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Should We Ban Single-Use Plastics? A Role-Playing Game to Argue and Make Decisions in a Grade-8 School Chemistry Class

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ABSTRACT: The social dimension of chemistry is relevant and present in numerous socio-scientific issues, for example, the use of plastics. These issues can be covered at school by implementing strategies such as role-playing, which allow different perspectives to be understood, thereby helping to promote changes in attitude. This paper presents a pilot-study about the design and results obtained in the role-playing game "Should we ban single-use plastics?", which covers the problem of plastics in a secondary school chemistry class by way of argumentation and decision making. Role-playing allows students to represent the viewpoints of different important actors in this area both in favor of a ban on their use (fisherman, environmental scientist, teenager, biodegradable material manufacturer) and against (manufacturer of disposable surgical products, teenager, worker in a plastic cutlery factory, director of an oil company). This role-playing was implemented virtually for a class of grade-8 school students (secondary schoolers in Spain). The main findings include the promotion of learning about the chemical aspects of plastics and the change in attitude of some students regarding this issue after preparing and using arguments and counterarguments based on scientific evidence in a debate. Role-playing is well received by students and helps them to experience positive emotions. Students were found to be very critical of the issue addressed, and the COVID-19 pandemic appeared to affect their decisions.

KEYWORDS: *First-Year Undergraduate/General, High School/Introductory Chemistry, Physical Chemistry, Collaborative/Cooperative Learning, Humor/Puzzles/Games, Applications of Chemistry, Student-Centered Learning*

BACKGROUND

The relationship between chemistry and society is clear. One sign of this is the improved lifestyle resulting from the knowledge provided by chemistry to society in different fields, such as healthcare, food, or materials.[1,2] This social dimension of chemistry can start to be covered from school age by presenting students with various socio-scientific issues. If the issue is approached from all perspectives, students will allow well-informed decisions to be made and actions to be promoted to generate a change of attitude in the population toward chemistry. This dimension is essential to further linking chemistry education to everyday life, technology, society, history, and the philosophy of science.[3] According to Van Berkel et al.,[4] "student activities in mainstream school chemistry[...] do not put emphasis in the curriculum on personal, socio-scientific and ethical questions that are relevant to students' lives and society". Consequently, new educational approaches are required in order to address this issue. Role-playing is an interesting activity to approach these problems in the school,[5] as it can help mobilize important resources to address the veracity of information in the face of the permanent state of scientific misinformation in which we live.

The study of chemistry-related socio-scientific issues helps to improve scientific literacy and create citizens with an understanding of chemistry that can be used to improve our society.[6,7] Thus, students also learn to question, discuss aspects of chemistry, or make decisions, all of which may affect their lives and society in general. This need to incorporate socio-scientific issues into the classroom is included in national educational standards for countries such as the USA, Germany, the UK, or Spain.[8] In the case of the Spanish curriculum,[9] objectives such as assessing scientific research and its impact on industry and the development of society, or interpreting information on scientific issues of an informative nature in publications and the media, are included. These goals show the concern of public officials in approaching novel educational tools to tackle socio-scientific issues. There are numerous socio-scientific issues in which chemistry plays an important role. These include fuels such as biodiesel,[10] mixtures of alcoholic beverages,[11] or pollution resulting from the degradation of plastics in ecosystems.[5] It is regarded as critical that students are enabled to construct and analyze arguments and make decisions, related to the social applications and implications of chemistry.

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If students engage in argumentation about socio-scientific issues included, among their goals, is the development of critical thinking. Such critical thinking is related to educating citizens with an empowerment for the capacity to reflect on and influence social issues of relevance for their lives.[12]

With regard to the problem of plastics, these materials present a complex situation in society. Plastics have helped to improve our quality of life, health, sanitation, transport, and communications, and they are found in essentially all objects around us, but, their high demand, production and presence in ecosystems is causing major environmental problems.[1,13] For instance, their high durability results in their build-up in the environment as waste,[5] especially in the oceans. This can be seen, for example, in the so-called Great Pacific Garbage Patch, which is a large accumulation of plastics in the middle of the Pacific Ocean.[14] Second, their manufacture requires the use of fossil fuels and other additives that are often toxic to plants and animals. To ensure a more sustainable future, it is important that current generations live in a manner that does not endanger the opportunities of future generations.[15] Some examples include the various alternatives for energy production and use, innovative products stemming from chemistry which may aid in preserving natural resources, or the interaction of chemical industry with local and regional economy and society.[16] Plastics have become an ideal context for involving secondary school students in reasoning and argumentation about chemistry, both of which are basic skills to ensure scientific literacy[16] and the development of critical thinking.[17]

