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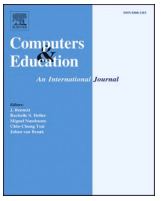

Learner behaviors associated with uses of resources and learning pathways in blended learning scenarios

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ABSTRACT

The objective of this research is to analyze learner behaviors, uses of resources and learning pathways in blended learning scenarios. Key principles and resources for blended learning practices are addressed in the theoretical framework, along with their relationships with learning pathways, student performance and ICT skills. A within-subject design was adopted, consisting in the application of an ICT skills survey to 92 low-income secondary school students from a Brazilian Northeastern public school, followed by the implementation of series of lessons comprising digital resources based on blended learning practices. Behaviors and uses of resources identified in screen recordings of learners' responses to tasks were contrasted among groups, learning scenarios and with regard to students' performance scores and ICT skills. Nonparametric tests pointed to significant differences between groups in terms of ICT skills and to no significant differences regarding performance. There were predominantly no significant differences within observed uses of resources and pathways in terms of associated performance or ICT scores. Differences between patterns of use and pathways observed in each lesson are analyzed. Data suggests pedagogical practices learners were previously exposed to impacted their engagement, and uses of different resources were interrelated in a systemic perspective. Task-orientedness, rather than approaches to digital tools or choices of pathway, emerges in discussions as a key factor for learner performance, reinforcing the importance of designing learning scenarios which promote behavioral engagement.

1. Introduction

Blended Learning practices have become increasingly popular over the past decades, often viewed as effective in promoting autonomy among different learner profiles in the context of the growing presence of ICT in educational systems (Boelens et al., 2017; Dziuban et al., 2018; Rasheed et al., 2018; Smith & Hill, 2018). But as the body of academic research on these practices evolves, new questions arise beyond their potential to promote learning in technology-mediated classrooms.

There is a need to understand the extent to which blended learning scenarios can be replicated and applied to different contexts through sets of adaptable frameworks and guidelines (Halverson et al., 2014; Rasheed et al., 2018). For this purpose, it's crucial to investigate the roles played by each of its components as well as their impacts on student's performance and behavior from a systemic

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perspective (Dziuban et al. 2018; Ramirez-Arellano, 2019; Valverde-Berrocoso & Fernández-Sánchez, 2020). Another important issue is the applicability of blended learning practices to different social groups considering variables such as age, race, socioeconomic status and geographic location (Hu et al., 2019; Kundu et al., 2021; Ruthotto et al., 2020). In this perspective, age and education levels or stages are also variables of interest as although several blended learning models for schools have been proposed over the past years, references for empirical research in these settings are still limited (Hu et al., 2019; Spring & Graham, 2017; Yang et al., 2021).

The objective of this study is to analyze learner behaviors, uses of resources and learning pathways in blended learning scenarios. This investigation also addresses possible relationships between choice of pathways and student performance, engagement, levels of familiarity with ICT and the teaching practices learners are predominantly exposed to. In this perspective, three research questions can be highlighted: how are learners' behaviors, uses of resources and learning pathways manifested in blended learning scenarios? What relationships are there between students' uses of resources, choices of pathways and their performance, engagement and levels of familiarity with ICT? Are the teaching practices learners were previously exposed to related in any way to their choices and behaviors regarding uses of resources and learning pathways? While the first question reflects the formerly expressed need to look beyond these practices' existing potential to promote learning, the follow-up queries point to roles played by the different components present in blended learning scenarios and their interrelationships.

2. Theoretical framework

Blended learning practices can take up different forms, gravitating around the key principle of combining face-to-face and online modes of communication (Dziuban et al., 2018; Horn & Staker, 2014; Smith & Hill, 2018) and incorporating different digital resources based on which lessons are structured.

2.1. Blended learning and digital tools

Audiovisual contents are often utilized in blended scenarios for delivering instruction (Allen et al., 2007; Laaser & Toloza, 2017), and their adoption by learners has been linked to perception of usefulness, enjoyment as well as connection with and relevance for graded assignments and exams (Pappas et al., 2017; Turan & Cetintas, 2020). For instance, association with a generative activity, first-person perspective and display of printed relevant written information to aid visualization and comprehension are characteristics known to engage learners which contribute to the effectiveness of the video (Mayer et al., 2020). Although the use of video as a learning resource has been comprehensively investigated over the years, there are still gaps in research regarding use-related behaviors (Pappas et al., 2017) as well as the consolidation of evidence-based principles for the design and use of these artifacts (Mayer et al., 2020).

Content-focused interactive applications are also frequently utilized in blended learning practices, addressing different user needs in terms of internet connectivity, modes of interaction and supporting devices, as seen in Ping et al. (2018) and Radović et al. (2020). These multimedia contents can aid understanding, recalling and application of concepts and facts as well as enhance problem-solving skills. Possible usage comprises in-lecture demonstrations and association with tutorials (Ping et al., 2018). Although learning apps can be designed to suit different modes of teaching (Pechenkina et al., 2017), literature sustains that such artifacts can be more effectively incorporated into blended learning practices, which intrinsically demand consideration of the nature of technology (Dziuban et al., 2018).

The Investigation of successful adoption of learning applications requires considering students' personal attitudes towards ICT, as these affect outcomes when learning is mediated by digital resources (Radović et al., 2020; Ruzek et al., 2016). Concrete design features such as accessible and understandable instructions also play a role (Falloon, 2013), along with aspects of subjective nature such as user perceived learning effectiveness and enjoyment (Wang et al., 2019; Zheng & Liang, 2017). With respect to subjectivity, Wang et al. (2019) also alert to possible method bias when findings rely solely on users' self-reported data, highlighting the importance of objective measurements.

Forums and message boards allow mediation of asynchronous interactions in blended and strictly online learning scenarios, fostering communication and types of interaction which are crucial for learning (Bliss & Lawrence, 2009; Delahunty, 2018). Non-active interactions such as viewing of content can also be relevant as predictors of peer learning and performance (Chiu & Hew, 2018). Forms of participation such as asking and answering questions, commenting and lurking (Chen et al., 2020; Ruthotto et al., 2020) are well documented behaviors. Nevertheless, in order to promote more effective discussions and meaningful collaborative learning (Chen et al., 2020; Delahunty, 2018), investigation of patterns of participation is still needed, especially within social minorities contexts and different demographic profiles (Ruthotto et al., 2020).

2.2. Learner engagement and performance

Although different views on learner engagement abound in literature, several researchers converge when it comes to acknowledging its associations with learning, academic achievement and performance, as well as describing it as a multidimensional construct which operates in the cognitive, emotional and behavioral domains (Fredricks et al., 2004; Reeve, 2013; Skinner et al., 2008). The behavioral component of learner engagement can be understood as the actions through which students take part in their learning processes (Sinatra et al., 2015). In this sense, observable markers such as intent towards a goal, delivery and time spent on task (Alexander, 2014; Taylor & Parsons, 2011; Vytasek et al., 2020) can be particularly relevant for the analysis of uses of resources by students in learning scenarios. The behavioral perspective can also be taken into account considering that the teachers' actions impact

learners psychologically triggering responses consecutive to underlying forms of engagement (Reyes et al., 2012; Roorda et al., 2011; Skinner et al., 2008). But in spite of its importance, the impact of the teachers' actions on students in blended learning scenarios remains under-investigated (Anthony, 2019).

Research carried out over the past decade has resulted in mixed findings on blended learning scenarios' potential to promote learner engagement, either associating it to higher levels in comparison to those obtained in traditional lessons (Delialioglu, 2011; Kundu et al., 2021) or concluding there was very little or no significant difference between measurements of predictors in the two types of scenarios (Baragash & Al-Samarraie, 2018; Dringus & Seagull, 2013; Law et al., 2019). Different results may also be observed when blended and non-blended scenarios are contrasted in terms of student performance, as the combination of face-to-face and online communication cannot be isolated as a single variable which determines better learning outcomes (Arrosagaray et al., 2019; Driscoll et al., 2012). Engagement and academic performance are heavily context-dependent, subject to factors which are typically characteristic of learning settings, such as the subject being taught or aspects of the learning design (Arrosagaray et al., 2019; Driscoll et al., 2012; Pöysä et al., 2018). The learning environment has a significant impact on students' abilities to engage in online and blended scenarios (Borup et al., 2021).

