"Adopt a Microorganism" methodology enhances the discourse richness of high school students in both hybrid learning and remote education

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ABSTRACT

The internet has changed the way teachers and students access information and build knowledge. The COVID-19 pandemic has recently created challenges for both teachers and students, demanding new methodologies for remote learning. In Life Sciences, mixing online content with practical activities represents an even greater challenge. In Microbiology, the implementation of an active teaching methodology, the #Adopt project, based on the social network Facebook®, represents a great alternative to associate remote education with classroom activities. In 2020, the version applied in high school, "Adopt a Microorganism", was adapted to meet the demands of emergency remote education due to the suppression of face-to-face activities caused by the pandemic. In the present study, we assessed how the change in methodology impacted the learning of Microbiology and the richness of the discourse of high school integrated to technical education in Business Administration of the Federal Institute of São Paulo, Campus Sorocaba. For that, three questionnaires related to the adopted microorganism species were applied. The responses of students in the 2019 and 2020 classes were compared in terms of content richness and multiplicity

of concepts through the application of the Shannon diversity index, an approach usually used to assess biodiversity in different environments. The observed results suggest that remote learning provided students with a conceptual basis and richness of content equivalent to those achieved by students submitted to the hybrid teaching model. In conclusion, this study demonstrated that the #Adopt project methodology can be used in both hybrid and remote models, indicating that it is a viable alternative not only for teaching Microbiology, but possibly for other areas of knowledge.

INTRODUCTION

Internet access grows everyday, with Brazil in a prominent position, since together with India and China it is responsible for about 70% of access, ranking 4th in this topic (1). Additionally, around 70% of the Brazilian population is connected to the Internet (2), with social media occupying an important space. According to the "We are Social" website (3), 62% of Brazilians are connected to social networks, specially to Facebook®, which has just over 127 million users in Brazil, according to data from the website.

These facts show the relevance that the Internet has in our lives and, consequently, in the lives of students, who now have immediate and unrestricted access to content that, previously, would only be found in textbooks or transmitted by the teacher (4). This scenario made it even more difficult to apply a traditional teaching model, in which the central role is that of the teacher (5), since he is no longer the sole holder of knowledge. Therefore, thinking about the Internet as an ally in pedagogical practices is interesting, as it promotes an expansion of learning environments and diversifies its mobilization strategies (6).

The Internet allows the students to take a more active role in their own learning, which facilitates the connection between the learned concepts and promotes the development of critical thinking (7). Moreover, the placement of the student as a central figure in the development of his activities makes teaching more meaningful and, therefore, creates the need to seek concepts for a greater understanding of a subject or idea, awakening the student's interest in learning (8).

Among all the possibilities of using the Internet, social media can be very interesting due to their relevance and wide reach, as already mentioned. Several studies have shown that its use has

contributed in some way to learning, both in higher education and in high school (9; 10). Among all the existing social networks, one of the most used by teachers and students is Facebook® (11), and Santos and Campos (2013) (28) demonstrated that its use for education purposes is interesting, as discussions and teacher-student relationships were expanded, compared to traditional teaching methods.

With that in mind, in 2013 the #Adopt Project was created using Facebook® as a didactic platform for teaching Microbiology, both in higher education – "Adopt a Bacterium" (12) - and in high school – "Adopt a Microorganism". The latter was applied to students of the 2nd year of high school integrated to technical education in Business Administration of the Federal Institute of São Paulo, Campus Sorocaba, during the years 2019 and 2020.

In 2019, the "Adopt a Microorganism" project was applied in its original hybrid version, alternating face-to-face classes and practices with online activities on Facebook®. In the year of 2020, however, education was drastically changed due to the COVID-19 pandemic. Schools and colleges were closed and, in most cases, classes started to take place online without prior planning or training (13), forcing both teachers and students to adapt to a new system in a very short time. The project had just started before the pandemic lockdown and had to be adapted to take place completely online.

Given these differences, the present work intends to explore possible differences in effectiveness between the two formats of the teaching methodology "Adopt a Microorganism". For this, we evaluated the richness of the students' discourse in the questionnaires applied during the project. For that, we used the Shannon Diversity Index (14), which is widely used in conservation biology (15; 16) and in microbiology to assess the richness of microbial populations (17; 18). Also, we analyzed the perception of these students about the strengths and weaknesses of the project.

MATERIALS AND METHODS

Study design

This study was conducted with high school students from the 2nd year of the Federal Institute of Education, Science, and Technology of São Paulo, Campus Sorocaba. The "Adopt a Microor-

