Online Verbal Argumentative Interaction (OVAI) in an Online Science Class During the COVID-19 Pandemic

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Abstract
As we begin the third decade of the twenty-first century, argument and debate are not habitual practices of university science education. This can be explained by the hegemony of instructor-centered traditional approaches in many of these practices. The Covid-19 pandemic has not only pushed university education online but also seems to provide an unforeseen opportunity to develop deep educational transformations. Here, we report on the case of a university online science course that, because of the Covid-19 crisis, used online verbal argumentative interaction (OVAI) to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments in an undergraduate-centered science learning environment. The written arguments and counterarguments co-constructed by forty students (20 females and 20 males, 19–24 years old) during OVAI sessions were analyzed to determine their quality. Also, students' opinions about the use of OVAI in times of Covid-19 were documented. The results indicate that the students co-constructed high-quality arguments and counterarguments in the OVAI sessions. Most importantly, participants showed positive impressions about the use of OVAI in university online science education. The outcomes carry important educational implications considering the growing university online science courses in the pandemic and post-pandemic eras.

Keywords: Argumentative interaction, COVID-19, online education, higher science education, online verbal argumentative interaction.

Archila, P. A., Truscott de Mejía, A., Restrepo, S. (2022). Online Verbal Argumentative Interaction (OVAI) in an online science class during the COVID-19 pandemic. *Online Learning, 26*(4), 236-258.

As we begin the third decade of the twenty-first century, we should recognize that "argument and debate are virtually absent from university science education" (Archila et al., 2020, p. 647). Recently, in *The Routledge International Handbook of Student-Centered Learning and Teaching in Higher Education* (Hoidn & Klemenčič, 2021a), Chang et al. (2021) pointed out that argumentative interaction through class discussion (e.g., debate) should be considered one of the multiple key allies of student-centered learning environments. They clarify that this implies moving from instructor-centered learning to student-centered learning. It may be obvious to point out that traditional science instructor-centered practices provide university students with very few opportunities to cultivate their argumentative skills. Nevertheless, the point of concern here is that many universities make little empirical effort in considering how to transform their outmoded educational practices (Ashwin, 2020). Tan and Chen (2020) remind us that technologies are just tools for functional improvements. They contend that transformation implies going beyond the mere implementation of instructional tools or making a simple tweak to a traditional instructional method. To be precise, they define transformation as "making a significant change in *teaching* and *learning interactions* or learning mechanisms that aims at improving students' learning" (p. 2, italics added). In the current article, online verbal argumentative interaction (OVAI) is assumed as a form of teaching and learning interaction.

A common conclusion of the twenty articles included in the special issue of *Online Learning Journal,* entitled *The Covid-19 Emergency Transition to Remote Learning* (Jaggars, 2021), is that the Covid-19 pandemic has pushed online education forward. In the case of higher education institutions, Al-Salman and Haider (2021), Morgan et al. (2021), and Johnson and Barr (2021) explain that these institutions may take advantage of this crisis to identify deficiencies and accelerate reform of online education. Likewise, several scholars stress that the pandemic and post-pandemic eras seem to be an unforeseen opportunity to develop substantial transformations in university education (e.g., Archila et al., 2022; Corbera et al., 2020; Erduran, 2020; Hall, 2020). Arguably, the creation and consolidation of student-centered science educational scenarios can be a legitimate and desirable result of these transformations.

The Covid-19 Pandemic Pushes University Science Education Online

In this article the term "online education" refers to the educational experience in synchronous and/or asynchronous environments using computers, smartphones, tablets and/or other devices with Internet access (Zhu & Liu, 2020). Some academics have started to document the effects of the Covid-19 pandemic on education. One clear effect is that universities have rapidly pivoted to fully online education practices (not only in science). Sun et al. (2020), for example, discuss the results of a survey conducted among 39,854 students at Southeast University in China. An interesting finding was that respondents considered online interaction might be relevant to increase students' participation. Likewise, Sun et al. (2020) assert that this pandemic should be assumed by universities as an unforeseen opportunity (1) to rethink the belief that students are passive recipients and (2) to create genuine teaching and learning scenarios for explicit online interaction through open discussions.

In Jordan, Al-Salman and Haider (2021) surveyed 4,037 undergraduates to examine the respondents' attitudes towards online learning during the Covid-19 emergency. A key outcome was that only 25% of the students in the sciences (*n* = 1,967) considered "that the course objectives and learning outcomes have been achieved through distance learning with the same degree of effectiveness and efficiency as in face-to-face education" (p. 291). In Indonesia, Jariyah and Tyastirin (2020) administered an 11-item questionnaire (*N* = 82 students) to analyze the processes and constraints of Biology online learning amidst the Covid-19 pandemic in the Biology Study Program of UIN Sunan Ampel Surabaya. Interestingly, they found that 61 out of the 82 Biology students preferred direct face-to-face courses. Jariyah and Tyastirin (2020) consider that this and the fact some students had to pay for data packages, had unstable networks, and lack of practical activities are some of the reasons that can explain this result. According to Sun et al. (2020), it is common that instructors simply duplicate online the disciplinary content of traditional classroom lessons. Clearly, this can exacerbate traditional science instructor-centered practices. It is, therefore, rational and reasonable that some scholars consider that the Covid-19 crisis is an invaluable opportunity to create university student-centered online learning environments (e.g., Rapanta et al., 2020; Zhu & Liu, 2020).