One contextual variable which is often discussed in terms of its possible effects on engagement and performance in technologically-enhanced learning environments is familiarity with technological tools. ICT skills are viewed as useful for learning in blended scenarios (Bueno-Alastuey & López Pérez, 2014; Kundu et al., 2021), and Hua et al. (2018) present evidence that familiarity with ICT impacts school achievement and performance. But they also highlight that researchers often reach diverging conclusions about this matter based on different study designs, given the very many associated variables at play such as age, grade, subject, school setting and the types of uses of technology focused on. Literature also presents mixed findings concerning the relationship between ICT and student engagement, either stating that technical skills do not have a significant impact (Cakir, 2013) or concluding that there may be a relationship mediated by related variables such as school engagement (Howard et al., 2016). In this sense, familiarity with technological tools needs to be taken as a variable of interest for the implementation of learning scenarios and the investigation of the use of digital resources by learners, especially considering that levels of familiarity with ICT and digital engagement can vary even in a single age group (Gurung & Rutledge, 2014; Rashid & Asghar, 2016).

2.3. Learning pathways

The term learning pathway refers to a learner's route through a variety of learning experiences towards a learning outcome (Falloon, 2013; Iatrellis et al., 2019; Ramirez-Arellano, 2019). Such trajectories are associated with the way students engage in their learning experiences (Calder, 2011; Reutlinger et al., 2019), and there is also evidence of potential relationships with achievement in the context of specific subject contents regarding the extent to which the adoption of a certain pathway contributes to a better learning performance (Kühne et al., 2013; Reutlinger et al., 2019). Furthermore, it is proposed that the suitability of a pathway comprising the use of technological tools hinges on the individuals' digital skills, and that through personalized pathways, individuals with different levels of knowledge of ICT can improve their skills (Różewski et al., 2019).

Two key principles which are often said to underlie blended learning practices are flexibility and autonomy (Dziuban et al., 2018; Horn & Staker, 2014; Smith & Hill, 2018), reflected in the variety of resources learners can choose from, based on their preferences and needs. In this perspective, blended learning practices can provide school programs with personalized and diversified pathways (Attard & Holmes, 2020; Yang et al., 2021). Halverson and Graham (2019) emphasize the need for looking into pathways in blended learning scenarios from an activity-level perspective in order to understand how learners engage in the use of technologies to achieve a learning goal. In this sense, Falloon (2013) addresses the role of educational apps in learning pathways, highlighting their potential for engagement and the importance of adopting resources and practices which contribute to a smooth distraction-free experience towards achieving a lesson goal. Attard and Holmes (2020) express a similar view, concluding that looking at pathways in learning scenarios, particularly regarding the integration and role of technology, is crucial for effectively informed pedagogical decision-making.

3. Method

This section describes the setting, resources and procedures for obtaining and analyzing data regarding the uses of resources and learning pathways observed in the blended learning scenarios.

3.1. Context and participants

This research was carried out in the outskirts of a 2.5 million-inhabited city located in the northeastern region of Brazil, at a small-sized state public secondary school attended by 273 students. This school is ranked on a 1–6 scale in the country's educational system's index of socioeconomic status[1] as level 2, meaning students belong to low-income families. They use cellphones on a regular basis, but access to computers and other ICT tools at home is limited. Although such devices are part of their school routine, effective use faces occasional challenges. Subnational and national educational policies in Brazil hold the integration of online communication and digital technologies to classrooms as a strategic goal, but the reality of most public schools still reveals serious struggles with outdated

[1] Information on The National Basic Education Assessment System can be found at *http://inep.gov.br/basic-education-assessments*.

equipment, insufficient internet connectivity and lack of efficient pedagogical practices, pointing to the need for investment in infrastructure and enforcement of national guidelines for teacher education (Organization for Economic Co-operation and Development [OECD], 2021).

Computer-assisted 10th grade math lessons were the setting for the implementation of the design. The rationale behind this choice considered the critical relevance of this subject given the role of mathematical reasoning in cognitive development, for which the teaching practices learners are exposed to constitute a crucial element (Spinillo et al., 2021), as well as the numerous challenges for mathematics education in Brazil (Ribeiro et al., 2018), especially with regard to the use of digital media to promote learning through collaboration and the need for teacher development aimed at pedagogically effective use of technology (Rosa et al., 2018). The study sample is composed of 92 students (♀ = 50; ♂ = 42) from the ages of 14–17 (μ = 15,3), divided according to school enrollment configurations into four groups which will be referred to as G_1 (N = 24; ♀ = 12; ♂ = 12); G_2 (N = 22; ♀ = 13; ♂ = 9); G_3 (N = 26; ♀ = 14; ♂ = 12), and G_4 (N = 20; ♀ = 11; ♂ = 9). Besides sharing a single syllabus, these groups also had the same teachers and were regularly exposed to the same set of pedagogical practices.

3.2. Methodological design

The study design consisted in exposing the 4 groups of participants to 2 blended learning scenarios structured as lessons featuring equivalent tasks and the same resources. This within-subject type of design (Maxwell et al., 2017; Mullet & Chasseigne, 2018) was conceived to analyze, compare and contrast choices, behaviors, performance and forms of engagement observed in each lesson.

The first of the two learning scenarios was implemented subsequently to a traditional lecture-based lesson focusing on the same content, and in which resources were used in a more teacher-centered single sequence of tasks. The idea was to look into whether student behaviors in the immediately upcoming blended learning scenario would be influenced by these practices, particularly concerning uses of resources and choices of learning pathways. A two-month interval was established to avoid memory or decisional carryover effects (Albers et al., 2015; Wehrman et al., 2020) on the second blended learning scenario, for which there was no previous lesson comprising any approaches to the same content subject and digital resources. As procedures and resources adopted in each learning scenario are described in the following subsections, this design will be referred to as *AB-B′*, with *A* identifying the traditional lecture-based lesson and *B* and *B′* the blended learning scenarios separated by the two-month interval, as shown in Fig. 1.

3.3. Components of learning scenarios

The learning scenarios conceived for this study featured the use of three open access digital resources based on which lesson tasks were structured.

3.3.1. Open learning object for exploring mathematical functions

The main component featured in the learning design was an open HTML-embedded web applet aimed at learning and practicing the concept of mathematical functions. Its interface displays a linear equation functioning as the processing algorithm of a manufacturing machine in which input and output respectively represent pre-images and images according to numerical values entered by users via keyboard. As more values are inserted, the applet shows the graph drawn from the *x* and *y* coordinates, as it can be seen in Fig. 2.

3.3.2. Short animated instructional video

A short animated video was produced with the aim of showing learners how the applet worked, which consequently also meant illustrating the concept of mathematical functions. The animation was essentially made from a screen recording of the applet in use, to which explanatory arrows and tags were added through a video editing software in order to highlight the functioning of the machine and the relationships between the values, the inputs and outputs as well as the coordinates in the graph.

3.3.3. Online message walls

A web-based application for generating and managing message walls was used with the purpose of providing the environment for the lessons' tasks to be displayed and for students' solutions to be presented. Wall page permissions set in the configurations menu allow access through a url link and enable users to post and view content such as text, images and video in real time. A screenshot exemplifying uses of the application can be seen in Fig. 3, showing both the area for posting and visualizing text, pictures and media as well as the configurations menu.

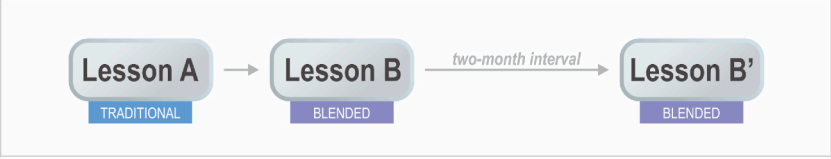

Fig. 1. Lessons in methodological design.