ganism" project was applied during the first semester to 36 students in 2019 and 38 in 2020. The students were distributed into five groups, each one being responsible for a microorganism: Archaea, Bacteria, Virus, Fungi or Protozoa. In addition to the theoretical classes regarding basic microbiology topics, the teacher posted weekly challenges (S1 Appendix) on Facebook®, based on PISA (International Student Assessment Program) and ENEM (National High School Exam), with increasing degrees of difficulty - easy, medium, and difficult - using Bloom's Taxonomy (19). The first three weeks included the same general challenges for all groups, regarding the biological definition of life and the main differences between the three domains of life. In the last three weeks, the challenges were specific to each group and promoted discussions about the "adopted" microorganism, its relationship with humans and the diseases caused by it. Student responses and discussions on Facebook® were mediated by undergraduate or graduate students who had already participated in the project and received brief training (20). The mediators were different for each group, and had the role of correcting possible errors, checking the sources cited, directing the study, instigating new discussions and deepening the content covered on Facebook®. Each challenge needed to be validated by the mediators, as soon as they thought that the objective had been reached, so that the student's score could be computed. At the end of all activities, students produced promotional material aimed at the lay public, with the intention of bringing scientific information to society. In 2019, students presented a seminar about their adopted microorganism to their classmates and other school members. They also participated in a diffusion course entitled "Journey into the world of microorganisms and human parasites" that was held right after the end of the general challenges on Facebook® at the São Paulo University. In this course, students could reinforce their knowledge about their adopted microorganisms through several laboratory activities, like seeding and cultivation techniques, microscopic analysis of microbiologic material, technical visits to research laboratories, and participation in ludic games alongside the mediators. Due to the COVID-19 pandemic, face-to-face classes were interrupted in 2020 and students were unable to participate in the diffusion course or to present seminars, so they prepared mental maps on the microorganisms adopted as promotional material.

Data collection

We administered three voluntary and anonymous surveys to evaluate the knowledge of the students about their adopted microorganisms. Students answered the question: “What do you know about the adopted microorganism?”. The first survey (Q1) was applied before the start of discussions on Facebook®. In the 2019 edition, the second survey (Q2) was conducted after the diffusion course and, in 2020, it was applied immediately after the end of the discussions on Facebook®. The last survey (Q3) was applied five months after the second survey was administered so we could evaluate students’ content retention.

To access the feasibility of using Facebook® as a teaching and learning platform for microbiology in biology classes, an anonymous and non-mandatory questionnaire was applied to the participating students at the end of the project (S2 Appendix). This survey contained questions such as: "point out the positive and negative aspects of using Facebook® for learning microbiology". In the 2020 edition, because of the suspension of classes due to the COVID-19 pandemic and the continuity of the project exclusively remotely, two questions were included, one to determine if the continuity of the project allowed communication and contact with colleagues, and another to find out if it was possible to continue learning and studying at home. Thirty-two students responded, and these responses were analyzed and categorized based on the extraction of nuclei of meaning according to Bardin (1977) (21).

Data analysis

For each survey, the students’ responses were evaluated to identify the presence and quantity in which each of the following topics was mentioned: taxonomy, morphology, metabolism, genetics, pathogenicity, treatment, prevention, ecology, reproduction, life cycle, social impact, examples and others. Also, we evaluated whether the topic worked in the responses had or not some conceptual error. After that, the frequency that the topics appeared was computed for each group and the whole class. The frequency that the topics appeared was also computed for the group of citations classified as conceptual errors.

To assess the average diversity of topics worked on by each group in each questionnaire, we

calculated the Shannon diversity index (H) for each group [14]. This index is not widely used to evaluate teaching, but it can be interesting when the data obtained involve specific knowledge categories and the frequency with which these categories are present in each speech given or written by students.

For this calculation, we have used the ecopy 0.1.2.2 library for python 3.8, following the equation:

$$H = -\sum_{1}^{k} p_k * ln(p_k)$$

Where p_k is the frequency of appearance of each topic in the responses of each group and k is the total number of different subjects that appeared in the answers. Thus, for each questionnaire, we obtained the Shannon index per group, for the whole class, and conceptual errors. The higher this index, the greater the diversity of topics covered in the responses. The confidence intervals for each index were estimated by bootstrap, as in Laura Pla, 2004 (22).

Furthermore, to assess the degree of dissimilarity between Q1 and Q2, as well as Q2 and Q3, for each year and between 2019 and 2020 edition, we calculated the Bray-Curtis dissimilarity between these questionnaires (23) and the difference between the Shannon index. To calculate the Bray-Curtis dissimilarity, we used the ecopy 0.1.2.2 library for python 3.8 again, following the equation:

$$D_{a,b} = 1 - \frac{2 * \sum_1^k min(x_{ak}, x_{bk})}{\sum x_a + \sum x_b}$$

Where k is the total number of topics that appeared in questionnaires “a” and “b” and x_{ak} and x_{bk} are the frequencies of appearance of topic k in questionnaires “a” and “b” respectively. The greater the Bray-Curtis dissimilarity, the larger the difference between the compared questionnaires. To calculate the difference between the Shannon index, we used a custom python 3.8 script. The confidence intervals for each dissimilarity and difference were estimated by bootstrap, as in Laura Pla, 2004 (22).

Lastly, we also counted the number of words in the questionnaires’ answers with the NLTK 3.5 library for python 3.8. The number of words was correlated with the number of errors in Q1, Q2

and Q3. This correlation was measured with Pearson's correlation coefficient, which was calculated with the pingouin 0.3.8 package for python 3.8. Also with Python 3.8, with the statsmodels 0.12.1 module, we built a linear regression model, relating the number of errors to the number of words used.

Data Plot

For data visualization, we built word clouds for the answers of each group concerning each survey. The clouds were built using a custom python 3.8 script. First, the answers were preprocessed with a tokenization and lemmatization step, using the NLTK 3.5 library. We also removed punctuations and stopwords. In some specific cases, the words were joined together so that the meaning of the student's sentence was not lost (for example: "naked eye"). So, the word clouds were created with the WordCloud 1.8.1 library and edited with Matplotlib 3.3.2. The largest and most prominent words are those that are repeated most often in the students' responses to the surveys.