Various authors have reported that role-playing is an appropriate tool for approaching socio-scientific issues in the chemistry classroom.[16,18,19] Role-playing is a simulation strategy in which students have to play a specific role assigned to them. This practice promotes dialogue and verbal communication in the classroom, provokes changes of opinion, and helps us to clarify our thoughts about a particular topic;[20] develops the ability to argue, thus helping students to understand chemistry as a social practice;[21] promotes the performance of various roles and the determination of criteria on which they are based;[20] and encourages students to learn aspects related to the issues concerned and may help them to view chemistry as being something close to them,[22] among others. Its advantages also include the ability to show students the complexity of the real world and the problems that appear in it, which cannot be solved simply by memorizing information.[23]

Role-playing is also an opportunity to put decision making regarding chemistry-related issues into practice. Banks et al.[24] indicate that it is recommended to put practices related to the evaluation of opinions and the making of informed decisions based on an understanding of chemistry, in combination with other factors (economic, social, environmental, etc.), into practice in the chemistry classroom at all educational levels. Moreover, Cook[5] states that role-playing helps students to understand and value different points of view concerning complex arguments.[25,26] Despite its importance, the use of chemistry to reach judgements and decisions is rarely discussed in conventional classrooms.[5] Some topics covered in the chemistry classroom using role-playing include fossil fuels[11] or the use of plastics.[16]

In addition, role-playing games include different gamification elements that make chemistry learning a more motivating and participatory process. A game is a "system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome".[27] According to Franco-Mariscal, Oliva-Martínez, and Almoraima Gil,[28] any game has a challenging component, by raising a personal challenge or a competitive drive, and also results in student learning, at either a cognitive or affective level, to enable the development of positive attitudes toward chemistry and society. To sum, the most important characteristics of role-playing are shown in Table 1.

Table 1. Characteristics of Role-Playing

Topic	Role-playing...
Chemistry education	encourages students to learn chemistry
	helps to understand chemistry as a social practice
	helps to view chemistry as being something close to students
	shows students the complexity of the real world
	approaches socio-scientific issues in chemistry education
	puts decision making regarding chemistry-related issues into practice
Argumentation skills	promotes verbal communication
	promotes dialogue
	provokes changes of opinion
	clarifies thoughts
	develops the ability to argue
	helps students to understand and value different points of view concerning complex arguments
Gamification	promotes the performance of roles
	encourages players to get involved
	raises a personal challenge or a competitive drive
	is defined by rules
	makes chemistry learning a more motivating and participatory process
	results in student learning at a cognitive and affective level

It is worth noting that we can find in the literature other educational activities other than role-playing that allow students to discuss and make decisions about chemistry in society[10] such as jigsaws,[11] learning stations,[11] short interactive lectures,[2] etc.

In light of the above, this paper presents a pilot study on the results of role-playing entitled "Should we ban single-use plastics?" in Spanish grade-8 students based on European regulations banning certain types of plastics.[29] The aim of (EU) Directive 2019/904 is to prevent and reduce the impact on the environment of certain plastic products and to promote a transition to a circular economy by introducing a mix of measures, including an EU-wide ban on single-use plastic products whenever alternatives are available. Such a ban, which appears to be novel in Europe, was implemented some years ago in various states in the USA.[30]

Although the topic proposed has already appeared in the literature,[5] this study provides several new aspects. The first of these is an analysis of decision making performed by grade-8 school students when faced with the problem before and after covering this topic in the classroom during role-playing. The second contribution is a study in the behavior of students' perception about the knowledge acquired concerning plastics at both stages. Finally, the emotions experienced by students during this activity are analyzed as this is essential if we wish to generate learning benefits.[31,32] Emotions are "brief, psychophysiological changes that result from a response to a meaningful situation in one's environment"[33] that usually arise in response to a specific person or event.[32] Emotions are fast, automatic, and occur unconsciously yet still have a marked influence on the way in which we think and interpret events.[34] In short, the arguments