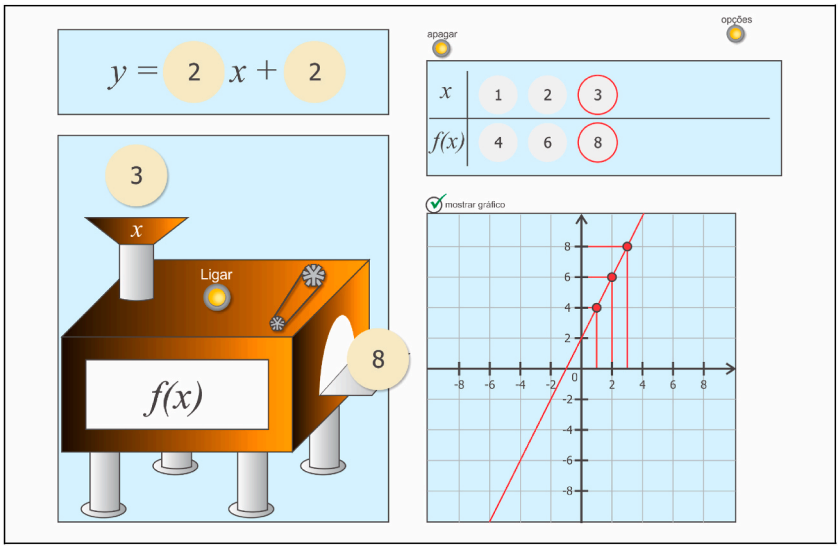

Fig. 2. Learning object screenshot.

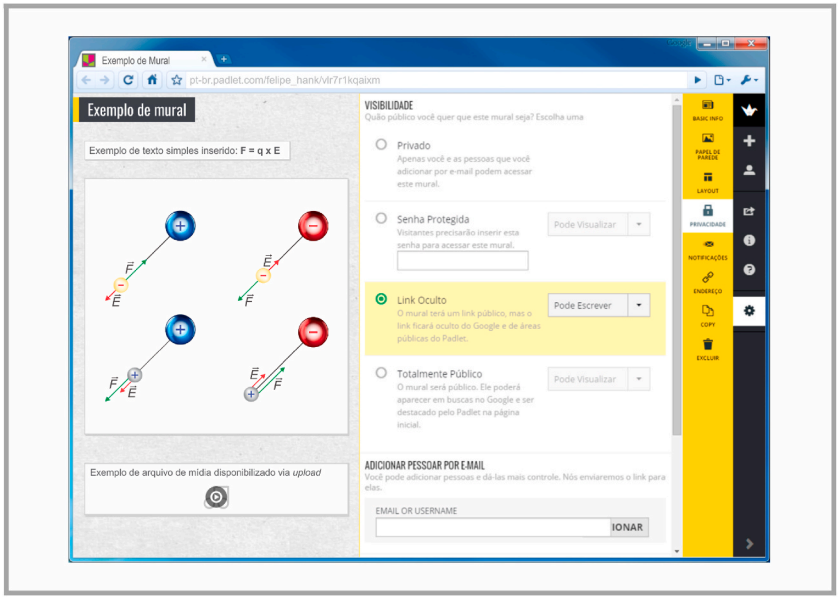

Fig. 3. Message wall application screenshot.

3.4. Procedures for the implementation of learning scenarios

The study was carried out in the school's computer lab in the form of math lessons focused on practicing and revising linear functions, taking place two months after students were first introduced to this content. All the lessons featured the resources presented in the previous subsection as well as sets of problems containing elements consistent with the terms in the equation $f(x) = ax + b$, which allowed solutions to be obtained via numerical operations focused on determining the value of one unknown variable of interest.

Although the numerical values and situations presented in the problem statements differed, the amount of elements, the operations required as well as the levels of difficulty set for the sequences of tasks were the same. In this sense, the lessons in the *AB-B'* design can be described as equivalent.

3.4.1. Previously taught lecture-based traditional lesson

Lesson A was initiated with an explanatory presentation by the teacher, aided by a screen projection of the applet, used to highlight its functionalities and revise the concept of linear functions. In pairs, learners were then instructed to work out a fixed sequence of tasks

presented on the wall pages on their computer terminals using the applet as a support tool. There were no shared walls in this lesson, so communication only took place within the pairs of students working together. Questions or difficulties were reported to the teacher, who would develop explanatory interventions addressing the issues.

3.4.2. Blended learning scenarios

Learning scenarios B and B′ designed to investigate the use of resources and learning pathways featured the short video described above, playing a similar role to the teacher's initial explanatory presentation in the traditional lesson. Learners also worked in pairs, and the applet as well as the message walls displaying the tasks were present, as in Lesson A.

Unlike in the traditional lesson, however, two shared message walls were utilized to enable online communication among learners and with the teacher: one of them was intended for student-student interaction, allowing learners to seek and provide peer support. The other wall was for student-teacher interaction, exclusively for questions or difficulties students hadn't been able to work out through peer collaboration. Another important element in this learning design which was entirely absent from the traditional lesson was the multiplicity of pathways given the possible uses of the resources in various orders composing different sequences. Resources utilized along with possible pathways for each lesson type can be seen in Fig. 4.

3.5. Procedures for data collection and analysis

The method for data collection comprised recording the screens of the computers used in the lessons and appling a survey on familiarity with ICT tools.

3.5.1. Survey on familiarity with ICT tools

Prior to the implementation of the lessons, a survey on familiarity with ICT tools was applied based on reflections presented in the Theoretical Framework subsection. Each item in the instrument described a gadget or activity related to ICT use such as using a tablet or playing online games.

Item scores were recorded as 0 and 1 values corresponding to responses expressing familiarity with each item. Descriptive statistics and nonparametric tests were used to map group profiles and identify possible influences these had on students' uses of resources and choices of learning pathways.

3.5.2. Recordings of responses to learning scenarios

A record of the pathways taken by students as well as their responses to the tasks and uses of resources was obtained through screen recording. The output material was analyzed with the goal of composing a data matrix of objectively identified quantifiable behaviors. Mapped uses of resources were represented as dichotomous categorical variables expressing presence or absence of behaviors among participants. Ordinal variables corresponding to resources utilized represented the order they first appeared in participants' pathways.

Descriptive statistics and nonparametric tests were also used with these datasets in order to map prevalence of behaviors, identify significant differences between groups and lessons as well as infer relationships. Considering their appropriateness for post hoc analysis of the multiple comparison tests carried out, Dunn's test (Dinno, 2015; Kronsberg et al., 2020) and Z-test (Sharpe, 2015) with Bonferroni's adjustment were used in conformity with standard procedures widely utilized in statistics software packages.

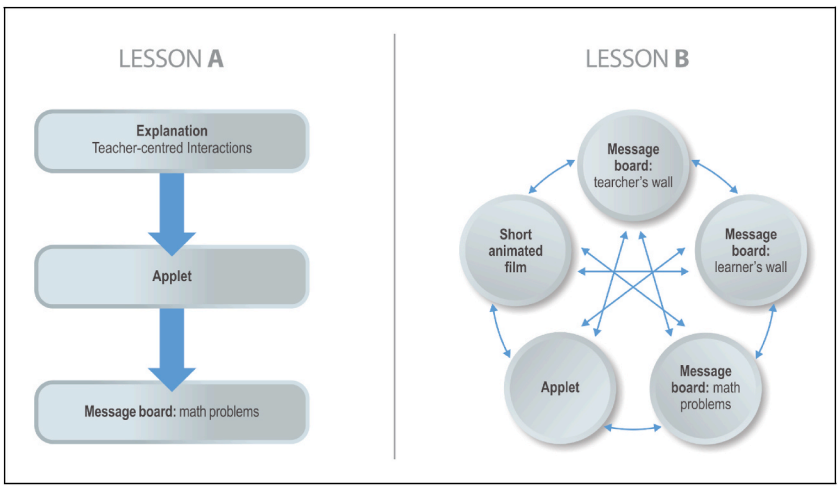

Fig. 4. Resources and possible pathways in lesson types.