For plotting graphs, we used another custom python 3.8 script with the Seaborn 0.11.0 and Matplotlib 3.3.2 libraries.

Ethics

All projects carried out at the Institute of Biomedical Sciences of the University of São Paulo (ICB-USP) are sent for approval by the Institute's Ethics Committee. This project (CEP ICB-USP Protocol #990/2018) was evaluated by the Ethics Committee of the Use of Animals (CEUA ICB-USP) and by the Research Ethics Committee of Human Beings (CEPSH ICB-USP) and was considered exempt from the need for a consent form (report #1247 issued in 11/26/2018). This exemption was because the present study does not carry out any procedure regulated by CONEP resolution #466/2012.

Limitations

In 2019, Q2 was applied shortly after the scientific diffusion course "Journey into the World of Microorganisms and Human Parasites", held in the middle of the project (just after the end of the

general challenges and before the specific challenges), while in 2020, due to the covid-19 pandemic, this course did not take place, and Q2 was applied only at the end of the project (after the specific challenges). Besides that, in 2020, Q2 and Q3 were applied remotely (via Google Forms), so that it was not possible to carry out a control that would prevent the search of didactic materials and websites by students.

Lastly, as the mediators are not the same for all groups and some have changed from one year to another of the project, this may have resulted in small differences in the content worked between different groups and between different years, as there may be an influence from mediators both in engagement and in the content being discussed with students.

RESULTS

To assess students' knowledge about the adopted microorganisms, before, during and after the "Adopt a Microorganism" project implementation, three voluntary and anonymous questionnaires were applied to high school students from the 2nd year of the Federal Institute of Education, Science, and Technology, Campus Sorocaba. In 2019, Q1 was applied just before the beginning of the project (and before Microbiology classes took place) and 36 responses were obtained; Q2 was applied shortly after the diffusion course with 34 responses; and Q3 had 32 responses and was applied 5 months after the project ended. In 2020, Q1 and Q3 were applied at the same time point as in 2019, with 36 and 32 responses, respectively; and Q2 was applied at the end of the project, with 24 responses.

We observed a large number of short answers in the 2019 Q1, and they reflected, in most cases, common knowledge about the adopted microorganism, generally addressing issues related to its pathogenicity or its social impact (benefits or harms brought by the microorganism) (Fig 1A). Conceptual errors were also common, mainly related to the morphology and ecology of microorganisms (Fig 1C). This scenario changed in Q2, in which there was much more information about the adopted microorganisms, especially in relation to its taxonomy, morphology and ecology (Fig 1A), and the conceptual errors were less frequent, focusing mostly on taxonomy and morphology. In Q3 we observed a greater amount of information about the microorganisms when compared to

Q1, predominantly related to taxonomy, morphology and ecology (Fig 1A). However, there was a slight increase in conceptual errors regarding mostly morphology (Fig 1C). The content richness of the students' responses increased in Q2 compared to Q1 ($H_{Q2\text{-}Q1}$=0.17, 95% CI=[0.07; 0.29]), and also increased when comparing Q3 with Q1 ($H_{Q3\text{-}Q1}$=0.08, 95% CI=[-0.05; 0.18])), remaining, however, lower than $H_{Q2\text{-}Q1}$ (Fig 2A and S3 Table). It is important to note that the confidence intervals for both effect sizes are wide. However, they remain predominantly at positive values, which is consistent with the increase in the Shannon index value in Q2 and Q3 over Q1. A similar trend was observed when the data were analyzed by groups, except for the Protozoa ($H_{Q2\text{-}Q1}$=-0.20, 95% CI=[-0.41; 0.05]; $H_{Q3\text{-}Q1}$=-0.13, 95% CI=[-0.77; 0.12]) and Virus ($H_{Q2\text{-}Q1}$=-0.21, 95% CI=[-0.49; 0.08]; $H_{Q3\text{-}Q1}$=-0.11, 95% CI=[-0.29; 0.18]) groups, in which there was a decrease in richness throughout the project (Fig 2C, S1 Table and S3 Table). Surprisingly, with regard to conceptual errors in general, we observed an increase in richness after each survey ($H_{Q2\text{-}Q1}$=0.07, 95% CI=[0.07; 0.07]; $H_{Q3\text{-}Q1}$=0.09, 95% CI=[0.09; 0.09]) (Fig 2C and S3 Table).

This variation in the richness of the students' responses between surveys was supported by the Bray-Curtis dissimilarities calculated (S1 Table). In all the cases the dissimilarity was higher than 0.15, and the confidence interval was restricted – in most cases – to values greater 0.15 and smaller than 0.50 (S1 Table). The main exceptions were the Virus group and conceptual errors (Virus: Q1-Q2=0.52, 95% CI=[0.45; 0.71]; Q2-Q3=0.44, 95% CI=[0.40; 0.61] | Conceptual errors: Q1-Q2=0.51, 95% CI=[0.51; 0.51]; Q2-Q3=0.55, 95% CI=[0.55; 0.55]). Moreover, it is interesting to note that the dissimilarities between Q1-Q2 and Q2-Q3, regarding each group, were very similar (S1 Table).