In the present article, *student-centered online learning environment* is defined as an approach to promote authentic, meaningful, and deep learning through the combination of online instructional methods and activities in which students and their learning are placed at the heart of the process (Hoidn, 2017). Naturally, in this type of environment online, straight lecturing stops being the center. Accordingly, more time is devoted to online meaningful and intellectually challenging tasks and activities deliberately designed to engage students with content and active participation (Hoidn & Klemenčič, 2021b). Jacobs et al. (2016) divide student-centered learning into ten overlapping elements that informed our study. We briefly describe them as follows:

(1) Students and instructors as co-learners—Instructors change their unquestioned authoritarian role and look forward to learning along with students.
(2) Student-student interaction—Students are provided with opportunities to share with their peers.
(3) Student autonomy—Students become lifelong learners; they are accountable for their educational process and become less dependent on instructors.
(4) Focus on meaning—Students strive to develop genuine and meaningful understanding of what they are studying.
(5) Curricular integration—Students perceive a clear integration between the topics, subjects, and the wider world.
(6) Diversity—Various learning activities are created to meet the needs of all students and to guide them in differentiating their different purposes.
(7) Thinking skills—Students are challenged to go beyond the information treated in the course, being helped to give examples, explain, debate, and criticize the views of others in order to enrich their thinking skills.
(8) Alternative assessment—Different nontraditional forms of assessment practice are adopted, such as (formal and informal) formative assessment, peer assessment, and self-assessment.

(9) Learning climate—Instructors strive to create an atmosphere in which all students spontaneously participate, ask questions, and communicate their viewpoints in content-related discussions.
(10) Motivation—Instructors foster authentic motivation and encourage students to motivate themselves, their peers, and their instructors to learn.

These ten elements give us an idea of how complex it is to create a student-centered learning environment. Therefore, it is not surprising that Jacobs et al. (2016) recommend small steps rather than one revolutionary leap to shift from science instructor-centered learning to student-centered learning. By the same token, Hoidn and Klemenčič (2021b) underscore the need to take concrete actions to make student-centered learning practices a reality rather than just rhetoric. In the next section, we shall discuss the main characteristics of OVAI and argue that this can be considered as a concrete action in a student-centered online learning environment.

Main Characteristics of OVAI

In his book, *Improving How Universities Teach Science*, Nobel laureate Carl Wieman (2017) criticizes the hegemony of the traditional science instructor-centered model adopted by many universities and invites us to transform university science education. According to Jacobs et al. (2016), activities involving student-student interaction can result in greater benefits, such as higher order thinking (e.g., argumentation, critical thinking, problem solving) and higher self-esteem. Also, they emphasize that these should be one of the various regular activities of student-centered learning environments. Unfortunately, "only a minority of students in secondary and postsecondary education receive direct and explicit instruction in argumentation" (Quintana & Correnti, 2019, p. 1133). At this point, it is important to clarify some key terms. In the present article, argumentation is considered as a scientific practice with the goal of "justif[ying] claims with reasons and/or evidence" (Erduran et al., 2022, p. 1). We use the term "reason" to refer to "the cause of an event or situation or something that provides an excuse or explanation" (Cambridge Dictionary 2021). Moreover, in this article the term "evidence" refers to "the facts, signs, or objects that make you believe that something is true" (Oxford English Dictionary 2021).

Within this perspective, the elaboration of reason-based and/or evidence-based arguments (and counterarguments) is an important aspect of authentic argumentative practices. An example of a reason-based argument is presented by Erduran et al. (2022) as follows: "Day and night occur because of a spinning earth" (p. 2). With respect to evidence-based argument, an example is communicated by Archila et al. (2020, p. 650): "Fever of 311.15 K (38 °C) and higher during the first 10 days following delivery or miscarriage is a key symptom" that can be used to diagnose puerperal fever. Archila (2015a) categorizes argumentation as a "cognitive-linguistic skill" due to its intellectual and communicative nature. Similarly, Plantin (2018) states that the goal of argumentation is to construct and communicate arguments in a rational and reasonable way. Moreover, he outlines that argumentation is a communicative and interactional act. With this in mind, we define "argumentative interaction" as a verbal and/or written communication in which two or more people exchange and/or co-construct arguments in a dialogic—egalitarian (symmetric) dialogue—atmosphere. For this article, "online verbal argumentative interaction" (OVAI) refers to verbal argumentative interaction that is mediated by the Internet.

As mentioned in the introduction to this article, the traditional science instructor-centered model is one of the major obstacles to success in implementing argumentative interaction in university science courses. There are various reasons that explain the hegemony of this model. First, some science instructors hold the following limited (and naïve) view of the teaching and learning process: "If I [we] know the subject well, I [we] can also teach it" (Kampourakis, 2017, p. 202). Second, in many universities around the globe, very few science instructors hold a degree in education (either an undergraduate degree or a postgraduate qualification) (Archila & Truscott de Mejía, 2020). Third, in many universities, to hold a degree in education is not considered an indispensable requirement to become a science instructor. The consequence of this is that many university students are enrolled in university science courses in which the instructors are experts in their field (e.g., astronomy, geosciences, physics). Nonetheless, they are certainly not experts in the *teaching* and *learning* of their field. To deal with this inconsistency, Kampourakis (2017) and Wieman (2017) have proposed deep and permanent collaboration between science education specialists and science instructors. Also, Wieman (2017) stresses that the instructors' use of evidence-based teaching practices in their courses should be imperative. As Archila (2014, 2017a), Uzuntiryaki-Kondakci et al. (2021), and Pabuccu and Erduran (2017) have demonstrated, even pre-service science teachers are not usually prepared to promote argumentation.