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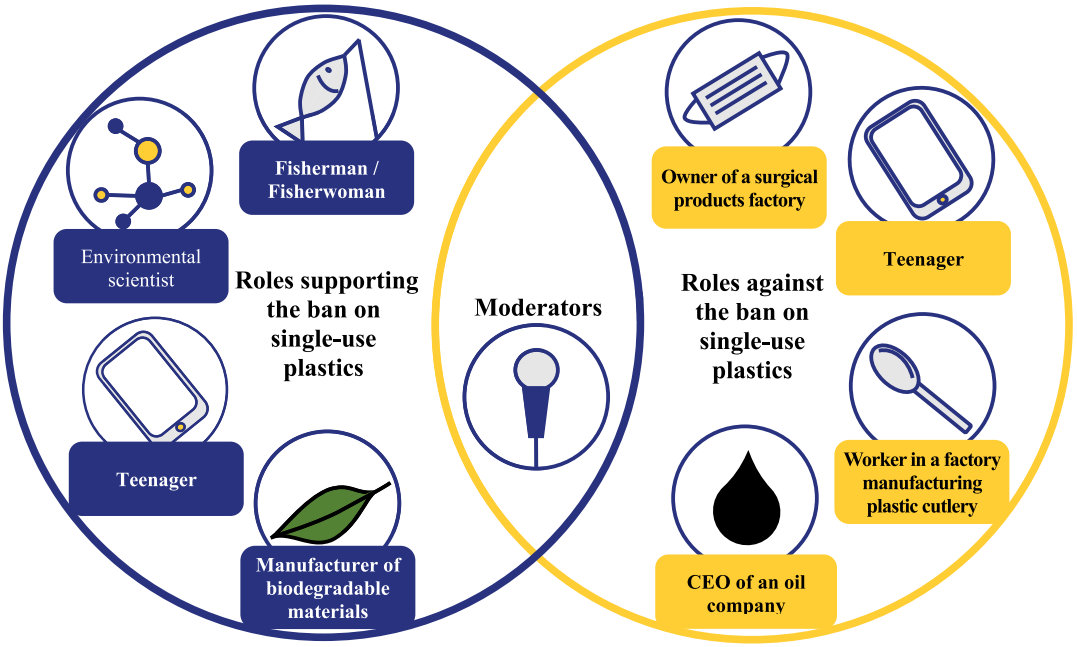

Figure 1. Roles supporting and opposing the ban used during the activity [own data].

taking place during the role-playing as well as the gamification elements of the activity may also help to improve the emotions experienced and contribute positively to chemistry learning.

AIM AND RESEARCH QUESTIONS

The aim of this study is to disclose the design and results of the role-playing "Should we ban single-use plastics?" implemented in Spanish grade-8 school students (13−14 y). This study proposes the following research questions:

- Research question 1 (RQ1): What decision do grade-8 school students make regarding the banning of single-use plastics before and after participating in the role-playing? How do they argue possible changes in their decision?
- Research question 2 (RQ2): What are the perceptions of students regarding role-playing and their understanding concerning plastics before and after the activity?
- Research question 3 (RQ3): What type of emotions appear in students during role-playing?

SCENARIO

The chemistry-related socio-scientific issue proposed concerns the legislation approved by the European Union banning single-use plastics in 2021 (EU Directive 2019/904)[29] as a means of decreasing ocean waste. This Directive, on the reduction of the impact of certain plastics products on the environment, promotes circular approaches that give priority to sustainable and nontoxic reusable products and reuse systems rather than to single-use products, even if they are biodegradable plastics, aiming first and foremost to reduce the quantity of waste generated. The plastic products to be banned under the directive include: cutlery (forks, knives, spoons, chopsticks), plates, straws, cotton bud sticks, beverage stirrers, sticks to be attached to and to support balloons, food containers made of expanded polystyrene and, products made from oxo-degradable materials.[29] The authors of this paper used this normative proposition to design the activity trying to give important insights into the interface between state regulation and widespread chemistry dissemination, particularly to grade-8 school students.

The scenario proposed to students involved a hypothetical situation in which the European Union contacted our secondary school to find out the opinion of teenagers about this legislation. To that end, students were asked to hold a debate in the classroom entitled "Should we ban single-use plastics?", which would then be published on their YouTube channel.

Students assumed roles representing the different points of view of different sectors of society and debated aspects such as the chemical composition of plastics, their physical and chemical properties, their degradation, environmental aspects, or the advantages and disadvantages of this new legislation. Specifically, various students were asked to support this ban and others to oppose it. A third group acted as presenters and moderators during the debate and were also responsible for deciding the winner thereof, based on their chemical argumentation. The roles during this role-playing were randomly assigned by the teacher. The roles are described in Figures 1 and 2 and correspond to an adaptation of a role-playing concerning the same problem designed previously for preservice science teachers to a secondary school setting.[35] Some of the modifications adopted included a reduction in the number of roles, the adaptation thereof to the age of these students and a balance in the number of men and women taking part in the role-playing to ensure gender diversity on the role (e.g., fisherman/fisherwoman).

Tasks Proposed

Role-Playing Involved Four Tasks. *Task 1: Presentation of the Problem and Initial Decision-Making.* The teacher presents the problem and asks each student to make their own decision about it, responding in a reasoned manner to the question "Are you in favor of, or against, banning single-use plastics?" Students were not allowed access to any type of information during this task; therefore, their responses were made based on their prior understanding of this problem.

