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Research Letter – Professional Development

Evaluation of student engagement through knowledge elaboration and the use of comics in Microbiology education

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Abstract

Despite the many challenges faced by the sudden adaptation of the teaching–learning processes during the emergency remote teaching (ERT) imposed by the COVID-19 pandemic, this period allowed the exploration of innovative educational methods. Here, we report the description and evaluation of a didactic activity designed to foster an active learning environment among Veterinary Medicine undergraduate students enrolling in Microbiology classes during the ERT period at the University of Minas Gerais. The activity consisted of initial expositive classes, followed by students' active search for information, and the execution of a report and short comics covering the topic. The activity was evaluated by a voluntary postquestionnaire. The results suggest that the students had good emotional and educational perception toward the task, and that they noticed the elaboration of the comics as the most valuable tool aiding in the retention of microbiological concepts. We conclude that the proposed strategy, specially by the incorporation of the comics, helped the meaningful learning of microbiology.

Keywords: microbiology, bacteriology, science education, comics, active-learning, knowledge elaboration

Introduction

A cartoon is a single illustration or panel, usually elaborated to convey an idea, while comics tell a story in sequential panels and frequently include dialogues. As means of communication, comics are a narrative system composed of visual and verbal codes in constant interaction, thus efficiently transmitting a message to the reader (Varnum and Gibbons 2002). Through the integration of pictures and short texts in sequential mode, comics are different from cartoons as the reader has the active role of mounting a logic story by imagining the link between the scenes. The comics, therefore, allow the reader to reflect and apprehend concepts through their own experiences and impressions, being an interesting tool for the transmission of complex information in a ludic way (Mayer et al. 1995, Mayer 2009, Cohn 2013).

From an educational perspective, comics may offer several advantages (Jee and Anggoro 2012, Mota et al. 2021): the multimodal nature of comics can increase the readers' engagement and facilitate learning (Eilam and Poyas 2010, Sousanis 2015) and the use of characters in a situation context can provide emotional attachment and self-reference, facilitating the formation of new memories (Symons and Johnson 1997). Indeed, recent studies emphasize the effectiveness of comics as a resource in science teaching and communication (Rota and Izquierdo 2003, Dahlstrom 2014, Kim et al. 2016, Roswati et al. 2019, Akcanca 2020).

As an educational tool, in addition to the use of ready-made comics by the educator to transmit previously prepared content, several simple and intuitive software are available for free (such as Canva and Pixton) allowing teachers and students to be authors of their own materials. By proposing an activity in which students create comics on a given subject, the teacher will be stimulating the development of critical thinking through the synthesis and analysis of concepts studied through a challenging, stimulating, and playful task. Once the activity provides interaction between students and also stimulates the imagination to produce stories in a context, meaningful learning occurs successfully.

Microbiology teaching and learning activities at Universities are, in most cases, based on traditional expositive talks, memorization of concepts, and definitions, placing students in a passive role (Hurtado et al. 2014, Joshi 2021). Innovative and active educational methods are necessary to involve students in the learning process and, thus enhance their interest in specific subjects (Akcanca 2020). On this premise, the use of activities proposing the development of comics by students can help in teaching practice, by allowing the student to create their way of interacting with the initial theoretical concepts presented. However, in higher education in the area of Biological Sciences, the use of comics in the classroom is still very limited. This scenario reveals an interesting gap in the search for active teaching methodologies that are also attractive and efficient involving everyday situations in society.

The COVID-19 pandemic and related lockdowns have forced the need for online and remote teaching within University settings. The temporary Emergency Remote Teaching (ERT), adopted during the closure of in-person activities, involved fully remote solutions for instruction and education. Despite the many challenges imposed by the abrupt adaptation of the teaching–learning processes, this period gave chance for the exploration of novel

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methodologies, enhancement of teacher creativity, and increased autonomy of learners (Ahshan 2021, Kawasaki et al. 2021).