4. Results

Observed performance and ICT scores, as well as prevalence of behaviors, uses of resources and learning pathways are presented in the following subsections.

4.1. Scores and adoption of resources

Global ICT survey scores are shown in Fig. 5 along with performance in each lesson. Responses recognizing the items in the survey as familiar were predominantly identified in G_1 (84.6%) and G_2 (75.4%) while a much smaller percentage of tools and habits was acknowledged by participants in G_3 (30.6%) and G_4 (44.35%) as part of their daily lives. Kruskall-Wallis' H test pointed to significant differences between groups ($X^2_{(3)} = 69.143$; $p < 0.01$) and post hoc analysis placed these differences in pairwise comparisons involving any of the two highest with any of the two lowest scoring groups ($p < 0.01$).

The average 0–100 performance score was lower in traditional lecture-based Lesson A ($\mu = 24.45$; $\sigma = 31.33$) and an increase was observed in Lessons B ($\mu = 77.17$; $\sigma = 20.85$) and B' ($\mu = 75.05$; $\sigma = 20.6$). Friedman's test indicated significant differences between these figures ($X^2_{(2)} = 127$; $p < 0.01$) and post hoc testing placed them in A-B and A-B′ comparisons ($p < 0.01$). Kruskal-Wallis' H test identified no significant performance differences between groups in Lessons A ($X^2_{(3)} = 1.77$; $p = 0.62$), B ($X^2_{(3)} = 5.4$; $p = 0.14$) and B' ($X^2_{(3)} = 2.19$; $p = 0.53$), and Spearman's test found no significant observable correlations between learners' ICT scores and performance results in Lessons A ($r = 0.05$; $p = 0.64$), B ($r = 0.2$; $p = 0.02$) or B' ($r = 0.8$; $p = 0.45$).

Overall use of resources among participants in each lesson, also seen in Fig. 5, shows the message wall, along with the applet, obtained the highest percentages of adoption by participants. Post hoc pairwise comparisons following Cochran's Q test in the scope of Lessons B ($X^2_{(3)} = 70.12$; $p < 0.01$) and B' ($X^2_{(3)} = 74.08$; $p < 0.01$) pointed to the same result: no significant difference between the frequencies of adoption of the applet and the message wall ($p > 0.99$), and both of them were significantly higher than those of unprescribed resources and the video ($p < 0.02$). McNemar's test shows the rejection of the audiovisual content grew significantly in Lesson B′ in comparison to Lesson B ($X^2_{(1)} = 18.3$; $p < 0.01$).

There were no significant differences between genders, as indicated by Mann-Whitney's *U* test, in ICT survey scores ($Z = -1.10$; $p = 0.28$) as well as in performance in lessons A ($Z = -1.88$; $p = 0.06$), B ($Z = -0.45$; $p = 0.65$) and B' ($Z = -0.03$; $p = 0.97$). The Chi-square test identified a significant difference in Lesson B ($X^2_{(1)} = 10.52$; $p < 0.01$) with respect to the adoption of the video, which was lower among female participants (22%) than among males (54.8%). However, this difference did not occur in Lesson B' ($X^2_{(1)} = 0.03$; $p = 0.863$) and no other gender differences were observed in any of the lessons in relation to the use of the applet ($p > 0.13$), the message wall ($p > 0.28$) or unprescribed resources ($p > 0.29$).

4.2. Behaviors and uses of resources

Learner behaviors associated with the uses of tools observed throughout the lessons are listed in Fig. 6. Rejection of the resources, as well as use unrelated to the tasks, were also observed among participants.

For the wall, messages regarding the problems, the subject content or the use of the supporting resources were considered related to the tasks. All online interaction took place among students, and no messages were posted onto the teachers' wall. Prevalence of specific uses of each resource in Lessons B and B' can be seen in Fig. 7.

The Chi-Square test of independence found an association between the group variable and the use of the video ($X^2_{(3)} = 11.27$; $p = 0.01$). Post hoc analysis showed proportions of rejection in G_2 (90.0%) and G_3 (46.2%), respectively highest and lowest among all groups, differed significantly ($p < 0.01$). G_1 and G_4 did not differ in the adoption of the video in spite of having significantly different survey scores. Furthermore, Kruskal-Wallis' test identified no significant differences in ICT scores in terms of associated video-related

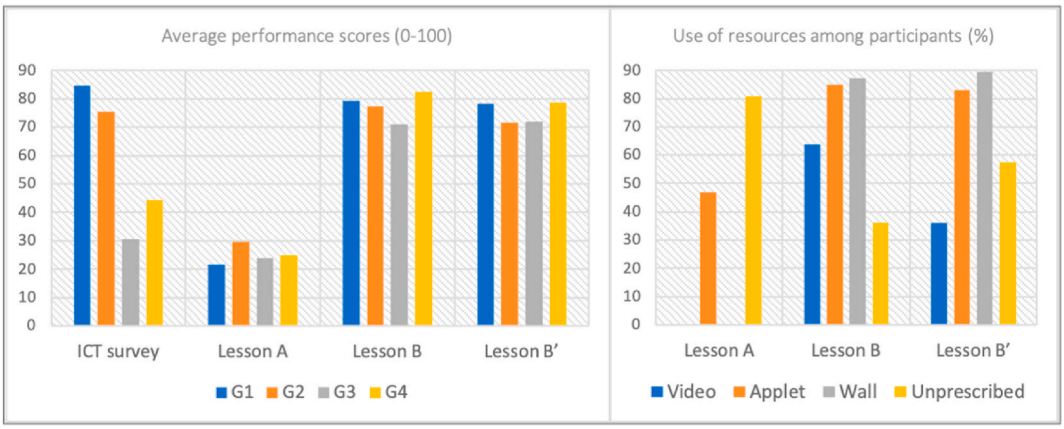

Fig. 5. Overall scores and uses of resources.

Video	Applet
[a] view as applet tutorial [b] look up concept / solution procedures [c] rejection / no use of video	[d] perform solution-informing calculations [e] perform solution-confirming calculations [f] plot function graph [g] use unrelated to tasks [h] rejection / no use of applet
Message wall	**Unprescribed resources**
[i] ask questions related to tasks [j] answer questions related to tasks [k] post comments related to tasks [l] lurking [m] use unrelated to tasks [n] rejection / no use of wall	[o] look up concept / solution procedures [p] use unrelated to tasks [q] rejection / no use of unprescribed resources

Fig. 6. Behaviors associated with the uses of tools.