Argumentative interaction is a valuable opportunity to engage university students in the co-construction of reason-based and/or evidence-based arguments and counterarguments when they debate in small groups. This type of interaction provides students with genuine opportunities to construct better-argued and more informed and critical views on science-related issues. To this end, it is fundamental that the instructor encourages them to co-construct reason-based and/or evidence-based arguments rather than that each group member imposes her/his viewpoint (Baker et al., 2020; Schwarz & Baker, 2017). Bova (2017) has studied the instructor's role in fostering argumentative interaction in higher education. He underscores the importance of the types of questions used by the instructor to engage students in argumentative interaction. Similarly, Archila (2017b) and Archila et al. (2021a) provide evidence for the claim that argumentative interaction is more productive when students are presented with questions in which diversity of reason-based and/or evidence-based arguments and counterarguments are possible.

At this point, an important question to ask is how it is possible to formulate questions that facilitate argumentative interaction. Baker (2002, 2003) has proposed five conditions that can prove useful for instructors to better engage students in argumentative interaction, namely:

(1) Diversity of proposals or viewpoints should exist relating to an issue (e.g., collaborative problem, controversial question, open-ended question)—there is no "right" answer, method, or solution to this issue.
(2) Two different proposals, at least, should exist in the same small group—these provide group members with the opportunity to evaluate evidence to determine which proposal is more plausible.
(3) Each proposal should be plausible (reasonable)—this elicits students' deep understanding.

(4) Each small group should be asked to decide (e.g., choose one proposal)—this condition makes it possible for students to evaluate and criticize the argumentation of the other group members.
(5) When choosing one proposal, each small group should carefully examine the arguments and counterarguments of the decision made—this provides students with a final opportunity to evaluate the plausibility of the proposal selected.

Previous studies have confirmed the coherence and usefulness of these conditions (Clark & Sampson, 2008; Clark et al., 2007; Jiménez-Aleixandre & Brocos, 2017). Archila (2015b, 2017b) and Archila et al. (2018, 2020, 2021a) have corroborated the usefulness of these five conditions after adopting them in the formulation of argumentative questions as a way to engage students in face-to-face (offline) argumentative interactions. In the present study, we use these in OVAI. We claim that OVAI can be a means to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments. This claim emerges as a response to Namdar and Namdar's (2021) call to give students opportunities to not only develop arguments but to go further by means of the formulation of counterarguments. They explain that this is fundamental to help students avoid adopting biased attitudes when making decisions. Naturally, this vision is incompatible with traditional science instructor-centered practices. Hence, an effective implementation of Baker's (2002, 2003) five conditions in OVAI practices that result in explicit opportunities for students to co-construct reason-based and/or evidence-based arguments and counterarguments requires student-centered online learning environments (Jacobs et al., 2016). In our case, we decided to include OVAI as one of the multiple types of activities of an undergraduate-centered science learning environment that will be discussed later.

Research Questions

The aim of the present study is to provide evidence for the claim that OVAI can be used to give students explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments when an undergraduate-centered science atmosphere is created. Our study is a realistic contribution to transforming university online science education. Specifically, the study seeks answers to the following two research questions:

(1) Can OVAI be used to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments?

(2) What is the opinion of the students about the use of OVAI in university online science education?

Methods

Setting

This research was carried out in a highly academic-ranked private university located in Bogotá, Colombia. Due to the Covid-19 pandemic, this higher education institution speeded up the implementation of online education. The university decided to assume this pandemic as an unforeseen opportunity to launch an ambitious plan to enhance its educational practices. Some of the concrete actions included the following: the robustness of the learning management system, Blackboard Learn™, changes in the evaluation methodologies prioritizing formative over summative assessment practices, and most importantly, permanent training and support to instructors not only in technological-related skills, but also in the creation, implementation, and assessment of activities for their online courses.

Before intervention start-up, permission was obtained from the University's Ethics Committee. We applied "convenience sampling" (Bryman, 2016, p. 187) and implemented our strategy in a science course in which the last author is the course instructor. This medium (40-60 students per semester) undergraduate course was called Food Microbiology. This course was taught over a 16-week period and consisted of lectures (two per week, 75 min each) and a practical laboratory session (one per week, 120 min). It was usually taken by undergraduates of different ages, who were studying different majors (e.g., Microbiology, Food Engineering, Chemical Engineering). The Food Microbiology course was offered initially in an online format. The course information, tools (e.g., audio and video recordings of the lectures), and assignments were available for the undergraduate students in Blackboard Learn™, while Zoom®—a video conferencing software app—was used for lectures and OVAI.

Participants

Of fifty eligible undergraduates enrolled in the Food Microbiology course, forty (80%) participated in this study. Out of these 40 participants, 20 were female and 20 were male. Most of the participants at the time of data collection were in their early 20s (M = 21.0; SD = 1.30). All participation was voluntary and, as required by the University's Ethics Committee, participants gave their consent for participation in writing. Students were informed about the aims of the project. It was emphasized that they could stop participating in the study whenever they wanted, and they were informed that their viewpoints and answers would have no influence on their final course grade.