During the ERT period of a Microbiology class at the Federal University of Minas Gerais (UFMG), Brazil, we developed an activity based on students' active search for information, following the execution of a traditional report and short comics covering the topic. The conception of the proposed activity was centered on the knowledge elaboration theory, in which pre-existing information is expanded, refined, and finally organized with new information, creating the opportunity for a meaningful learning (Kalyuga 2009). We hypothesized that this approach would benefit students by promoting an active learning experience, making microbiology more meaningful during the ERT. We also suggested that this approach would help them retain basic concepts in microbiology.

Methods

Study design

The study was conducted at the Department of Microbiology of the Institute of Biological Sciences (ICB) in the UFMG. Students involved in this study were enrolled in Microbiology classes for the Veterinary Medicine undergraduate course, with a biannual offer. For the present study, we considered a total number of 189 learners participating in the course during the second academic semester of 2020 and the first and second academic semesters of 2021. During this period, the course was offered remotely due to the restriction of in-person activities imposed by the SARS-CoV-2 pandemic.

Study development

During the bacteriology module of the course, the students were asked to form groups (4–6 individuals) and were presented to the guidelines of the final evaluative bacteriology task, briefly described. One bacterial genus or species relevant to the veterinary context and not covered during regular classes was designated to each group via random draw from a list. Based on a template (Table 1), each group had to prepare a simple report with the main microbiological characteristics of the designated microorganism, supported by active literature research. The task also comprised the creation of short comics (6–15 scenes) representing microbiological, clinical, and/or diagnostic aspects of the bacteria. The students were encouraged to cover the topic in a playful and enjoyable way. The guidelines included the suggestion of online platforms for the creation of the comics (such as Canva, Pixton, StoryBoard, and StripGenerator). However, it was made clear that hand-drawn comics or text editing of existing comics would also be accepted, being the content and not the artistic part the object of evaluation. All the interaction of the students within the groups was not supervised by the instructor. The students were free to organize themselves and even to eventually divide the activity into tasks to be done by each group member. The instructor did not have access to the time spent by each group or group member in the literature search, elaboration of the reports, and creation of the comics.

After the activity delivery and correction of the reports and comics by the educator, the final class of the bacteriology module was an informal discussion about the task and the main characteristics of the bacteria, mediated by the instructor. After, the groups were invited to correct eventual conceptual errors or mistakes in the report and comics. Then the reports and comics were compiled in a single portable document format (PDF) file by the instructor and shared with the class via message or email after the students' consent.

Data collection and analysis

After the bacteriology module, the students were invited to fill out an anonymous and voluntary online survey. The survey aimed to evaluate the benefits of the proposed activity for the learning process, as well as the impressions of the students. Although all students joined the activity, the questionnaire for the feedback was voluntary.

The form included 17 closed and three opened questions (Table 2). The closed questions comprised the following alternatives as to the answers: (i) I do not know or do not want to answer; (ii) I strongly disagree; (iii) I moderately disagree; (iv) neither agree nor disagree; (v) I moderately agree; and (vi) I fully agree. All the questions were optional, so students could leave them blank. The answers to the closed questions were analyzed quantitatively in the GraphPad Prism software. The answers to the open questions were translated to English and used to generate clouds of words at the Edwordle website. Terms considered meaningless when isolated were excluded, such as articles and conjunctions, and words expressing actions, opinions, feelings, quantity, quality, and suggestions were included.

Ethics

This study was evaluated and approved by the Research Ethics Committee of the Institution. All the participants had to read and accept the Free and Informed Consent Form before accessing the survey content.

Results

The main goal of this study was to develop an approach for the active learning process of bacteriology during the ERT period. After being taught the introductory microbiology and bacteriology concepts as passive conventional lectures, the students developed an evaluative activity in groups. The task comprised the literature search about a designated bacterium, as well as the production of a report with the main microbiological data (Table 1) and short comics representing microbiological, clinical, and/or diagnostic aspects of the bacteria.

The activity was conducted with three classes in consecutive semesters of the pandemic ERT, and all the 189 students enrolling in the course participated. We applied an online survey (Table 2) to evaluate the efficacy of the proposed activity to the learning of microbiology, and the involvement and acceptance of the students. The questionnaire, which was anonymous, was voluntarily answered by 79 students (41.8%).