In 2020, a pattern similar to that of 2019 was observed in Q1, in which the students presented short answers related to common knowledge, mainly about morphology, pathogenicity and ecology of the adopted microorganisms (Fig 1B). Conceptual errors were unusual and concentrated on topics such as morphology and pathogenicity (Fig 1D). In Q2, the responses were much more comprehensive covering a wider range of topics, predominantly morphology, ecology, metabolism,

taxonomy, and reproduction (Fig 1B). Conceptual errors, in turn, were much less frequent and focused on metabolism (Fig 1D). In Q3, many topics were covered, and the responses addressed mainly the morphology, ecology, and reproduction of microorganisms (Fig 1B), and very few conceptual errors were made, mostly related to taxonomy (Fig 1D). In general, the richness of the students' answers increased ($H_{Q2\text{-}Q1}$=0.31, 95% CI=[0.18; 0.44]; $H_{Q3\text{-}Q1}$=0.35, 95% CI=[0.15; 0.51]) and the richness of the conceptual errors decreased ($H_{Q2\text{-}Q1}$=-0.20, 95% CI=[-0.20; -0.20]; $H_{Q3\text{-}Q1}$=-0.30, 95% CI=[-0.30; -0.30]) during the project (Fig 2B and Fig 2D, respectively, and S4 Table). Analyzing by groups, the rise in richness was maintained for all microorganisms in Q2, with a slight decrease in Q3 (Fig 2D, S2 Table and S4 Table). Interestingly, in the Virus group, there was a more expressive increase in richness throughout the project than in relation to the other groups ($H_{Q2\text{-}Q1}$=0.48, 95% CI=[0.29; 0.85]; $H_{Q3\text{-}Q1}$=0.61 95% CI=[0.25; 0.94]) (Fig 2D and S4 Table).

As observed in the 2019 edition, for the 2020 edition, the variation in the richness of the students' responses between surveys was supported by the Bray-Curtis dissimilarities calculated (S2 Table). For 2020, dissimilarities were slightly greater than in 2019. In general, the dissimilarity was higher than 0.20, and the confidence interval was consistent with values between 0.20 and 0.60 (S2 Table). As in 2019 edition, the main exception was conceptual errors (Conceptual errors: Q1-Q2=0.68, 95% CI=[0.68; 0.68]; Q2-Q3=0.71, 95% CI=[0.71; 0.71]). Furthermore, the dissimilarity, between Q1-Q2 and Q2-Q3, regard to each group, were very similar (S2 Table), although in some cases, the point estimate was smaller between Q2-Q3 (as in "All groups", "Archaea" and "Fungi"). It is worth noting that, in these cases, the 95% confidence intervals remained consistent with similar values in Q1-Q2 and Q2-Q3 (S2 Table).

We also used the Bray-Curtis dissimilarities to compare the richness of the students' responses between 2019 and 2020 editions (Table 1). Considering each group, the dissimilarities between 2019 and 2020 in Q1, Q2 and Q3 were very similar (Table 1). The exception was the Bacteria group, that had a greater dissimilarity in Q3 than in Q1 and Q2 (Q1: 2019-2020=0.39, 95% CI=[0.30; 0.68]; Q2: 2019-2020=0.40, 95% CI=[0.35;0.57]; Q3: 2019-2020=0.64, 95% CI=[0.66;0.86]).

Generally, the confidence intervals are wide and include values of dissimilarity between 0.20 and 0.60 (Table 1). Also, the point estimate dissimilarities, in most cases, were smaller than 0.50. The main exception, as in previous comparisons, was the conceptual errors, that had the biggest value of dissimilarity between 2019 and 2020 in all questionnaires (Q1: 2019-2020=0.51, 95% CI=[0.51; 0.51]; Q2: 2019-2020=0.72, 95% CI=[0.72;0.72]; Q3: 2019-2020=0.72, 95% CI=[0.72;0.72])).

According to the "Adopt a Microorganism" evaluation survey, the main positive aspect pointed out by the students in 2019 was the use of Facebook® as a teaching platform, due to its accessibility. They also highlighted the autonomy experienced during the learning process, which allows them to define their own study plan and search for the information they find most interesting (Fig 3A). Few negative points were brought out and they referred mainly to the difficulty of communicating with their group and the ease of losing focus while studying (Fig 3B). In 2020, students also highlighted accessibility to Facebook® and autonomy, as well as interaction with the group, as a positive aspect (Fig 3C). And as in 2019, few negative points were pointed out, and they referred to the difficulty of accessing the Internet, the difficulty of communicating with group members and the distraction of the social network during the research (Fig 3D). Two questions were added to the 2020 questionnaire, to assess the importance of the "Adopt a Microorganism" project during the suspension of face-to-face classes due to the COVID-19 pandemic, and most students mentioned that the project allowed them to keep in touch with colleagues during social distancing, mostly due to the routine of publications and challenges posted on Facebook® (Fig 4A). In addition, most of them also pointed out that the project allowed the continuation of learning, even remotely, mainly because it motivated students to research on the proposed themes and encouraged group discussions (Fig 4B).

DISCUSSION

The cornerstone of Blended Learning is the use of the Internet associated with traditional face-to-face classes (24) and this has been the model of the "Adopt a Microorganism" project applied in high school at IFSP, Sorocaba campus. In 2020, however, classes were suspended due to the COVID-19 pandemic and the project was developed entirely remotely, relying only on the

activities and virtual discussions that took place on Facebook®. It is important to assess whether both models promote an increase in discourse richness on the part of students, as this may suggest the consolidation of learning. An unusual way of analyzing richness in discourse is through the Shannon Diversity Index (14), which is widely used in biology to understand community dynamics and species diversity (16; 15). This index is also commonly used in microbiology, mainly in studies related to microbiome composition (18; 17). In education, and specifically in this work, the Shannon index was chosen because the responses to the questionnaires provided us with data on the amount of approach on a given microbiology subject, that is, the number of responses ("species") on a given category ("region"). Thus, we opted to extrapolate this index to analyze the questionnaires and verify whether both teaching models, which were applied in 2019 and 2020, promoted an increase in the content richness of the participating students.