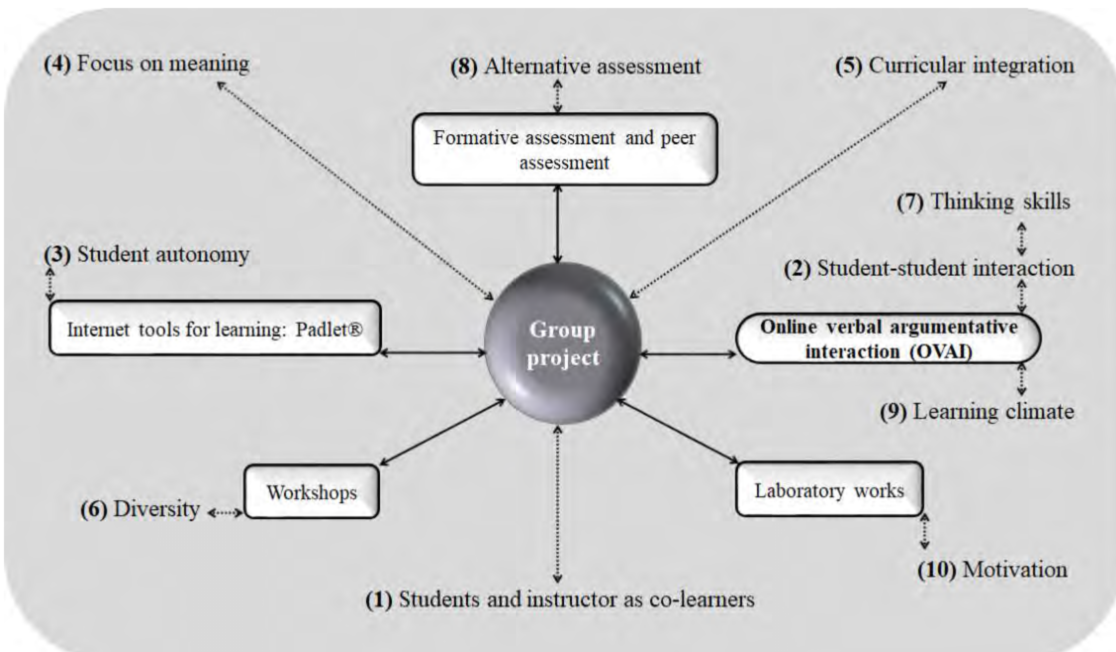
Intervention

Throughout this article, we claim that the Covid-19 crisis is an unforeseen opportunity to use OVAI to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments in an undergraduate-centered science learning environment. Thus, in this section we describe the main features of the student-centered science learning environment created and implemented in the Food Microbiology course. Our learning environment (Figure 1) was informed by the ten elements proposed by Jacobs et al. (2016) and discussed earlier. The activities (e.g., group project, laboratory work, OVAI) were deliberately designed to place students and their learning at the center of the process. A group project was the main activity.

The students worked in small groups (4-5 students) throughout the course to do a project together in which they proposed an innovative solution to treat (control) a microorganism (e.g., *Clostridium botulinum*, *Staphylococcus aureus*) (freely chosen by each group) in the food industry (e.g., the dairy sector, fruit, and vegetable industry). We created this main activity as a co-learning scenario to support the instructor learning along with the students, as well as curricular integration, and the development of genuine and meaningful understanding of what students were studying (focus on meaning). Workshops, laboratory works, Padlet®, formative assessment, and OVAI were the activities created to help students develop their innovative solutions as part of the main activity (group project). Padlet® is an online platform on which students can post observations about any topic treated in the course (e.g., nature of microbiology, toxins found in food).

Figure 1

Our Undergraduate-Centered Science Learning Environment. Numbers Indicate the Ten Elements Proposed by Jacobs et al. (2016).



Each type of activity was associated with at least one of the ten elements of student-centered learning proposed by Jacobs et al. (2016) (Figure 1). Nevertheless, as they remind us, these are “overlapping elements” (p. xiv) which means that this association is only informative because the same element (e.g., motivation) is, of course, involved in more than one activity. In this article, we report on one activity: OVAI. A total of four OVAI sessions (Weeks 4, 6, 12, and 14) were organized over the 16-week period of the Food Microbiology course. In these sessions, video conferencing features were used to divide the class into small groups. Each small group was asked to decide about an argumentative question (four in total).

It was explained to the participants that the requirement that each group should make a single decision implied reaching a consensus as far as possible, and perhaps most importantly, they were asked to evaluate the arguments for and against presented by each small group member to co-construct small-group arguments and counterarguments. Clearly, this implies a challenge that should motivate participants' argumentation involving deliberation. Each small group was also asked to report in writing the group decision as well as the arguments and counterarguments which had been co-constructed. The four argumentative questions presented to the students were as follows:

(1) What could be an effective and feasible home food preservation technique? (OVAI session 1, Week 4, Topic: Food preservation methods).

(2) Which technique would you recommend for the identification of microorganisms in food? (OVAI session 2, Week 6, Topic: Testing methods in food microbiology).

(3) Think about a pathogen that affects fish or shellfish and the method employed by a specific country to prevent or control it. In your opinion, is this method rational and reasonable? (OVAI session 3, Week 12, Topic: Microbiology of food products of animal origin).