Figure 1 depicts the answers to the open questions (Q1–17) represented as percentages. All the students considered the activity clear on what they should do (Q1). The impact of the task (research followed by a report and comics) on the education process from the students' point of view was positive, as 96.20% answered they agree that doing the activity improved their learning acquired with the theoretical classes (Q2). A total of 77 (97.47%) of the responders agreed that the activity was of an adequate intellectual level (Q3), while 73 (92.40%) agreed that the production of the comics was of an appropriate artistic or digital level (Q4).

The Q5 aimed to understand whether the students enjoyed the proposed active-based learning methodology, or prefer passive-learning traditional expositive classes about the subject. Most of

Table 1. Information included in the template report delivered to the students. The groups were instructed to fill in the report in topic format, not as plain text.

Topic	Description
Bacteria	Genus or species
Taxonomic classification	Phylum, class, order, and family
General micromorphological and structural characteristics	Cell shape, arrangement, cell wall characteristics, Gram stain, and so on.
Relevant metabolic and biochemical characteristics	Relationship with oxygen, classification as to carbon source, metabolic pathways (i.e. fermentation, respiration, and so on), relevant enzymes, and so on.
Nutritional requirements and environmental characteristics for laboratory cultivation	Cultivable or noncultivable *in vitro*, fastidious or not, simple or complex culture media requirements, temperature, oxygen atmosphere, and so on.
Main pathogenicity factors	Most important, when known: capsule, toxins, adhesins, enzymes, and so on.
Resident microbiota (asymptomatic carriers)	Indicate if there are known asymptomatic carriers, informing the colonized anatomical site.
Most relevant veterinary disease(s)	Types of infection and the affected organs.
Pathogeny	Describe all the steps (from the port of entry until the establishment of the disease and interaction of the microorganism with the host), citing the effect of the main virulence factors, when known.
Laboratory diagnosis	Main microbiological, serological, and/or molecular techniques used, culture media for isolation, and so on.
Treatment	Indicate whether the disease treatable, citing the use of antibiotics, supportive measures, and so on.
Acquired antimicrobial resistance	Is there a problem with acquisition of resistance within this bacterium?
Control	Is there a vaccine available? Protection measures, hygiene, and so on.
Other relevant information	Any information that the group finds relevant, such as outbreaks, curiosities, epidemics, and so on.
Bibliography used in the research	Use only reliable sources.
Light and electron microscopy photos	N/A

Table 2. Questions included in the online survey the students were invited to anonymously respond to. The form comprised 17 closed questions and three opened questions. All the questions were optional.

Question	Type
1. The activity was clear on what I should do.	Closed
2. Doing this activity (report and comic strip) improved my learning acquired with the theoretical classes I had during the course.	Closed
3. The activity (report and comic strip) was of an adequate intellectual level (hard/easy).	Closed
4. The activity (comics) was of an appropriate artistic or digital level (use of programs and software).	Closed
5. I enjoyed learning this way (report and comic strip) more than attending a class on the subject I researched.	Closed
6. I believe I will remember more of the content I researched because I had to contextualize it and create a comic strip.	Closed
7. I found the final discussion of the groups' work useful and interesting.	Closed
8. I felt more motivated to contribute to the final discussion in the proposed format than if I had to present a formal seminar on the subject I researched.	Closed
9. I felt comfortable sharing the material produced by my group with the rest of the class.	Closed
10. I enjoyed receiving the material produced by the other groups.	Closed
11. I preferred to read only the comics produced by the other groups.	Closed
12. I preferred to read only the reports produced by the other groups.	Closed
13. I read both the reports and the comic strips produced by the other groups.	Closed
14. I believe I will remember more of the content researched by the other groups because of the comics they created.	Closed
15. I believe I will remember more of the content researched by the other groups because of their reports.	Closed
16. I found this learning method stimulating and/or interesting.	Closed
17. I felt like showing the comic strip produced by my group to my family or friends.	Closed
18. If you enjoyed doing this type of activity, or thought it was useful, why did you enjoy it or learn from it?	Opened
19. What do you suggest to improve this activity?	Opened
20. Would you like to leave any more comments, criticisms, or suggestions?	Opened