A major concern with remote learning, especially when applied on an emergency basis, is the decrease in student engagement in the proposed activities (25). In fact, in 2020 we were able to observe a lower engagement in some project activities, especially in the responses to the questionnaires, which were shorter and more objective, when compared to the answers obtained in 2019 (S1 Fig). Despite that, the richness of the students' discourse was quite similar when comparing the two years (Fig 2A, Fig 2B, and Table 1), suggesting that although the information was presented in a more concise way, remote learning also promoted greater richness in the content discussed by students at the end of the project, similarly to what was observed in the blended learning format.

It is important to note that the conceptual errors made by students in the questionnaires were less frequent in 2020 (Fig 1D) compared to 2019, which may be an indication that in the remote learning model there was no loss of content, since the themes addressed by them in the two years of application of "Adopt a Microorganism" were very similar (Fig 1A and Fig 1B). Clearly this observation is also related to the fact that, in 2020, students were much more concise in their responses. To clarify this, we made a linear regression model (S2 Fig) based on the correlation between the number of words written and the number of mistakes made by the students in their answers. The correlation coefficient suggests that there is a positive correlation between the number of words written and the

number of mistakes. Interestingly, the lower regression coefficient in Q2 and Q3 suggests that in the two years, the "Adopt a Microorganism" allowed a reduction in the number of errors by words written by the students.

With the absence of theoretical classes in 2020, the importance of the teacher in the education of students was evident, since knowledge is the product of human relationships and the teacher consists of an intermediary between the concepts to be learned and their assimilation by students (26). In addition, the teacher creates emotional bonds with students, which influences the teaching-learning process in a very positive way, as it facilitates interactions and, consequently, students' cognitive development (27). This was clearly observed in the topic "metabolism", in which there was a significant increase in the number of mistakes made by students in Q2 in 2020, when compared to 2019 (Fig 1D and Fig 1C, respectively). Since in 2020 the students did not have theoretical classes on microorganisms, due to the suspension of activities at IFSP - Sorocaba, there was no greater theoretical support on this topic, which is worked in a more direct and profound way in the classroom, having only depended to the research carried out by students and discussions with mediators via Facebook®. It is worth mentioning that the topic "metabolism" was much more addressed by students in Q2 in 2020 (Fig 1B) compared to 2019 (Fig 1A), which increases the likelihood of errors. The topic "morphology" also called attention, as it presented fewer errors in 2020 (Fig 1D) than in 2019 (Fig 1C). This may be directly related to the fact that students addressed this topic much less in their questionnaires in 2020 (Fig 1B), when compared to 2019 (Fig 1A), probably due to the absence of theoretical classes, when this content is more deeply addressed. Certainly, the possibility of a problem with the consolidation of this content in 2019 cannot be ruled out, which can have numerous causes that are beyond the scope of this work.

A very important point in carrying out the "Adopt a Microorganism" project in 2020 is the covid-19 pandemic, which puts the theme of viruses at the center of discussions and in the spotlight of all media, directly influencing the retention of concepts related to this type of microorganism (29). This was very evident to us, since the group of students who "adopted" the viruses showed a greater consolidated learning in 2020, when compared to 2019 (Fig 2C, Fig 2D and Table 1), and it was

not possible to observe overlap in the intervals of confidence of Q3 and Q1 for this group (H_{Q1} = 1.56, 95% CI = [1.08; 1.64]; H_{Q2} = 2.18, 95% CI = [1.71; 2.23]). Furthermore, there is also the fact that usually what most catches people's attention when talking about microbiology are viruses and bacteria (29), which, in part, may be related to the data observed in our study.

For meaningful learning, it is important that there is a mix between verbal and visual resources, as this allows students to create deeper connections regarding the content, so that the information is retained more effectively (30; 31). Visual resources were more widely used in "Adopt a Microorganism" during 2019, when the face-to-face scientific diffusion course "Journey into the World of Microorganisms and Human Parasites" was held, and the topics covered in the course were widely represented in the clouds of words of Q2 (S3 Fig), in addition to the greater mention of examples of groups or species of microorganisms (Fig 1A). Since one of the objectives of the diffusion course is to introduce students to the "adopted" microorganisms in the form of practical activities (use of microscopes and visits to laboratories), it is possible that this style of activity has increased students' interest in these themes and facilitated the appropriation of examples.

During the pandemic period, it has been widely discussed that remote learning promotes a decrease in student interaction (25; 32), which would be quite worrying, since interactions are an essential part of the teaching-learning (33). However, this was not clearly observed in the "Adopt a Microorganism", since a similar portion of students pointed out that there was a lack and that there was a promotion of interaction with colleagues (Fig 3). In addition, in 2020, about 90% of students considered that there was a promotion of this interaction during the pandemic (Fig 4A), which for us is very important, since the project is based on group activities. This positive assessment of remote learning was also demonstrated in the study conducted by Jackson (2020) (34), which pointed out that students emphasized how much this experience kept them connected. It is important to point out that this interaction between students promoted by the "Adopt a Microorganism" is also very likely related to the platform on which it was developed, since social networks, such as Facebook®, allow for greater interaction when compared to other platforms used for educational purposes (35). We cannot attest, however, that this interaction is greater than or equal to what occurred in the

blended learning model, but that it existed in these two models.