(4) Choose two fruits and/or vegetables. In your view, which are the greater sources of contamination in the agricultural production-consumption chain of such fruits and/or vegetables? (OVAI session 4, Week 14, Topic: Microbiology of fruits and vegetables).

The role of the instructor in these OVAI sessions was to encourage the undergraduates, while maintaining her neutrality throughout to avoid influencing students' decisions. In each OVAI session (in total four), small groups were given 45-60 min (in total 180-240 min) of the 75-min lecture to discuss and report in writing the decision made and the co-constructed arguments and counterarguments. At this stage, it is important to clarify that the number of members of each group varied to give students the opportunity to interact with different partners. Specifically, in OVAI sessions 1, 2, and 4, small groups consisted of 5-6 students while 2-3 was the number of participants in small groups in the third OVAI session.

Research Design

Data Collection

The data corpus is composed of the arguments and counterarguments co-constructed by each small group during the four OVAI sessions as a response to the four argumentative questions and reported in writing. Each small-group writing is assumed as a concrete product of each OVAI session. The data also include the participants' responses to an anonymous 11-item feedback survey (Appendix) adapted from previous surveys about the promotion of argumentation in higher science education (Archila et al., 2018, 2020, 2021b). It was self-administered (5-8 min) in the last session of the Food Microbiology course through the survey administration app, Google Forms™.

The purpose of this instrument was to find out about the students' opinion relating to the use of OVAI during Covid-19, and thus receive valuable feedback from participants for future improvements in the promotion of OVAI in the pandemic and post-pandemic eras. Instrument completion was voluntary. Thirty-two out of the 40 participating students answered the survey.

Data Analysis

In order to answer the first research question, "Can OVAI be used to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments?", and to arrive at valid conclusions from arguments and counterarguments co-constructed in OVAI sessions and reported in written mode, we adopted a *magnitude coding method*—commonly used to indicate the variable characteristics of data such as intensity, presence, or evaluative content (Saldana, 2021). To be precise, we used a single valid-invalid evaluative content. Table 1 shows the six codes used. The coding was conducted independently by the first and the last author. Cohen's kappa coefficient (Cohen, 1960) calculated was 0.61 for OVAI session 1 (Week 4); 0.80 for OVAI session 2 (Week 6); 0.77 for OVAI session 3 (Week 12); and 1.00 for OVAI session 4 (Week 14). According to Bryman (2016, p. 276), "a coefficient of 0.75 or above is considered very good; between 0.6 and 0.75, it is considered good" inter-coder agreement. All discrepancies were discussed, and a consensus was reached after further examination of the corpus. Additionally, the first and the last author classified independently the arguments and counterarguments co-constructed by the participants into two categories, namely "reason-based" and "evidence-based" (Table 2). Kappa coefficient calculated was 0.66 for OVAI session 1 (Week 4); 0.64 for OVAI session 2 (Week 6); 0.70 for OVAI session 3 (Week 12); and 0.82 for OVAI session 4 (Week 14).

Table 1

Rubric Used in the Coding Data of the Quality of the Arguments and Counterarguments Co-Constructed

Code	Description
1A = Low quality	More than one of the arguments co-constructed is invalid
2A = Satisfactory quality	One of the arguments co-constructed is invalid
3A = High quality	All the arguments co-constructed are valid
1C-A = Low quality	More than one of the counterarguments co-constructed is invalid
2C-A = Satisfactory quality	One of the counterarguments co-constructed is invalid
3C-A = High quality	All the counterarguments co-constructed are valid

A Argument, *C-A* Counterargument

Table 2
Rubric Used in the Coding Data of the Nature of the Arguments and Counterarguments Co-Constructed

Code	Example
1R-BA = Reason-based argument	"Freezing of food is a good preservation method because the enzymes of some microorganisms do not work at low temperatures, so their functions will be affected, and thus its growth in food will be inhibited" (Small-group 4, OVAI session 1, Week 4, Topic: Food preservation methods).
1R-BCA = Reason-based counterargument	"Freezing of food only stops the growth of microorganisms, but there is no elimination of these" (Small-group 4, OVAI session 1, Week 4, Topic: Food preservation methods).
2E-BA = Evidence-based argument	"It has been demonstrated that the use of organochlorine and organophosphate pesticides is an effective way for treating the pathogen: *Argulus japonicus*" (Small-group 2, OVAI session 3, Week 12, Topic: Microbiology of food products of animal origin).
2E-BCA = Evidence-based counterargument	"Evidence suggest that the use of organophosphate pesticides is expensive and harmful to the environment and the host" (Small-group 2, OVAI session 3, Week 12, Topic: Microbiology of food products of animal origin).

Finally, to answer the second research question, "What is the opinion of the students about the use of OVAI in university online science education"? the participants' responses to Questions 1 to 5 of the online anonymous survey (Appendix) were analyzed using "frequency of occurrence" (Erickson, 2012, p. 1462). In order not to exceed the word limit for this article some answers to open-ended questions 2 and 4 are briefly commented on in the Results section. Moreover, responses to Questions 6 to 11, were placed on a rating scale range of frequency from Strongly Disagree (1) to Strongly Agree (5). To measure the internal consistency reliability of these questions, the Cronbach's alpha coefficient was calculated using the *Statistical Package for the Social Sciences* (SPSS®). The coefficient obtained was 0.97. According to George and Mallery (2020), this value corresponds to an "excellent" (p. 244) internal consistency.