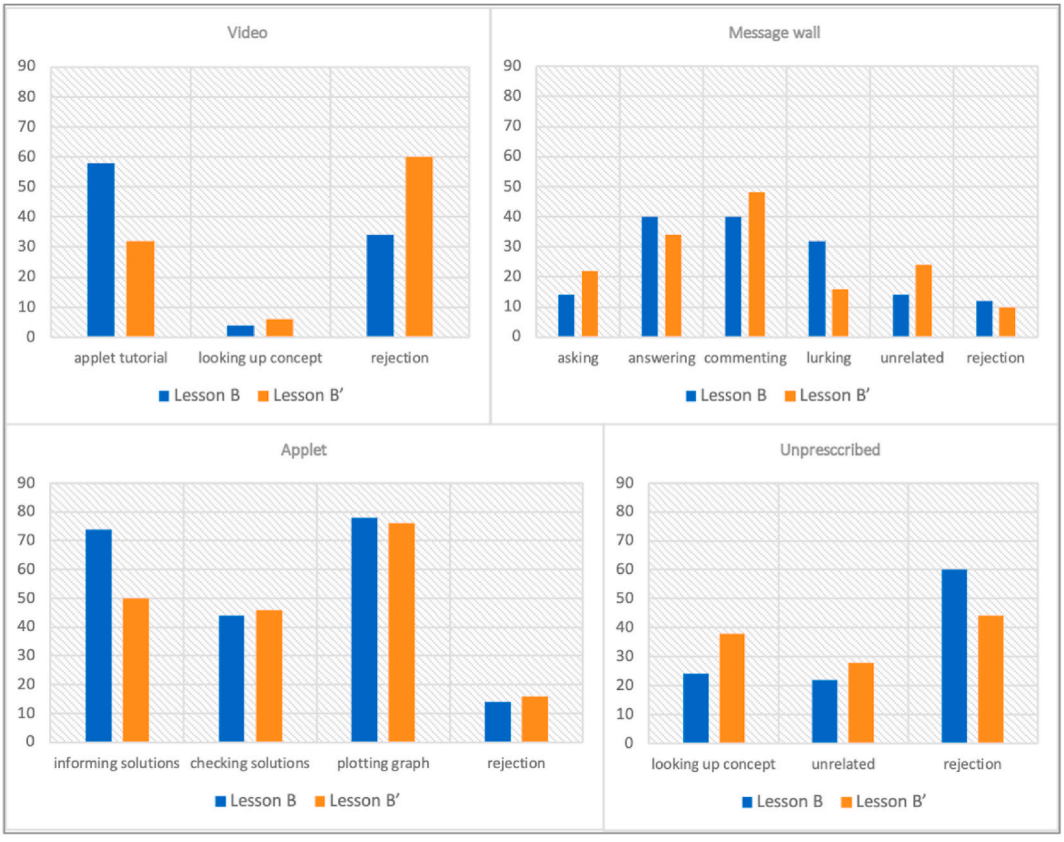

Fig. 7. Prevalence of uses of resources among participants (%).

behaviors in Lessons B ($X^2_{(2)} = 1.81$; $p = 0.4$) and B' ($X^2_{(2)} = 3.19$; $p = 0.2$).

A significant B–B′ decrease in the use of the applet to inform solutions is inferred from Fig. 7 and confirmed by McNemar's test ($X^2_{(1)} = 16.53$; $p < 0.01$). Chi-Square tests showed no association between reduced adoption of the applet and uses of message wall to ask questions about the content ($X^2_{(1)} = 1.94$; $p = 0.16$) or of unprescribed resources to look up concept ($X^2_{(1)} = 0.08$; $p = 0.78$), while the number of occurrences of use of the video to look up concept was too low to test for. McNemar's test shows no significant differences in uses the video ($X^2_{(1)} = 0.1$; $p = 0.75$) or the message wall ($X^2_{(1)} < 0.01$; $p > 0.99$) specifically to inform solutions, and it confirms a significant increase in the use of unprescribed resources to look up concept ($X^2_{(1)} = 5.63$; $p = 0.02$), as shown in Fig. 7.

Regarding the message wall, B–B′ comparisons through McNemar's test point to a significant decrease in the number of lurkers ($X^2_{(1)} = 14.1$; $p < 0.01$) and a significant increase in use unrelated to the tasks ($X^2_{(1)} = 5.8$; $p = 0.01$). Commenting became the preferred form of intervention in Lesson B′, significantly more frequent than answering ($X^2_{(1)} = 7.68$; $p < 0.01$) and all other lower-occurring behaviors. Fig. 7 also suggests an increase in the use of the wall to ask questions related to the tasks, confirmed as significant by McNemar's test ($X^2_{(1)} = 4.1$; $p = 0.04$). While the use of the wall to ask questions regarding the target content was stable ($X^2_{(1)} < 0.01$; $p > 0.99$), a higher occurrence of questions about the applet ($X^2_{(1)} = 13.14$; $p < 0.01$) was the cause of the significant variation. A Chi-Square test identified an association between the behaviors of posting questions about the applet and using the applet ($X^2_{(1)} = 5.38$; $p = 0.02$).

Fig. 8 shows the combinations of uses of the different resources observed in learning scenarios B and B' according to prevalence among participants. Uses of the video (blue), applet (gray), message wall (green) and unprescribed resources (yellow) are proportionally represented. Values in bold indicate associated performance score mean ranks and values in italics correspond to associated ICT score mean ranks. Letters a - q correspond to behaviors listed in Fig. 6 and superscript letters r - z identify behaviors which are significantly different. For instance, the area designated as "i, j, k" (green) on the left indicates the prevalence of the combination of uses of the wall to ask and answer questions as well as post comments related to the task proportionally among all behaviors observed in Lesson B. Within the scope of use of the message wall, performance scores associated with the "i, j, k" behavior (53.5) are significantly different from those associated with the "n" behavior expressing rejection of the wall (6.67).

Besides the previously observed shift from high rates of adoption of the video ("a") to its rejection ("c"), comprehensive rejection of unprescribed resources ("q") in Lesson B can also be seen in Fig. 8. When patterns of use observed in Lessons B and B' are contrasted within the scope of each tool, the Chi-Square test points to significant associations between uses of the video ($X^2_{(4)} = 21.42$; $p < 0.01$), the applet ($X^2_{(12)} = 97.3$; $p < 0.01$), the message wall ($X^2_{(60)} = 292.93$; $p < 0.01$) and unprescribed resources ($X^2_{(9)} = 62.79$; $p < 0.01$).

No significant associations between the variable group and the approaches to the video ($X^2_{(6)} = 7.86$; $p = 0.25$), the applet ($X^2_{(9)} = 7.53$; $p = 0.58$) and the message wall ($X^2_{(18)} = 26.05$; $p = 0.09$) was observed in Lesson B. On the other hand, in Lesson B′ responses across groups varied significantly resulting in associations with the video ($X^2_{(6)} = 13.97$; $p = 0.03$), the applet ($X^2_{(12)} = 26.65$; $p = 0.02$) and the message wall ($X^2_{(30)} = 46.77$; $p = 0.03$). Also, analysis of resources present in Lessons A and B shows significant associations between observed uses of the applet ($X^2_{(9)} = 20.15$; $p = 0.02$) and of unprescribed resources ($X^2_{(9)} = 21.7$; $p = 0.01$). However, for Lessons A and B', there are no significant associations between uses of the applet ($X^2_{(12)} = 9.61$; $p = 0.65$) or unprescribed resources ($X^2_{(12)} = 9.61$; $p = 0.65$).

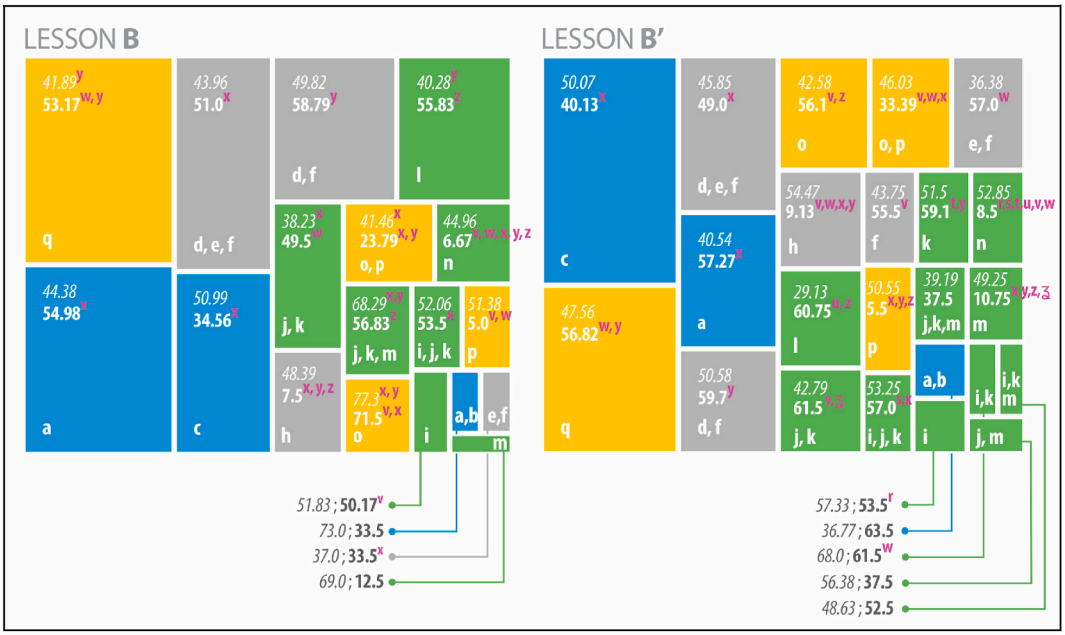

Fig. 8. Combinations of uses of resources.

