5.** The teacher regularly poses questions for students to discuss outside of class **6**. I reply to the teacher's messages when requested	Totally disagree Disagree Neither agree nor disagree I agree I totally agree

	7. I receive timely feedback from the teacher whenever I need it **8.** With some frequency I interact with my colleagues about class contents **9.** I communicate with my colleagues through various electronic means (email, zoom, ms teams, facebook, etc.) **10.** I share my ideas or reflections with other colleagues on topics presented in class **11.** I comment on the other classmates' ideas or reasoning during **12**. Group activities provide opportunities to interact with other colleagues **13.** Learning in a b-learning environment is more motivating than through face-to-face classroom **14.** A complete course can be taught without difficulty using b-learning **15.** Strengthens the ability to perform tasks autonomously	

Note. Items 2.5, 2.6, 2.8 and 2.9 from q8 were excluded from the present analysis as they are outside the scope of the research questions. Original version is in Portuguese.