Results

The findings are presented in two sections. The first section deals with the outcomes of the arguments and counterarguments co-constructed in small groups during the four OVAI sessions, while the second section reports the results of the 11-item anonymous survey that asked for the students' opinions about the OVAI sessions.

Quality and Type of Arguments and Counterarguments Co-Constructed in Small Groups

As previously mentioned, in the four OVAI sessions students interacted argumentatively in small groups. The number of members per group varied depending upon the session. For example, 14 small groups were organized for OVAI session 1, while 6 small groups were organized for OVAI session 4. As explained earlier, the purpose of this variation was to foster the interaction of students with different partners in variable membership proportions, and thus facilitate the presence of diverse viewpoints and counterarguments. Table 3 shows the quality of the arguments and counterarguments reported in writing by participating students as product of the co-construction process carried out in each of the four OVAI sessions.

Table 3

Quality of the Arguments and Counterarguments Co-Constructed in Small Groups in Each OVAI Session

	Arguments			Counterarguments		
	Low	Satisfactory	High	Low	Satisfactory	High
OVAI session 1 (Week 4–Food preservation methods)						
Small-groups (*n* = 8)	1	2	5	1	-	7
OVAI session 2 (Week 6–Testing methods in food microbiology)						
Small-groups (*n* = 9)	1	3	5	1	3	5
OVAI session 3 (Week 12–Microbiology of food products of animal origin)						
Small-groups (*n* = 14)	2	2	10	2	-	12
OVAI session 4 (Week 14– Microbiology of fruits and vegetables)						
Small-groups (*n* = 6)	-	1	5	-	-	6

It is interesting to note that OVAI session not only provided students with explicit opportunities to co-construct arguments and counterarguments, but also offered them a scenario in which most of the small groups co-constructed satisfactory or high-quality arguments and counterarguments. Perhaps most importantly, these outcomes (Table 3) indicate that many small groups went further to co-construct valid counterarguments. In other words, they answered the argumentative question (e.g., Which technique would you recommend for the identification of microorganisms in food?) in each OVAI session, based on reasons and/or evidence rather than on biased views. This assertion is corroborated by the results displayed in Table 4. These outcomes suggest that the small-groups effectively co-constructed reasons and/or evidence arguments and counterarguments. We found that participants tended to co-construct more reason-based arguments and counterarguments than evidence-based arguments and counterarguments. It is important to clarify that this trend is just informative and cannot be assumed as an indicator to assess the quality of the co-constructed arguments and counterarguments.

Erduran et al. (2022) remind us that the type (reason-based or evidence-based) of the argument does not determine its quality. In our case, we consider that the nature of the four argumentative questions that stimulated the four OVAI sessions could have contributed to the formation of this reason-based (counter) arguments trend.

Table 4
Type of Arguments and Counterarguments Co-Constructed in Small Groups

	Arguments		Counterarguments	
	R-B	E-B	R-B	E-B
OVAI session 1 (Week 4–Food preservation methods)				
Small-groups (*n* = 8)	7	5	7	4
OVAI session 2 (Week 6–Testing methods in food microbiology)				
Small-groups (*n* = 9)	9	1	9	1
OVAI session 3 (Week 12–Microbiology of food products of animal origin)				
Small-groups (*n* = 14)	13	5	13	5
OVAI session 4 (Week 14– Microbiology of fruits and vegetables)				
Small-groups (*n* = 6)	6	3	6	2

R-B Reason-based (counter) argument, *E-B* Evidence-based (counter) argument

Students' Opinions About the OVAI Sessions

Switching from instructor-centered learning to student-centered learning is a *sine qua non* condition among many, to implement argumentative interaction practices in higher education (Hoidn & Klemenčič, 2021b; Jacobs et al., 2016). Accordingly, we created and implemented an undergraduate-centered science learning environment in which OVAI is one of the multiple activities deliberately designed to place students and their learning at the center of the process (Figure 1). Importantly, our online learning environment was pushed forward by the Covid-19 crisis. For all the reasons just mentioned, it makes sense to report the impressions of the participating students about the OVAI sessions. A first result of the 11-item survey to mention here is that 26 out of the 32 participants who completed the instrument had received instruction in argumentation before taking the Food Microbiology course (Question 1 in Appendix). Although one would assume that this is a favorable contextual factor for instructors to become more interested in the implementation of argumentative interaction scenarios, the reality does not necessarily support this assumption. The reality shows that 14 out of the 32 respondents never (2/32) or infrequently (12/14) had the opportunity to participate in student-student OVAI sessions in other university online courses in times of Covid-19 (Question 5 in Appendix). Therefore, the data collected from Question 5 is important for two reasons. First, these suggest that student-student OVAI was not adopted by as many instructors as expected during in the Covid-19 emergency transition to online learning (Al-Salman & Haider, 2021). And second, they reaffirm Sun et al.'s (2020) idea that most of the instructors carried out this transition attached to traditional science instructor-centered practices.

