Use of Interrupted Case Studies to Promote Argumentation in Chemistry

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There has been an increase in the number of studies about educational scenarios aimed at promoting argumentation. Special attention is given to scenarios involving case studies. In this article, we report on the application of an interrupted case study to develop argumentation skills supported by information and communication technologies. The case study solved by students in an undergraduate chemistry course addressed water resources contaminated by heavy metals and their effects on human health. The activities carried out led to the students preparing an oral presentation and arguing the resolution of the case, which was analyzed from an epistemic point of view. The case provided rich debates among students and stimulated participation in the activities. Students developed a strong argument in which theoretical claims were supported by experimental data in the form of visual representations.

Argumentation is present in numerous stages of scientific investigation, such as raising hypotheses, constructing predictions, and drawing conclusions. In recent years, there has been an increase in the number of studies on the subject, showing its relevance for developing students' reasoning, critical thinking, and understanding of the nature of science (Erduran et al., 2015; Souza & Queiroz, 2019).

Regarding the educational scenarios aimed at promoting argumentation, special attention is given to those involving case studies, which in this article we recognize as the use of narratives about scientific or socioscientific issues to increase students' curiosity and motivate them to critically apply disciplinary concepts in an authentic context (Silva & Queiroz, 2021; White et al., 2009). There are several types of case studies, one of which is the interrupted case method, which presents the problem in a progressive disclosure format. According to Herreid (2005), in this method, the narrative can be developed by following the content of a research article, and the interrupted case can portray a problem that was faced by researchers in a certain area.

Based on a review conducted by Selbach et al. (2021) on publications in the field of chemistry teaching in Brazil, the use of case studies to promote argumentation is remarkable, especially in chemistry in higher education. The study carried out by Selbach et al. also shows some gaps, such as the development of studies on argumentation in contexts that include information and communication technologies (ICT), which, more than ever, are on the rise, given the physical restrictions imposed by the COVID-19 pandemic.

Based on this research, in this article, we aim to report on the application of a case study called *Remnants of a Lead Past* to develop the argumentation skills of students in an undergraduate chemistry course supported by ICT.

Case study: *Remnants of a Lead Past*

Regarding the methodological aspects of the work, the interrupted case study *Remnants of a Lead Past* was produced by taking into consideration the characteristics of a good case (Herreid et al., 2016) and the application steps of interrupted case studies proposed by Herreid (2005). The case study was created from the research article titled "Evaluation of Metal Content in Sediments of the Betari River in the Parque Estadual Turístico do Alto Ribeira: PETAR, São Paulo, Brazil" (Cotta et al., 2006) and addresses the contamination of water resources by heavy metals and the effects on human health.

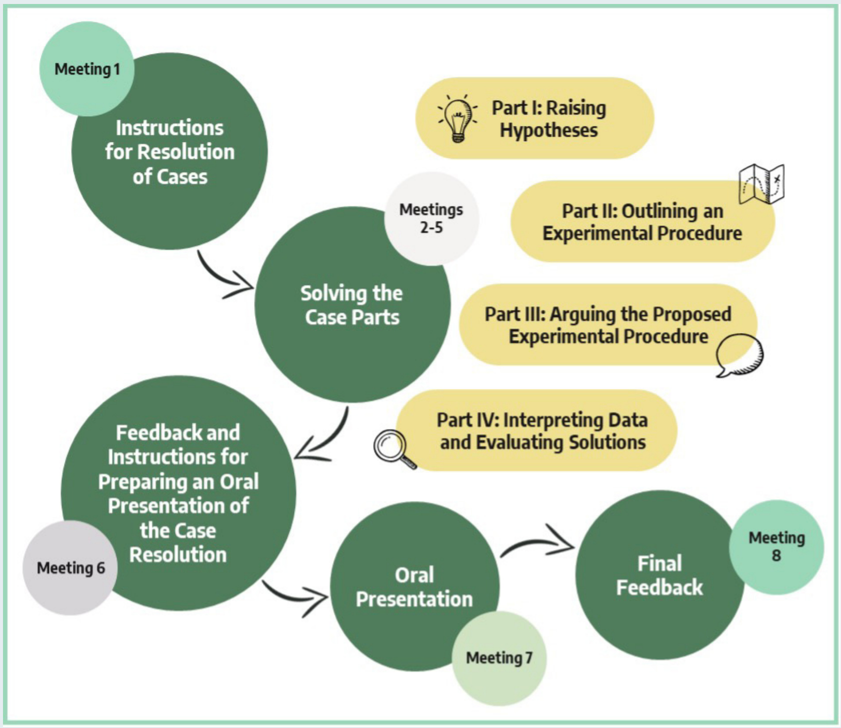
The case study tells the story of Victoria and Igor, two graduate students in chemistry who decide to visit Paulo, their friend who works in the Divina