The use of social networks for educational purposes, such as Facebook®, has been widely discussed in the literature and much is said about its benefits and harms (36; 37; 38; 39). One of the drawbacks usually pointed out is the high capacity of distraction that these platforms can offer, which was also highlighted by the students as one of the negative points of the project (Fig 3B and Fig 3D). In 2019, a small portion of students stated their preference for using other social networks to conduct the "Adopt a Microorganism" (Fig 3B), probably because they had face-to-face classes and other activities that allowed the learned content to be more structured and organized. This preference for other social networks disappeared in 2020 and we believe that, as the only "place" of studies in that year was the Facebook®, the organization and structure that this platform allows (posting styles and distribution of students in closed groups) may have been interesting and effective so that they would not judge other social networks as more suitable for carrying out the project. It has already been demonstrated that the students' perception of the learning environment changes with the current context and the circumstances imposed by the covid-19 pandemic may have contributed to a more positive perception of the platform used, precisely because it stimulates the continuity of studies and coexistence interpersonal (34).

Another very important point to be considered when applying the "Adopt a Microorganism" is the need for Internet access, a problem that was very evident in the context of the pandemic, not only in Brazil (40; 41; 42). In fact, this was a negative point pointed out by students, specially in 2020, perhaps due to the possibility of accessing the school's computers and being able to do their research and work more comfortably. In 2020, those who may not have access to the Internet may have found it more difficult to participate in the project, as well students who may have had to share their computers with others at home. It is worth mentioning that the students unanimously opted to continue the project after the suspension of classes, even with possible difficulties in accessing the internet and without face-to-face theoretical classes, and they pointed out that this allowed them to continue their studies during the pandemic (Fig 4B).

It is believed that in a moment of suspension of classes, encouraging students to continue their stud-

ies is very important for the learning process, although it has already been demonstrated that online classes are not able to engage students and guarantee their motivation (32). However, the students who participated in the "Adopt a Microorganism" stated that the project increased their interest in conducting research on the contents that were discussed (Fig 4B), which is extremely relevant for us, since this is related with one of the main pillars of Education, the "Learning to Learn" (43), which consists of awakening in students an interest in seeking information and promoting their own knowledge.

Much is questioned about the real effectiveness of exclusively remote learning, however, our results showed that in both blended and remote learning, students achieved a similar word diversity index and that this occurred regardless of the richness of terms observed in their previous knowledge. Together, these data suggest that the "Adopt a Microorganism" project was effective for the students' learning process in both learning formats. In addition, we found that the remote model is feasible and generates good results, in the same way as the hybrid model, since we were able to observe learning gains in both (S3 Table). We can also attest that there was consolidated learning by the students, since the observation of the Q3 indices (Fig 2) allows us to state that they remain higher than those observed in Q1 for both models of the "Adopt a Microorganism" project. We also observed that there was no loss of content for students who participated in the remote model, which corroborates the idea that the use of the Internet for educational purposes should consist of an expansion of the physical space of the classroom (44; 45), so that the contents worked are equivalent (in the case of completely remote education) or complementary (in the case of teaching in a hybrid model).

Thus, we concluded that both models of the "Adopt a Microorganism" project proved effective for enriching students' speech in microbiology. In addition, comparing the hybrid version with the remote version, we were unable to observe a difference in the quality of the content discussed by these students in social network groups, which suggests, again, that both models are effective for the learning process.

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TABLE 1. Bray-Curtis dissimilarity calculated with the survey responses of the 2019 and 2020 edition.

2019 edition X 2020 edition						
Group	**Q1**		**Q2**		**Q3**	
	Bray-Curtis	**CI 95%**	**Bray-Curtis**	**CI 95%**	**Bray-Curtis**	**CI 95%**
All groups	0.2052	[0.1659; 0.3794]	0.1690	[0.1148; 0.2555]	0.2530	[0.1784; 0.3738]
Archaea	0.4324	[0.2603; 0.6472]	0.3976	[0.2614; 0.5442]	0.3913	[0.2382; 0.5262]
Bacteria	0.3871	[0.2958; 0.6859]	0.3958	[0.3416; 0.5724]	0.6452	[0.6569; 0.8628]
Fungi	0.2598	[0.2000; 0.5080]	0.2892	[0.1724; 0.3636]	0.2672	[0.1842; 0.3952]
Protozoan	0.4412	[0.3223; 0.6224]	0.4318	[0.4084; 0.6160]	0.4000	[0.2500; 0.6388]
Virus	0.3429	[0.2548; 0.5796]	0.3962	[0.3396; 0.5285]	0.4321	[0.2778; 0.6983]

In the Q1 columns, we have a comparison between the questionnaires Q1 from 2019 edition and Q1 from 2020 edition with a 95% confidence interval. Similarly, in the Q2, Q3, there are the values of Bray-Curtis dissimilarity for the Q2 (2019 and 2020 edition) and Q3 (2019 and 2020 edition) surveys.