4.3. Observed pathways

Learning pathways, understood as a learner's route towards a learning outcome, were identified as the different sequences of resources adopted by participants in blended scenarios in response to the tasks. The video was predominantly the first resource used in the pathways observed in Lesson B (63%) and predominantly absent from pathways in Lesson B' (58.7%). The applet was predominantly the second component in pathways observed in both Lessons B and B' (63% and 45.7%) while the message wall was third (54.3% and 43.5%) and the use of unprescribed resources was predominantly absent from pathways in both lessons (65.2% and 67.4%).

Fig. 9 shows the different pathways observed in Lessons B and B'. Similarly to the previous figure, sequences are proportionally represented in terms of their prevalence among learners. Values in bold represent associated performance score mean ranks and values in italics correspond to associated ICT score mean ranks. Letters V (video), A (applet), W (wall) and U (unprescribed) represent resources utilized in the order they appeared in pathways, and superscript letters r - z indicate significant differences between adoption behaviors. Gray areas indicate pathways present in both lessons while areas in blue represent pathways which emerged in one particular lesson.

The Video-Applet-Wall (V-A-W) pathway's prevalence among participants decreased from 46% in Lesson B to 18% in Lesson B'. This is identified by McNemar's test as a significant difference ($X^2_{(1)} = 20.25$; $p < 0.01$). The analysis of ICT scores considering the pathways chosen by participants did not point to significant differences in Lessons B ($X^2_{(6)} = 10.39$; $p = 0.11$) or B' ($X^2_{(9)} = 12.53$; $p = 0.18$). When performance scores are analyzed in terms of the pathways chosen by participants, Kruskal-Wallis' H test points to significant differences in Lessons B ($X^2_{(6)} = 40.79$; $p < 0.01$) and B' ($X^2_{(9)} = 53.9$; $p < 0.01$). But post hoc analysis places these only in pairwise comparisons involving pathways characterized by the use of unprescribed resources (U) as a key element and rejection to other resources.

5. Discussion

Overall group responses to learning scenarios as well as patterns of use behavior and learning pathways observed among participants are discussed in the following subsections.

5.1. Overall responses to learning scenarios

Analysis of global survey scores shown in Fig. 5 indicated groups G_1 and G_2 were significantly more familiar with ICT than the other groups. This is consistent with reports that technology use may vary within one age group (Gurung & Rutledge, 2014; Rashid & Asghar, 2016) and that sometimes these differences cannot be explained by demographic markers such as socioeconomic status (Drabowicz, 2017). In this sense, student familiarity with ICT cannot be discarded as a variable of interest for the implementation of technologically-enhanced learning scenarios, especially considering the school's role of providing learners with support on the use of tools and acquisition of ICT skills (Rasheed et al., 2018).

Performance scores were significantly higher in blended learning scenarios in comparison to the traditional lesson, which is congruous with Fazal and Bryant's (2019) reports that blended learning contributes to improving student performance in math. There were no observed correlations between ICT scores and performance results in any of the lessons, and although groups differed significantly in familiarity with ICT, they did not differ in terms of performance scores. Such results appear to be divergent from claims that attitudes towards ICT affect learning mediated by digital teaching resources (Radović et al., 2020; Ruzek et al., 2016). But

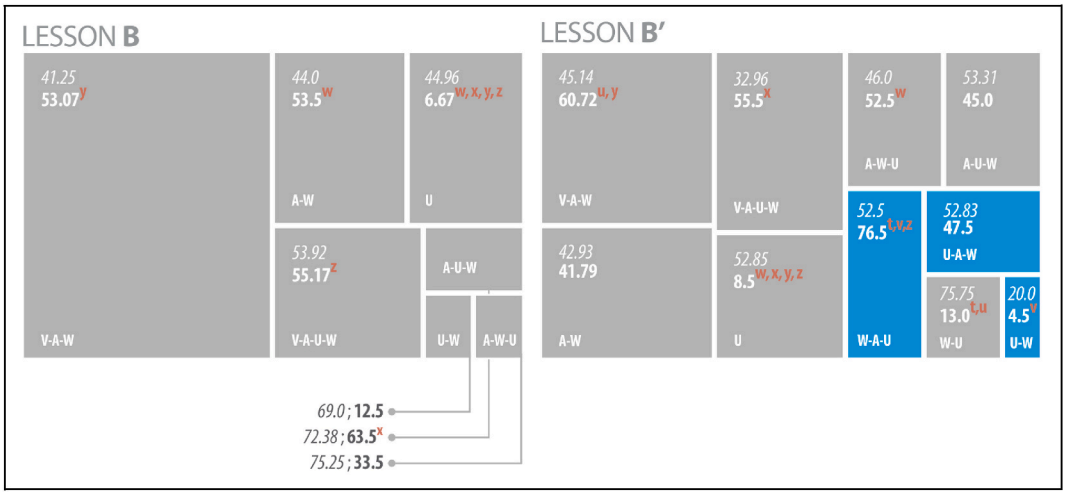

Fig. 9. Pathways observed.

adopting the usefulness of ICT skills for student performance in blended learning scenarios (Bueno-Alastuey & López Pérez, 2014; Kundu et al., 2021) as a premise, it can be suggested that the use of the tools promoted in the learning design was suitable to students' abilities, and the activities were generally accessible regardless of differences in ICT skills.

Also, performance scores must be interpreted considering that the blend of face-to-face and online communication alone does not explain better learning outcomes (Arrosagaray et al., 2019; Driscoll et al., 2012) and that effectiveness must be looked into in terms of context-specific factors. In this perspective, having all the lessons structured around the use of artifacts highly compatible with blended learning practices may explain the lower outcomes obtained in Lesson A, which was not conceived according to such practices. This reinforces Dziuban et al.'s (2018) position regarding blended learning's alignment with characteristics of digital technologies. It is also consistent with Ping et al.'s (2018) findings on the limited learning outcomes resulting from the combination of educational applications and in-lecture demonstrations.

The fact that the message wall and the applet obtained significantly higher percentages of adoption than the video and unprescribed resources can be interpreted in light of learners' perception of relevance of these tools. As discussed in the Theoretical Framework section, perceived relevance is a key factor for the adoption of resources by students in blended learning scenarios, comprising the meaningfulness of interactions (Delahunty, 2018) or connection between the tool available for use and the tasks proposed (Pappas et al., 2017; Turan & Cetintas, 2020). Unprescribed resources can be considered less likely to be perceived as relevant as their use was not stipulated, promoted, or necessary to accomplish the tasks. Moreover, while the applet and the message wall were directly utilized in the problems solutions, the video may have been more generally perceived as an auxiliary tutorial, unnecessary for those who set out to figure the use of the applet by themselves.

With regard to gender, data indicating no significant differences in both ICT and performance scores between male and female participants is consistent with Kundu et al.'s (2021) report on the benefits of blended learning practices for school-aged learners irrespective of gender, comprising no significant differences in lesson engagement as well as in managing technical aspects of the digital tools available. These findings highlight blended learning's potential to promote educational practices exempt from gender bias as educators and educational institutions become more aware of the issue of gender inequality in education (Psaki et al., 2018).