Ecological Park. Paulo tells his friends that he was intoxicated with lead, and the doctor in the region believes the water that supplies the village where he lives is the origin of the contamination. Genuinely concerned about the situation of their friend, Victoria and Igor volunteer to investigate the dilemma. Searching for information, Victoria and Igor discover that there are several lead mines in the park and that they were explored 10 years ago by a company called Garden Mining. These activities involved extracting galena, processing lead, and disposing of residual materials along the banks of the Beans River. The main problem of the case study is to verify the concentration of lead, among other metals, in river sediment that supplies the village where Paulo lives and to show the connection between the lead concentration and the presence of lead mines in the area.

The case study was organized into four parts (Figure 1) that have two different sections: a narrative through which information about the problem was presented and questions that supported the research activities and search for solutions.

FIGURE 1

Activities carried out for application of the case *Remnants of a Lead Past*.



Course settings

The case study was solved by undergraduate chemistry students at a Brazilian university who were enrolled in a scientific communication course. The use of case studies meets the course aims to improve students' writing, reading, and oral communication skills, all of which support the development of skills related to argumentation. The case study required the students to make decisions based on a data set that was gradually disclosed. In other words, the students were engaged in the production of arguments in a scenario that portrays an authentic scientific practice.

For the application, 28 first-year students worked in small groups (four or five students in each). Due to the COVID-19 pandemic, the course was taught in a remote format, and two virtual environments were used. Google Meet was used for weekly meetings with students and to enable discussion of the case narrative and activities. Tidia-Ae was used for the teacher to send notifications and materials to students (e.g., answers to activities for each part of the case). Eight meetings were held to solve the case study; Figure 1 presents the activities carried out in each meeting.

The activities listed in Figure 1 led to the students preparing an oral presentation (OP) about the resolution of the case, featuring the following sections: Narrative Recap, Contextualization, Elaborated Hypotheses and Questions, Experimental Procedures, Results and Discussion, Conclusions, and Group Response to the Case Characters. One student from each group conducted the group's OP on Google Meet.

Epistemic levels for the analysis of oral arguments

All OPs were recorded and transcribed. By using this material and the slides prepared by the students, we conducted analyses regarding the quality of the students' oral argumentation. To do this analysis, we used the analytical framework proposed by Kelly and Takao (2002), which we adapted for the theme of the case (see Figure 2).

The analytical framework proposed by Kelly and Takao (2002), which is based on Latour and Wool-

FIGURE 2

Definitions and examples of epistemic levels for the analysis of arguments produced by students during the oral presentation of the case resolution.

Epistemic Levels	Definitions	Examples (G4)
6	General propositions describing environmental processes or scientific concepts usually present in textbooks or technical standards. The knowledge represented may not necessarily refer to data that is specific to the area of study.	Lead processing and refining were done by the traditional way, which is the roasting of galena, which is a chemical process used in metallurgy that consists of heating lead sulfide in the presence of oxygen, which would form lead oxide and later, it would be turned into metallic lead.
5	Propositions in the form of theoretical claims specific to the area of study.	As the region of Divina Park was a region where it rained a lot, these metals flowed into the river.
4	Propositions in the form of theoretical claims, illustrated with data specific to the area of study.	We can also conclude that there was sediment transport along the river, as we can see in points five and six.
3	Propositions establishing patterns, trends, and relations among environmental samples from the area of study.	We can see that at point one, there is a concentration above the maximum permissible concentration.
2	Propositions identifying and describing properties of environmental samples[a] from the area of study.	The first two points, points one and two, which are the ones next to the mining company...
1	Propositions making oral and explicit reference to data (graphs, charts, tables, maps etc.) of the area of study.	In this graph, we can see zinc concentrations from the analysis of pseudototal and bioavailable metals.