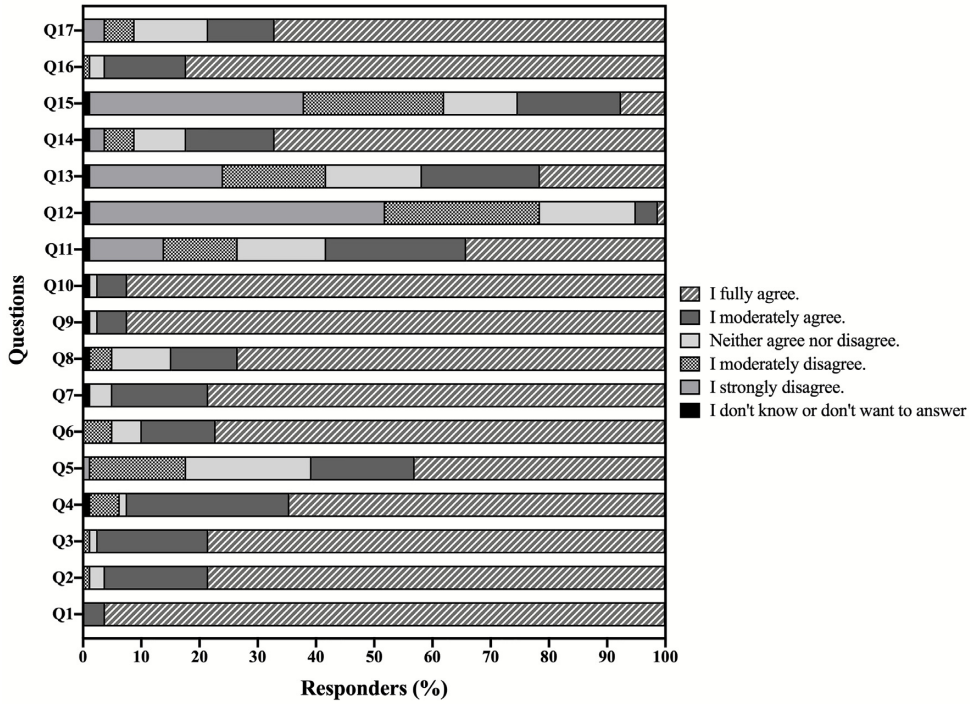

Figure 1. Graphic representation of the students' answers to the closed questions of the questionnaire. The answers were analyzed by the software GraphPad Prism and are represented as percentages.

the students agreed or moderately agreed (34 and 14, respectively) that they enjoyed more the proposed activity, while 17 neither agreed nor disagreed, 13 moderately disagreed, and one responder fully disagreed.

When questioned if they believe they will remember more of the researched content because they had to contextualize it and create comics (Q6), 71 (89.88%) answered they agree (fully and moderately). Questions 7 and 8 intended to evaluate the students' opinion regarding the task final discussion. A total of 75 responders (94.94%) agreed that the final discussion was useful and interesting (Q7) and 67 (84.81%) felt more motivated to contribute to the final discussion in the proposed format than if they had to present a formal seminar (Q8).

After the completion of the activity, all the groups consented to the sharing of their work. The majority (97.47%) of the survey participants agreed they felt comfortable sharing the material produced by their group (Q9) and enjoyed receiving the material produced by the other groups (Q10). Concerning the reports and comics, 46 responders (58.23%) agreed (fully and moderately) that they preferred to read only the comics produced by the other groups (Q11). A total of four responders (5.06%) agreed (fully and moderately) that they preferred to read only the reports produced by the other groups (Q12). The proportion of learners agreeing and disagreeing they read both the reports and the comic strips was 41.77% and 40.50%, respectively (Q13). A total of 68 (82.23%) students agree they will remember more of the content researched by the other groups because of the comics (Q14), while 20 (25.31%) agree the reports will aid them more in remembering the content (Q15). Altogether, these results indicate a clear preference for the reading of the comics, which the students also believe will help them attain the microbiological concepts.

Most of the learners (76; 96.20%) found the learning method stimulating and/or interesting (Q16). A total of 64 students (78.48%) fully and moderately agreed they felt like showing the comics they produced to their family and friends (Q17), suggesting they were excited about the activity.