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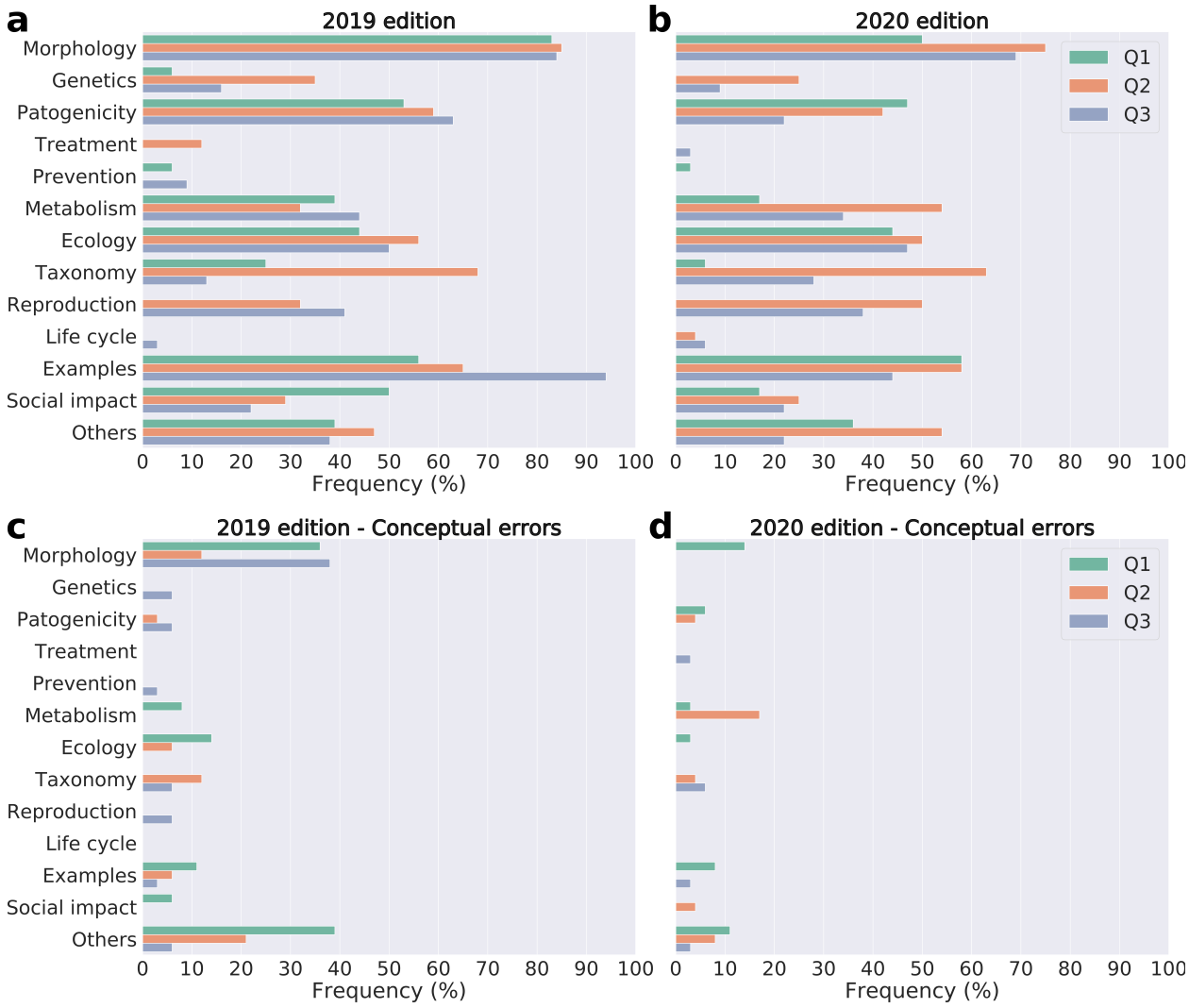

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Fig. 2. Word richness in the questionnaires. Graphs showing the variation in the student's responses richness (calculated by the Shannon index) over the three surveys: Q1, applied before the beginning of "Adopt a Microorganism"; Q2, applied after the diffusion course in 2019 and immediately after the end of Facebook® discussions in 2020; Q3, applied 5 months after the end of the project. **[a]** variation in the Shannon index for all surveys analyzed in 2019; **[b]** variation in the Shannon index for all surveys analyzed in 2020; **[c]** variation in the Shannon index of the surveys answered by each group (Archaea, Bacteria, Fungi, Virus and Protozoa) in 2019; **[d]** variation in the Shannon index of the surveys answered by each group (Archaea, Bacteria, Fungi, Virus and Protozoa) in 2020.