[a]Environmental samples: water, sediment, fish, aquatic plants, soil, etc.

Note. Adapted from the analytical framework proposed by Kelly and Takao (2002).

gar's (1979) modality of claims, captures discourse movements made by participants to bring relevant information and draws conclusions on an epistemic status. Using Figure 2 to analyze an argument consists of classifying all of the propositions that compose it in the epistemic levels according to their definitions.

The Results and Discussion and Conclusions sections from the OP were selected for analysis because the data provided in the case are presented and debated in these sections, so most of the argumentative sentences are produced in the referred sections. The speech during each slide was taken as a unit of analysis (UA). Each UA was numbered and sorted into the six epistemic levels shown in Figure 2.

Resolution and arguments for the case

Initially, the fact that students participated in the meetings is highlighted. From the discussions held on Google Meet and the written materials handed in by students on Tidia-Ae, we observed that the case allowed for rich debates among students and stimulated participation in the activities. In the application, several chemistry topics associated with the themes of the case were discussed, such as bioavailability of metals, bioaccumulation, biomagnification, sediments, and maximum recommended and maximum allowed values.

Next, we discuss details of Group 4's OP (G4-OP), which included 16 slides that the group made and presented in 16 minutes. Figure 3 presents the slides used in the Results and Discussion and Conclusions sections from the G4-OP, in which five were for the Results and Discussion section and one for the Conclusions section. The first two graphs in Figure 3 give an overview of the pseudototal and bioavailable content of zinc, copper, manganese, iron, nickel, and lead in six sample points for sediment in the Garden River. Then results for lead, zinc, and copper are highlighted with the other three graphs, in which the pseudototal and bioavailable content of these metals are shown in more detail. A photograph of metal slags in Brazil is also included.

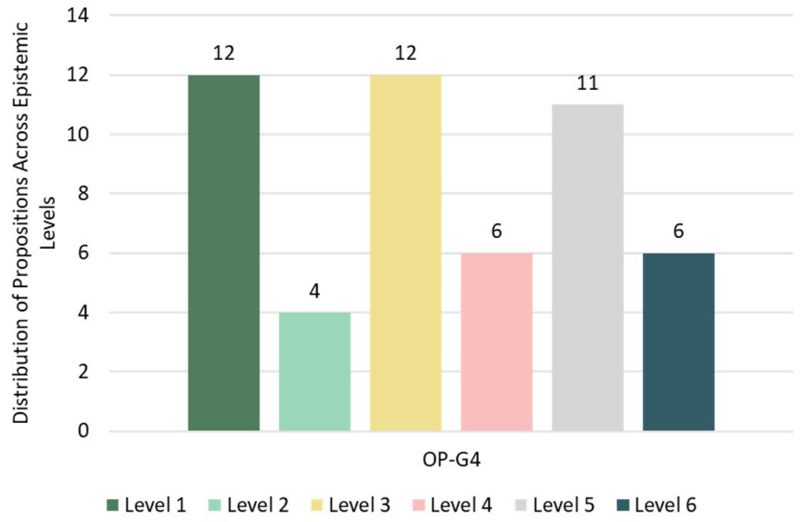
Looking at these slides, we see that the main resolutions elaborated by the group for the case refer to high values of pseudototal content of zinc, lead, and copper at sample points 1 and 2; high values of bioavailable content of zinc and lead at sample points 1 and 2; pseudototal and bioavailable content of lead and zinc at several points above maximum recommended values; and pseudototal content of copper at several sampling points above maximum recommended values. The group related these results to the unplanned exploration of the mines in the region and, more specifically, to the deposition of metal slag on the riverbank, as they were dragged into the aquatic environment through leaching processes. The group also highlighted some health problems for human beings who were poisoned by these metals. The validity of information and conclusions presented by G4 were adequate from a scientific point of view and corresponded to considerations shown in the article that gave rise to the case narrative (Cotta et al., 2006), which

FIGURE 3

Slides used in the Results and Discussion and Conclusions sections from Group 4's oral presentation.

FIGURE 4

Distribution of Group 4's oral presentation propositions across epistemic levels.