The open questions intended to analyze qualitatively the students' perception. The responders of the survey had a positive overall evaluation of the task. According to their answers, the activity improved their learning ability, helping to retain the concepts presented in expositive lectures. The Q18 (If you enjoyed doing this type of activity, or thought it was useful, why did you enjoy it or learn from it?), was answered by 28 students. After translating the answers into English, we generated a cloud of words consisting of the main qualitative and descriptive words the responders used (Fig. 2). The most used words can be considered positive for the dynamic analysis: learned, different, fun, creativity, learning, knowledge, retention, enjoyed, and interest. The students pointed out that it was a complete activity, emphasizing the effectiveness of transforming the research object into a report and short comics. However, the main point raised was the development of the comics. Most students answering the Q18 mentioned the elaboration of the comics as a very positive way of retaining the knowledge, highlighting the enthusiasm to use creativity and art in an activity different from the conventional in college. Some responders praised the task as something light, smooth, and fun, helping to face the stress of the ERT during the COVID-19 pandemic. Below are transcribed excerpts of Q18 answers.

> "(…) the most interesting and that contributed even more to the learning process was to make the comics since we had to use the knowledge acquired in the research and explain it in a playful and simple way as if we were going to explain the subject to a layman."

> *"(…) as it was a relaxed way to assimilate the content, it relieved some of the stress of the semester in ERT as it was a fun activity."*

> *"Putting art and creativity together with theory helps to fix the content, especially when we run out of in-person practical classes (…)."*

Figure 2. Graphic representation of the answers to the question 18 of the questionnaire. Q18: If you enjoyed doing this type of activity, or thought it was useful, why did you enjoy it or learn from it? The answers were translated into English and used in the elaboration of a cloud of words. The cloud of word represents the most used words by the responders. The larger the letter in which the word is written, the more used the word.

A total of 13 responders answered Q19 ("What do you suggest to improve this activity?"), which mostly found the activity very well-elaborated, and did not register constructive criticisms about it. The students mentioned the adequacy of time and methodology. One responder suggested the activity could be done in smaller groups or individually if wished, and another suggested that the activity could be focused only on the comics, without needing to do the reports. A total of 16 responders (20.25%) answered Q20 ("Would you like to leave any more comments, criticisms, or suggestions?"), which addressed only positive comments and compliments, as some transcribed below.

> *"(…) it was a great learning experience and the activity helped and facilitated the understanding of the subject."*

> *"I found it very stimulating and interactive. It was good to work in a group and create something involving both creativity and content, which we will take to our professional lives."*

All the groups participated in the final discussion of the activity, contributing microbiological aspects and curiosities about their designated bacterium. In general, students used solid scientific concepts in a playful and enjoyable way. In conclusion, the results suggest that the proposed activity provided a number of valuable approaches to enhance the undergraduate learning process of microbiology.

Discussion

Solid comprehension is essential for students to learn well-defined concepts that will form the foundation of their knowledge. Microbiology is a vast compilation of knowledge, in which students first need to learn basic terms, then achieve proficiency in basic information, and eventually, they understand more complex ideas. Most Microbiology classes—and STEM (Science, Technology, Engineering, and Mathematics) in general—are usually taught in a teacher-centered way, prioritizing memorization (Merkel 2016). However, students learn more when actively engaged in learning than in a passive lecture environment (Freeman et al. 2014). Various studies support this observation, especially in university-level science courses (Hake 1998, Freeman et al. 2014, Deslauriers et al. 2019). Using active learning student-centered strategies means that students participate by discussing, writing about, researching, or solving problems, therefore, promoting skills such as application, conceptual understanding, and critical thinking (Merkel et al. 2010, Merkel 2016).

Here, we report the description and evaluation of an educational activity initially designed to foster an active learning environment among Veterinary Medicine undergraduate students enrolling in Microbiology classes during the COVID-19 pandemic ERT period, centered on the knowledge elaboration theory. Knowledge elaboration is using prior information to expand and refine the knowledge based on processes such as organization, restructuration, interconnection, integration of new elements of information, and identification of relations (Kalyuga 2009). Knowledge elaboration is essential for meaningful learning since it allows the organization of knowledge into a coherent structure and integrates new information with pre-existing ones.