As highlighted in the previous section, there were also no significant differences between male and female students regarding adoption of the resources - with exception of the video in Lesson B when rejection was higher among female participants. In this perspective, it is possible to conclude that gender did not play a comprehensively relevant role in the uses of resources. Concerning the video, it could be conjectured that female students anticipated the perception of its relevance which would be subsequently shared with their male classmates, as rejection prevailed among both genders in Lesson B'. But there is no other evidence to support such a conclusion and further investigation is required.

Observed behaviors associated with the uses of tools listed in Fig. 6 can be described as consistent with the uses of educational video (Mayer et al., 2020; Pappas et al., 2017; Turan & Cetintas, 2020), apps (Ping et al., 2018) and forums or message boards (Chen et al., 2020; Ruthotto et al., 2020) addressed in literature. The fact that online interaction took place only among students and no messages were posted onto the teachers' wall highlights the potential of peer collaboration in dealing with casually arising questions about the subject content. Such development suggests peer instruction can be effective in addressing the issue of teacher overload, often pragmatically viewed as relevant for educators who incorporate digital technologies into their practices (McGarr & Gallchóir, 2020; Picciano, 2015). It is also consistent with Keaton and Gilbert's (2020) report that students in online learning scenarios often view the teacher as a facilitator, but not as the only source of instruction, and that learner-learner interactions are a useful and effective way for students to address questions and difficulties related to course content.

5.2. *Learner behaviors associated with increasing rejection of resources*

Adding to the discussion on learners' perceived relevance of resources, the Increase in the rejection towards the video from Lesson B to B′ suggests more willingness or openness to use resources prescribed by the teacher at first, and then a reconsideration of this decision informed by experience of use. This points to implications for the assessment of adoption and rejection of audiovisual content as learners' attitudes towards it may change some time after a resource is introduced to them. This trend regarding the video in Lesson B′ was more impacted by behaviors manifested in specific groups, as rejection was significantly higher in G_2 than in G_3. Considering the differences between these groups expressed in the survey results, one possibly-arising question would be whether higher levels of familiarity with ICT are associated with less interest in the video given the learners' presumed ability to work out the use of the applet by themselves. However, such differences were not observed between G_1 and G_4 although these groups also differed in survey scores, and tests of association between familiarity with ICT and video-related behaviors pointed to negative results. Taking these considerations into account, results can be interpreted looking at Turan and Cetintas' (2020) reports that although computer self-efficacy impacted ease of use, it did not have any effect on students' intent to use instructional video. Modeling or recommendation from the teacher, on the other hand, appear to have had an impact.

The significant B′ decrease in the use of the applet to inform solutions in Lesson B′ raises questions on whether participants set to achieve this specific purpose through other resources which can also potentially inform solutions, but no associations in this sense were found, as highlighted in the previous section. An improved understanding of the content subject allowing participants to plan and structure their solutions without resorting to the applet could be proposed as a possible explanation. However, such a phenomenon would also likely comprise a significant reduction in aforementioned uses of the other resources focused on informing solutions, which was not observed with respect to the video, the message wall or the use of unprescribed resources. It can be suggested nonetheless that increased interest in this use of the applet in Lesson B is consistent with its use in the demonstration by the teacher in Lesson A: students adopted the resource on the immediately subsequently-occurring lesson as proposed by the teacher. This view is supported by claims

that the teacher's behavior impacts the way learners engage in learning activities (Reyes et al., 2012; Roorda et al., 2011; Skinner et al., 2008).

Concerning the decrease in lurking in Lesson B′, it can be proposed that initial reluctance to post in the previous lesson, when students were first introduced to the interactive wall, may be associated with diligence regarding exposure or lack of confidence (Miyazoe & Anderson, 2011; Ruthotto et al., 2020; Sun et al., 2014). Reinforcing this argument, the emergence of more active forms of participation in Lesson B' was characterized by the prevalence of commenting over other behaviors. Comments are viewed as a less risk-taking form of participation, as they are associated with less responses and a reduced likelihood of triggering controversy and correction from classmates (Chen et al., 2020). The posting of comments can also be considered relevant for students as it allows them to encourage one another, which represents a form of interaction learners in online environments enjoy and often engage in (Keaton & Gilbert, 2020).

5.3. Learner behaviors associated with increasing adoption of resources

Increase of non-academic use of resources indicates lower levels of student engagement, which was not detected from a global perspective as B–B' performance results did not differ significantly. Although concurring or overlapping forms of academic and non-academic digital engagement observed in school may not be a solid predictor for learning performance (Gurung & Rutledge, 2014), these results project the analysis of behaviors related to the use of specific resources in blended learning scenarios as a possible strategy to monitor levels of student engagement beyond task accomplishment and associated performance scores. This is a pertinent measure to be taken as performance scores do not necessarily reflect learning, and lack of behavioral engagement for accomplishing tasks can later result in inability to complete a course (Borup et al., 2021).

The increase in the occurrence of questions about the applet associated with its actual use indicates a genuine intent behind the questions and also that responses from peers are likely to have aided the use, as students did not need to resort to their teacher for assistance. This is congruent with Keaton and Gilbert's (2020) previously presented position on the effectiveness of learner-learner interactions to address course content-related issues. Differently from the video, the message wall was not pedagogically conceived to aid learners in the use of the applet: the emergence of such unpredicted relationships reinforces the need for blended learning scenarios to be studied from a systemic perspective, rather than with a focus restricted to individual components (Dziuban et al., 2018; Ramirez-Arellano, 2019).

5.4. Patterns of combined uses of resources

Fig. 8 shows the message wall featured the widest variety of combinations of use behaviors. Occurrence of these is consistent with the multiplicity of communication strategies (Chen et al., 2020; Delahunty, 2018) observed in online forums and discussion boards. The student behavior of plotting graphs ("f"), seen in Fig. 8 in all observed uses of the applet, can be considered teacher-produced as it was demanded by the tasks proposed. This is concordant with the argument that teacher-produced actions and behaviors impact forms of engagement (Reyes et al., 2012; Roorda et al., 2011; Skinner et al., 2008) in subsequent learning experiences. It is also consistent with the previously reported B–B' shift from high rates of adoption of the video ("a") to its rejection ("c") as well as the comprehensive rejection of unprescribed resources ("q") in Lesson B.

Overall, data is concordant with Cakir's (2013) position that familiarity with ICT did not play a comprehensively relevant role in learners' approaches to using the resources. Only 6 out of 41 globally observed uses' associated ICT scores shown in Fig. 8 differed significantly from any of their counterparts' in the scope of each tool. The few occurrences in this sense were observed in Lesson B, when higher levels of ICT skill were associated with the use of unprescribed resources to look up concepts or solution procedures ("o") and the use of the message wall to answer questions and post comments related and unrelated to the tasks ("j, k, m"). Familiarity with digital tools may explain both the managing of concurrent unrelated use and focused replies to classmates' questions as well as why some learners, unlike most of their peers, went beyond the teacher-prescribed tools utilized in the previous lesson. Juhaňák et al., 2019 highlight higher levels of familiarity with ICT resulting from early adoption of tools, interest and use everyday social interactions lead to user autonomy and independence. Looking at the present data from this perspective, it can be suggested that digitally skilled learners may not thoroughly adhere to teacher-provided models and procedures as much as the average learner, and might prefer their own approaches to addressing resources and tasks in technologically enhanced learning scenarios.

With regard to associated performance scores, Fig. 8 shows several significant differences identified in the scope of each tool's set of observed uses. Nevertheless, these are mainly due to rejection or unrelated-use behaviors ("h", "m", "n") which tend to be more present among - although not exclusive of - globally unengaged students and therefore associated with significantly lower performance scores. In this perspective, task-orientedness gains relevance as a crucial factor for a better learning performance, regardless of the approaches adopted for the tools. This reinforces the importance of designing learning scenarios which stimulate behavioral engagement (Reyes et al., 2012; Roorda et al., 2011; Skinner et al., 2008). Practical implications for designing such engaging blended learning scenarios can be inferred with respect to the conception of learning activities' goals, dynamics and even sets of rules and instructions, since well structured tasks provide organized learning opportunities supporting individuals' personal preferences and contributing to lesson engagement (Rice & Stevens, 2021). This is consistent with Anthony's (2019) position that instructional practices and classroom management are key factors for producing the desired impact on learners.