	Levels					
Sections	**1**	**2**	**3**	**4**	**5**	**6**
Results and Discussion	12	4	12	5	5	5
Conclusions	0	0	0	1	6	1
Total	12	4	12	6	11	6

also indicates that the case study activities proposed were aligned to the level of knowledge expected from first-year undergraduate students.

The propositions from the G4-OP were sorted into the epistemic levels of Figure 2, and considerations regarding the quality of the arguments are presented based on three criteria established by Kelly and Takao (2002). Some examples of G4-OP's propositions can be seen in Figure 2.

The first criterion considers as a strong argument one that contains its propositions uniformly distributed into the six epistemic levels. As shown in Figure 4, G4-OP's propositions were distributed in all the epistemic levels defined in Figure 2, with more recurrent propositions of Levels 1 and 3 and less recurrent propositions of Level 2. Observing that the propositions distribution is irregular, one could conclude that G4 did not present a strong argument. However, discursive patterns of G4-OP allow us to classify the produced discourse as a good argument.

As mentioned, in the analyzed sections, a total of six data representations were discussed. For a single representation, the student presenter usually pointed out several of its aspects (Level 1 propositions). Such mentions were usually accompanied by establishing relationships between metal concentration at points of the area of study and maximum permissible values (Level 3 propositions) and were justified considering information about the area of study (Level 5 propositions). This shows that the group performed a satisfactory and appropriate exploration of the case study data and had an understanding of the aims and problems covered in the activity.

Regarding the lower recurrence of Level 2 propositions, when the full G4-OP is observed, this result may be related to the locations of environmental samples that were discussed predominantly in the Experimental Procedures section; if reiterated in analyzed sections, such information would have a redundant aspect. This lower recurrence of Level 2 propositions also indicates that the group demonstrated understanding about developing an oral presentation with regard to its aims and the standards established by the scientific community.

The second criterion concerns the ratio of propositions with data references and those that make theoretical statements about the area of study. As shown in Figure 4, 12 propositions were sorted into the epistemic Level 1 and 17 propositions in Levels 4 and 5, which indicates proportionality and corroborates the exhaustive exploration of data to obtain conclusions and justifications supported by evidence in representations.

Finally, the third criterion discusses the location of propositions in specific sections of the OP. In this study, a strong argument would include Level 1, 2, and 3 propositions predominantly only in the Results and Discussion section. In Figure 4, it can be observed that G4-OP's argument meets the third analysis criterion, as no Level 1, 2, or 3 propositions can be found in the Conclusions section. By properly presenting what is expected for each section of a scientific text, a presenter can increases the text's rhetorical power and reinforce the positive classification of the argument produced.

Conclusions and implications

Using the proposed activities, we can conclude that students developed, from an epistemic point of view, a strong argument to justify solutions given to the case study issues. We also found that students demonstrated an adequate understanding of the proposed problem and the aims of the activity. Furthermore, the analytical framework used is suitable for assessing the appropriation of scientific language and students' ability to argue in chemistry courses. These results also indicate that the case study created was adequately aligned with the level of knowledge exhibited by students finishing their first year in college.

This work highlights the possibility of elaborating on and applying a didactic sequence based on solving case studies, whose focus is to have the desired authenticity to develop students' content knowledge and argumentation in chemistry teaching. The scientific practice can be seen as a process composed of three phases: creation, validation, and incorporation of knowledge. These phases correspond to the raising and testing of hypotheses and the social process of acceptance and registration of scientific knowledge (Praia et al., 2002). Part I of the case study was concerned with the first phase mentioned (i.e., the generation of hypotheses to guide the investigation). Parts II, III, and IV related to the process of verifying hypotheses through experimental design and data analysis. Finally, students communicated their observations in the form of an oral presentation.

Distinguishing the different phases of scientific work for the students provides them with clarification about the purpose of the activity. When carried out in this way, the interrupted case study method can be perceived by the students as representative of an authentic scientific practice, with a variety of processes that make up scientific practice, and the results can be visualized as dependent on the resolution process.

Finally, we emphasize the potential of the interrupted case study method supported by ICT in promoting argumentation based on using evidence to draw and justify conclusions. The advantages of using ICT are related to breaking spatiotemporal limitations of the school space, which can now expand to new times and places.

Acknowledgments

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