The knowledge elaboration theory and the learning process focused on developing inquiry-based thought combine very well with comics. By presenting information visually and verbally, comics improve mental processes indispensable for the recall and recognition and develop aesthetic pleasure in students (Akkaya 2013).

The students came into contact several times with the concepts of microbiology through the dynamic we proposed: expositive introductory classes, literature research, a report, and the application of knowledge in the confection of comics. Therefore, they had the opportunity to learn through knowledge elaboration perspective. The students eventually might have achieved a meaningful learning by applying creativity, personal experience, investigation, verification, argumentation, and discussion.

The activity was evaluated by a voluntary postquestionnaire, filled by 41.8% of the learners enrolled in the course. Based on the answers, the students had good receptivity and perception toward the activity. However, it is clear that some students still resist student-centered strategies and prefer traditional teacher-centered methods, as almost 40% of the responders did not agree they prefer the proposed activity instead of expositive classes (Q5). This is in line with the general perception of undergraduates about active-learning methodologies (Fagen et al. 2002, Dancy and Henderson 2005, Felder 2007). It is common for instructors to return to passive lectures after trying active teaching, many of them citing student complaints as the main reason (Henderson et al. 2012). Other common obstacles preventing educators from adopting student-centered learning are insufficient time, limited resources, a lack of institutional support, and concerns about content coverage and evaluations (Felder and Brent 1996, Silverthorn et al. 2007).

The most used course material in the learning process of science is undoubtedly the textbooks. On the other hand, we live in an age of technology and information in which, however, less and less time is spent reading long texts. In this sense, it is necessary to evaluate other resources that can provide the transmission of information quickly and efficiently. In this eminently visual society, comics should be considered a powerful tool in favor of education due to their visual appeal and texts that are generally easy to understand. As they are a language full of meanings and close to the daily reality of the population, they are adequate resources facilitating the learning of scientific concepts. The answers to the questionnaire support these thoughts, as students mostly preferred to get into contact with the subject researched by the other groups through reading the comics and not the reports.

As expected, the students remarked the elaboration of the comics as the most valuable educational tool aiding the recall of the content they actively researched. The contextualization of microbiological content in the elaboration of the comics can foster students' imagination and, thus contribute to their creative thinking processes. Similarly, most responders believe they will remember more of the content researched by the other groups because of the comics and not the reports. Supporting this, pictures are a powerful tool to increase comprehension of written information, which can be overwhelming, leaving readers with a sense of information overload (Niederdeppe et al. 2019).

The incorporation of the comics in the proposed activity seemed to be effective in engaging and shaping student attitudes positively. The answers to the postquestionnaire suggest that comics were a useful resource to deliver information in a short, appropriate, and effective way. Comics also facilitated the application of knowledge to different aspects of illnesses by the Veterinary Medicine students, using uncomplicated terms and even jokes (Delp and Jones 1996, Green and Myers 2010).

The proposed teaching strategy developed in this project can be applied to other disciplines, with adaptations to specific fields (scientific or technical). We also acknowledge limitations of our study, as the development of the activity occurred during a specific educational period (pandemic ERT) at one institution. Therefore, our results might not be similar in other settings or in-person activities. Additionally, although the students indicated an improvement in understanding of common microbiology concepts, the study design did not allow a more robust and objective examination of the impact of comics on meaningful learning, particularly when compared to other more traditional forms of instruction.

Conclusion

We conclude that the proposed strategy, especially by the incorporation of the comics, potentially helped the meaningful learning of microbiology, both from the instructor's and students' perspectives. The application of knowledge elaboration theory might also have facilitated students to consolidate microbiology basic and more complex concepts by revisiting the concepts in many levels and by different tools: lectures, research, report, comics, and discussion. The didactic activity proved essential to alleviating the stress and uncertainties of the ERT period adopted during the COVID-19 pandemic. A study to evaluate the same strategy applied to the in-person course after the end of the pandemic restrictions is currently under development.

Ethics statement

This study was evaluated by the Federal University of Minas Gerais (UFMG) Research Ethics Committee and approved under the protocol number CAAE 43916421.0.0000.5149.

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