Another key finding is that nearly all the respondents (29/32) considered that the Food Microbiology course provided them with opportunities to interact argumentatively with their partners (Question 2 in Appendix). As shown in the comments that follow, participating students appreciated the fact that this course gave them opportunities to interact and discuss various topics. Such opportunities seemed to be almost inexistent in other courses. Some of the comments were: "It was important to discuss and interact with people from different areas"; "I had the opportunity to debate about specific topics of the course via Zoom, I liked this so much"; and "in other courses, small-groups discussion activities do not exist, this has been probably the second course in which I have got engaged in small-groups discussion, and I am already in 7th semester." In view of these comments, it is certainly not surprising that all the respondents of the survey considered that the sessions of argumentative interaction with their partners were useful for them (Question 4 in Appendix). It is interesting to note that undergraduates perceived the utility of argumentative interaction to enrich their learning process as illustrated in the following opinions: "It was useful to achieve deep understanding"; "I could get to know new ideas and perspectives that I had not considered"; and "there were concepts that my partners understood better than me, therefore discussing with them helped me to better understand their ideas. Moreover, some of them were microbiology students who had clearer previous knowledge that was very helpful." Even though these are promising impressions, 14 out of the 32 participants who answered the survey mentioned that "little time to discuss" was one of the difficulties they found when interacting argumentatively with their partners. Other difficulties included the following: an unstable network (7/32) and mastery of scientific knowledge (6/32) (Question 3 in Appendix).

In closing, Table 5 displays the respondents' average scores along with the standard deviations on questions 6 to 11 of the anonymous survey (Appendix). The maximum possible average score for each item was 5. The results indicate that the average scores varied between 3.68 and 4.06 with a mean of 3.88 which corresponds to the "agree" choice (Bringula et al., 2012, p. 1073). This suggests that the students appeared to have positive impressions about the implementation of OVAI practices in the Food Microbiology course.

Table 5

Descriptive Statistics of Survey Questions 6 to 11

Question	Mean	SD	Cronbach's alpha if item deleted
6. I liked the student-student OVAI sessions	3.81	1.22	0.960
7. The student-student OVAI sessions helped me to develop deep learning	3.87	1.23	0.963
8. The student-student OVAI sessions were an opportunity to practice my argumentation skills	3.68	1.17	0.968
9. The student-student OVAI sessions helped me become aware of my learning process	3.90	1.14	0.964
10. Student-student OVAI sessions should continue to be promoted in the Food Microbiology course	4.06	1.21	0.962
11. Student-student OVAI sessions should be promoted in other university online courses as well	4.00	1.24	0.967

Discussion and Educational Implications

Several scholars writing about the COVID-19 crisis have called for the implementation of research-based change in educational practices (Archila et al., 2022; Corbera et al., 2020; Erduran, 2020; Hall, 2020; Sun et al., 2020). In this sense, Erduran (2020) maintains that "the pandemic context has reiterated the importance of promoting students' understanding of uncertainty in science, acquisition of critical thinking skills, as well as the ability to engage in argumentation and problem-solving" (p. 488). Consequently, in this article we report on the case of a university online science course that, pushed forward by the Covid-19 pandemic, implemented OVAI practice to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments in a student-centered science learning environment. In this section, the results are discussed in the light of the literature. Moreover, educational implications are presented in relation to the two research questions that guided this study.

Regarding the first research question— "Can OVAI be used to provide students with explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments"? —an overview of the results showed that participating students co-constructed valid arguments and counterarguments in small groups when explicit opportunities were given in the form of the OVAI session (Table 3). All four OVAI sessions were fruitful for this co-construction. The planning process of these sessions was inspired by the five conditions proposed by Baker (2002, 2003) and described earlier. Therefore, the positive results reported here reinforce the idea that Baker's (2002, 2003) conditions offer a pragmatic and effective framework for those instructors interested in the implementation of argumentative interaction scenarios in their courses (Archila, 2015b, 2017b; Archila et al., 2020, 2021a; Clark & Sampson, 2008; Clark et al., 2007; Jiménez-Aleixandre & Brocos, 2017). In this regard, the contribution of our study is that it provides research evidence to demonstrate the usefulness of Baker's (2002, 2003) conditions to engage students in the co-construction not only of arguments but also of counterarguments. This is an authentic contribution if we acknowledge the need to give students opportunities to not only construct arguments, but to value diverse viewpoints and anticipate counterarguments (Erduran et al., 2022, Namdar & Namdar, 2021).

Erduran et al. (2022) insist that the formulation of reason-based and/or evidence-based arguments is a fundamental aspect of the argumentative process. Results showed that the small-group decisions students made during OVAI sessions were supported by both reasons and evidence (Table 4). This suggests that these sessions were an explicit opportunity for undergraduates not only co-construct valid arguments and counterarguments, but also to diversify the nature of these. Thus, it is plausible to suggest that OVAI can be used to help students to become engaged in the practice of "the meta-linguistic features of argumentation (claims, reasons, evidence, and counterargument)" (Osborne, 2010, p. 466). It is relevant to remember that OVAI was one of various activities of an undergraduate-centered science learning environment. Two implications emerge from these results. First, policymakers and stakeholders should take more account of Chang et al.'s (2021) invitation to abandon the instructor-centered learning approach.

Second, instructors should be trained, guided, and supported in the creation, implementation, and evaluation of student-centered face-to-face and online learning environments for the post-pandemic era. Importantly, as Kampourakis (2017) and Wieman

(2017) assert, much of the success of this transformation process is determined by permanent collaboration between science instructors and science education specialists.