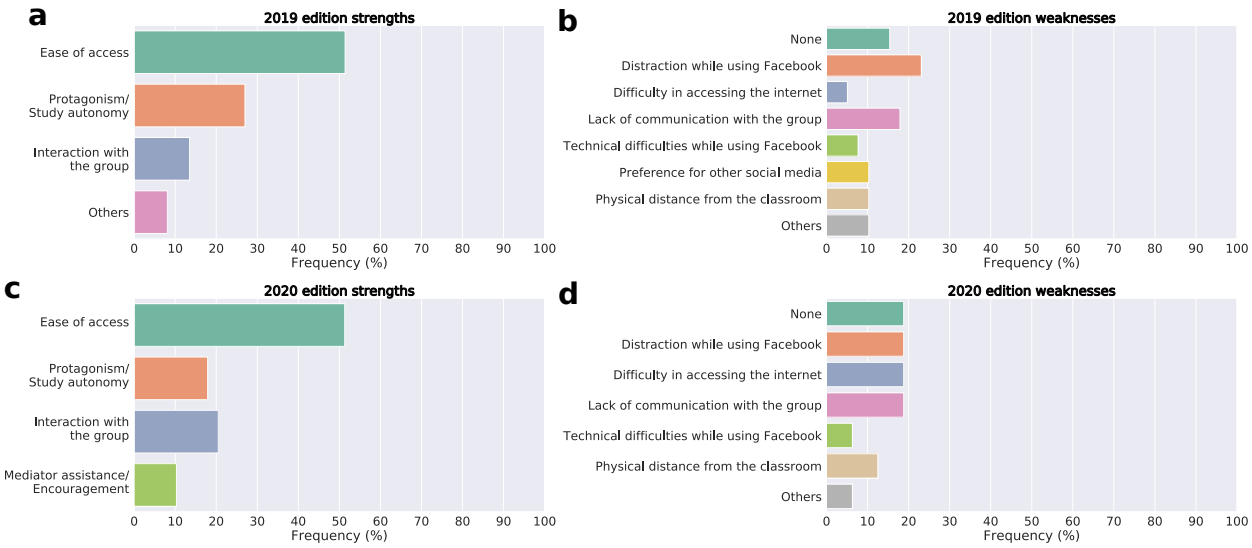
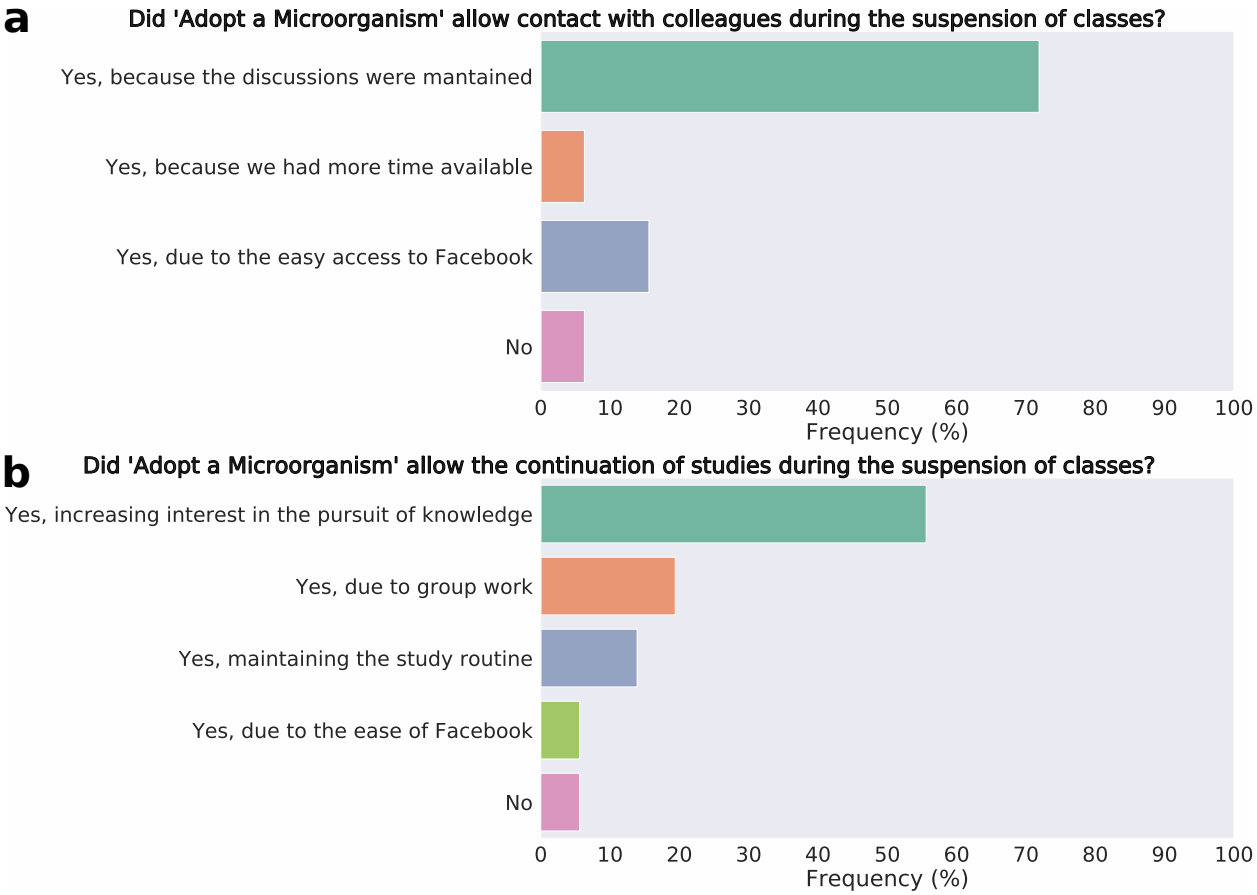


Fig. 3. Students' perception of the "Adopt a Microorganism" project. **[a]** positive points highlighted in 2019; **[b]** negative points highlighted in 2019; **[c]** positive points highlighted in 2020; **[d]** negative points highlighted in 2020.



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