The fact that there were no differences between groups in approaches to using each resource in Lesson B but such differences emerged in Lesson B′ suggests proximity with Lesson A was associated with more uniform responses to the tasks. On the other hand, observed associations between patterns of use of resources in Lessons B and B′ is consistent with the argument that individual factors

also affect task-related choices, decisions as well as forms of digital engagement (Drabowicz, 2017; Gurung & Rutledge, 2014) independently of what took place in the previous lesson. The associations observed in the uses of the applet and unprescribed resources in Lessons A and B, and the fact that no such associations were observed between Lessons A and B′ suggest the use of resources in Lesson A had some influence in the way students approached them in the following lesson, corroborating conjectures drawn from data reported in previous subsections regarding the impact of the teachers' actions on forms of student engagement (Reyes et al., 2012; Roorda et al., 2011; Skinner et al., 2008). This points to implications for teaching practice as learner responses to computer-assisted learning scenarios, and the extent to which they can benefit from such scenarios, may be circumstantially bounded by pedagogical practices they have been exposed to.

5.5. Pathway trends and relationships with learner behaviors

The manifestations of various pathways corroborate views that blended learning allows students to take up personalized and diversified learning trajectories (Anthony, 2019; Attard & Holmes, 2020; Halverson & Graham, 2019) and that although group dynamics and relations play a crucial role in learner engagement, individual preferences and needs should be taken into account in instructional design (Borup et al., 2020; Rice & Stevens, 2021). One important practical implication for teaching in this sense relates to blended learning's potential to effectively engage mixed-ability groups, as personalized pathways allow differentiated instruction for students at varying levels of achievement (Fazal & Bryant, 2019).

A prevalent trend in the sequences of use of learning resources was observed: beginning with the video if support to work out the functioning of the applet was needed; using the applet to produce solutions, and then the message wall to seek help if questions arise or to aid struggling peers. Like the single-pathway approach utilized in Lesson A, this Video-Applet-Wall (V-A-W) pathway shown in Fig. 9 is based on the notion of exposure to input, followed by practical problem solving with the possibility of requesting some form of support. Nevertheless, there was a significant decrease in its prevalence in Lesson B′, when Lesson A was no longer present in the design and more pathways emerged. This reinforces previously raised questions about impacts Lesson A may have had on behaviors manifested in Lesson B. Ramirez-Arellano (2019) states classroom environments have an influence on learning pathways throughout a course, which supports the conclusion that practices students have been exposed to may impact choices in subsequent lessons. Such influence can also be inferred from Anthony (2019) as she highlights blended learning's potential to provide students with multiple pathways according to individual learning goals and also emphasizes the impact teaching practices have on students' learning outcomes. Attard and Holmes (2020) defend structuring syllabus units with the purpose of allowing different self-paced pathways learners can adopt consecutively of their understanding of each topic. This position also holds the underlying premise that students' perception of the learning experience in progress will impact the way upcoming tasks are addressed by them.

The fact that adopted sequencings of resources did not differ in terms of associated participant ICT scores is consistent with previously reported overall use of resources also not differing. The position that the tasks and resources were generally accessible to students regardless of their different levels of ICT skills can also be adopted with respect to learning pathways, reinforcing the conclusion that lesson trajectories may have been impacted by students' individual preferences as well as the teaching practices they were exposed to, but not by their levels of familiarity with ICT. Pathway differences regarding associated performance scores essentially placed in sequences comprising unprescribed resources and/or rejection towards prescribed resources are also concordant with previously reported results on patterns of use behaviors: significant performance differences are more likely to be associated with unengaged behaviors, which reinforces the role of task-orientedness as a key element for student performance. It can then be concluded that looking into the pathways adopted by learners led to results consistent with those obtained from the analysis of their patterns of use of individual resources, including degrees of relationship with ICT skills and performance scores, as well as potential relationships with teaching practices.

5.6. Study limitations and future research

The study design does not support conclusions about performance responses or adoption of behaviors over longer periods of time. Another limitation is that the evidence for the impact one lesson had on subsequent student choices is restricted to learning scenarios within scope of a single content subject. Further research comprising lengthier sequences of lessons could also address a wider range of contents and subjects. This would enable a better understanding of the extent to which teaching practices learners are exposed to may impact their digital engagement from a global perspective.

Data pointed to different levels of familiarity with ICT among participants, indicating ICT scores were not significantly relevant in the use of the learning resources. But it does not support further conclusions on potential relationships between the findings and characteristics of the sample population, and thus requires more investigation. Future studies should also consider a larger participant sample to enable further statistical analysis. A higher number of cases obtained for lowest-occurring pathways and approaches to resources would also decrease the likelihood of distortions by chance outliers.

It's also important to highlight implications of the analysis of learning pathways focused on the first time each resource was effectively used: this does not necessarily coincide with the first time each resource had its interface visualized, nor does it provide a record of times participants went back to each formerly used resource. This limitation should be considered in the planning of similar studies in the future, especially concerning the number of digital resources adopted and complexity regarding their potential resulting patterns of use.

Finally, as the investigation, findings and discussions presented here are circumscribed to a study design interested in student engagement, performance and ICT skills, it can also be suggested for future work that learning pathways in blended learning scenarios

can be looked at from different theoretical and even epistemic perspectives. Exploring other facets of blended learning practices as well as introducing or placing a stronger or lesser emphasis on different frameworks can contribute to a better understanding of learning pathways and related implications for teaching.

6. Conclusion

The analysis of uses of resources and learning pathways in blended learning scenarios points to practical implications for teaching, linking scientific research and educators' everyday practices from the concrete perspective of the planning and execution of lessons and learning activities. The methodological design effectively allowed the mapping of uses of the resources by learners characterizing engaged and unengaged combinations of behaviors comprising exploring functions of the tools as well as using unprescribed resources. Learning pathways, understood as the students' routes adopted in each lesson towards a learning outcome, were described as distinct sequences of tools utilized reflecting different approaches to the tasks. The analysis of these elements answers the main research question, concerning the manifestations of the uses of resources and pathways.

Main findings feature solid associations between engaged behaviors and better learning performances. But overall, among pathways and uses associated with engaged behavior, performance scores did not vary significantly. This discussion addresses the question regarding possible relationships between these variables and an important conclusion was that task-orientedness emerged as the key element, as the different student pathways and approaches to using the tools are legitimized as possible strategies for an effective learning performance. This highlights blended learning practices' potential to address different individuals' learning preferences and needs and reinforces the importance of designing learning scenarios which stimulate behavioral engagement.

Another important finding was that familiarity with ICT did not impact learning performance or participant choices of uses of resources and pathways in spite of significant group differences in terms of ICT scores. This holds learners' ICT skills as a relevant matter for the implementation of technologically-enhanced learning scenarios, but also indicates an effective pedagogical design can provide mixed-ability groups with balanced and accessible use of tools. It can also be concluded that the low-income setting was not an obstacle for the implementation of blended learning once the learning tasks and scenarios were appropriate for the group and consistent with the infrastructure available. Overall, findings are consistent with research carried out among other cultural and socioeconomic groups, referenced throughout previous sections. This points to the potential of blended learning core principles to be adapted across a variety of settings, informing effective planning focused on different groups' characteristics and needs.

The evidence that student behaviors in blended learning scenarios are to some extent influenced by practices learners have been exposed to in previous lessons is supported by a variety of data regarding different elements observed in the lessons, and answers the last research question posed for this study. Although performance was not impacted, associations between student behaviors and the practices produced in the previous lesson raise questions about the nature of learner responses to the implementation of blended learning systems and scenarios given the pedagogical practices predominantly adopted in the classroom or school setting. Considering the limitations highlighted in the previous subsection, further investigation is needed so such arising queries can be addressed and more solid conclusions can be drawn.

Data availability

The data that has been used is confidential.

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