The fact that the encouraging results of the OVAI sessions have been obtained in a student-centered learning environment supports what Chang et al. (2021) and Jacobs et al. (2016) have noted, namely, that student-student argumentative interaction should be considered one of the multiple key allies of student-centered learning environments. One implication here is that the creation of this type of environment in the post-pandemic era should be guided by research-based frameworks. In our case, Jacobs et al.'s (2016) ten elements inspired our environment (Figure 1). In the twenty-first century, this implication may seem obvious at first glance. Nonetheless, "a look in many classrooms today shows a predominance of teacher centered practices" (Jacobs et al., 2016, p. xiv).

Regarding the second research question— "What is the opinion of the students about the use of OVAI in university online science education"? —the results of the 11-item survey revealed that, in general, students seemed to have positive opinions about the OVAI sessions. This is consonant with a key result of the survey reported by Sun et al. (2020) in China: respondents were aware of the importance of online interaction in higher education practice in times of Covid-19. Unfortunately, we found that undergraduates' opportunities to become engaged in student-student OVAI are still limited in other university online courses, even in times of Covid-19. Interestingly, this issue of concern has been reported in previous studies focused on face-to-face educational practices before the Covid-19 pandemic (Archila et al., 2020; Pabuccu & Erduran, 2017; Quintana & Correnti, 2019). Recently, Erduran et al. (2022) presented us with the following paradox formulated in the pre-pandemic era: Instructors tend to consider argumentation as important, but they rarely include activities such as "debate, valuing different positions and getting students to anticipate in counterarguments" (p. 12) in their science courses. It is, therefore, plausible to suggest that our results reaffirm Sun et al.'s (2020) contention: The response of some university courses to the Covid-19 crisis was merely to duplicate online the outmoded traditional instructor-centered practices.

Limitations and Scope for Future Research

Four serious limitations of this study should be acknowledged. The main limitation is the lack of a control group. Undoubtedly, more robust evidence would have been produced if we had had the opportunity to compare our results with those of a control group. Second, our sample size is quite small (forty participants). Hence, caution needs to be taken regarding the generalizability of our outcomes which are exploratory, preliminary, and tentative. Third, more than half of the undergraduates had received previous instruction in argumentation. This situation could have influenced the co-construction of arguments and counterarguments. It would be interesting to design and conduct replication studies with students who have not received previous instruction in argumentation to enrich the corpus.

The fourth limitation is that we implemented our strategy in only one Food Microbiology course in a Colombian university. Exploring the use of OVAI to give students explicit opportunities to co-construct reason-based and/or evidence-based arguments and counterarguments in other online undergraduate-centered science learning environments, in other universities, and in other countries is critical to establish additional validity.

Much work remains to be done in relation to the creation of genuine and meaningful OVAI scenarios. Thus, the results reported here are certainly far from infallible. Due to the growing number of university online science courses in the pandemic and post-pandemic eras, there is a need for additional research related to the design of pragmatic and effective OVAI activities in which students can enrich their argumentation skills. Also, more research on how to productively use OVAI to promote the co-construction of reason-based and/or evidence-based (counter) arguments with graduates and undergraduates from multiple education majors (not only science) would help to better understand the ways in which OVAI could be implemented in accordance with the nature of each discipline (e.g., Anthropology, Architecture, Chemistry).

Declarations

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

The authors assert that permission to do this work was obtained from the Universidad de los Andes, Colombia Ethics Committee prior to the study and that all participation was voluntary. As required by the university's ethics committee, participants gave their consent for participation in writing.

The authors declared that this work was supported by funding from the Vice-Presidency of Research and Creation, Universidad de los Andes, Bogotá, Colombia.

Acknowledgement

The authors wish to thank all the undergraduates at the Food Microbiology course for allowing them to investigate the OVAI sessions in which they were engaged. The study reported in this article was supported by funding from the Vice-Presidency of Research and Creation, Universidad de los Andes, Bogotá, Colombia.

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Appendix A
Survey

1. Have you ever received instruction in argumentation?
   a. Yes
   b. No
2. Do you consider that the Food Microbiology course provided you with opportunities to interact argumentatively with your partners?
   a. Yes
   b. No
   Why?
3. In the Food Microbiology course, which type of difficulty did you come up against in interacting argumentatively with your partners? (More than one option is possible)
   a. Unstable network
   b. Little time to discuss
   c. Mastery of scientific knowledge
   d. Other …………………………..
   e. I did not encounter any difficulty
4. Were the sessions of argumentative interaction with your partners useful for you?
   a. Yes
   b. No
   Why?
5. In times of Covid-19, how often do you have the opportunity to participate in student-student online verbal argumentative interaction (OVAI) sessions in other university online courses?
   a. Very frequently.
   b. Fairly frequently.
   c. Infrequently.
   d. Never.

How well do you agree with the following statements: (1) Strongly disagree, (2) Disagree, (3) Neither agree/ disagree, (4) Agree, and (5) Strongly agree.

		1	2	3	4	5
6.	I liked the student-student OVAI sessions	□	□	□	□	□
7.	The student-student OVAI sessions helped me to develop deep learning	□	□	□	□	□
8.	The student-student OVAI sessions were an opportunity to practice my argumentation skills	□	□	□	□	□
9.	The student-student OVAI sessions helped me become aware of my learning process	□	□	□	□	□
10.	Student-student OVAI sessions should continue to be promoted in the Food Microbiology course	□	□	□	□	□
11.	Student-student OVAI sessions should be promoted in other university online courses as well	□	□	□	□	□