Task 2: Preparation of Role-Playing. The roles (Figure 2) were assigned in the classroom to groups of three students, one

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Roles supporting the ban on single-use plastics		Roles against the ban on single-use plastics	
Manufacturer of biodegradable materials	The materials you manufacture are an alternative to the use of plastics. For instance, bags, cups and other packaging, all made from materials that can be readily destroyed in nature. You employ five technicians and a technical engineer.	Numerous single-use plastic products are manufactured using the crude oil extracted by your company. The new legislation may lead to closure of the company.	CEO of an oil company
Teenager	You are a teenager aged between 12 and 16 years. The consequences of plastic contamination are of interest to you and you believe this is a problem of vital importance. Yesterday you heard a news item on the TV about the new European legislation concerning the ban on single-use plastics in 2021 and you consider this to be a good idea.	You work in a factory manufacturing plastic plates and cutlery. More than 1000 items are manufactured every day. The new legislation may mean that you and all your workmates lose their jobs due to closure of the factory.	Worker in a factory manufacturing plastic cutlery
Fisherman/ Fisherwoman	You go out fishing every morning. Every day, your nets collect more plastics and fewer fish. You think that the new European legislation banning single-use plastics in 2021 may be a solution to your problem.	You are the owner of a factory manufacturing disposable plastic sanitary products, such as gloves or masks, to prevent disease transmission with 100% effectiveness. The new legislation will lead to these products being banned.	Owner of a surgical products factory
Environmental scientist	You are researching the levels of plastic contamination in ecosystems. Your findings show that contamination of the oceans has increased markedly over the past 10 years, that increasing numbers of species have microplastics in their stomachs, and that this situation is having irreversible effects on the environment.	Yesterday you heard about the new legislation banning single-use plastics in 2021 on the news. You have thought about this topic and realized that, because of this legislation, you will no longer be able to take doughnuts or crisps to school as a snack as many types of packaging will have to modified and this will require an effort from everybody.	Teenager

Figure 2. Description of the different roles.

of whom defended their position in the game, with the other two acting as advisers. Each group was given 1 week to find reliable information on the Internet regarding the role assigned and prepare chemical evidence-based arguments to defend their role and counterarguments to criticize the other roles. These students had previously been trained in how to search for reliable information on the Internet and were provided with some criteria (author of source, author's institution, references provided by source, presence of pop-up messages on the web, etc.).[36] Students compiled the information in a file (Figure 3).

Task 3: Staging of Role-Playing. The debate was staged in three parts:

- Presentation of the problem by the presenters and initial intervention of each role (10 min). Each character presented their arguments in 1 min, and the advisers took note of the strengths and weaknesses of the arguments for the other roles.
- Meeting of each role with their advisers to exchange notes and provide counterarguments (5 min).
- Debate. Reply and counter-reply (20 min).

Task 4: Making a Final Decision about the Problem. Each student was again asked to make a final and reasoned decision about the problem individually, changing their initial posture if

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Role TEENAGER against banning single-use plastics	
First and Last Name(s):	
Course:	*Date:*
Description of role: Yesterday you heard about the new legislation banning single-use plastics in 2021 on the news. You have thought about this topic and realized that, because of this legislation, you will no longer be able to take doughnuts or your favorite crisps to school as a snack as many types of packaging will have to modified and this will require an effort from everybody.	
Provide arguments to defend the position of your character. To do that, use scientific articles, newspapers, web pages with scientific rigour, videos, images, etc. - - -	
Write down arguments by other characters that you think you can refute - - -	

Figure 3. Examples of a file used to compile arguments to defend the role and prepare possible counterarguments.

necessary. Once this task had been completed, the presenters finished the game by choosing the winning character.

Importance of Arguing about Chemistry

Role-playing is centered on argumentation and decision making as two important skills for the development of critical thinking by students.[17]

The aim of this activity is to ensure that students are able to draft evidence-based arguments related to plastics based on their chemical knowledge that also provide a justification and a conclusion,[37] as can be seen from the following argument used by a student:

> *Single-use plastics are only used for a very short period of time but take millions of years to decompose. There are around 8 million tonnes of plastic in the oceans, and 50% of this comprises single-use plastics. This process is very slow, and they don't usually disappear completely as they are highly resistant. These plastics become smaller and smaller and cause many plastic-related deaths in animals. If [there] are no plastics, there will be more animals.*
>
> Fisherwoman

As can be seen, this argument includes evidence regarding the quantity of plastic present in the oceans or some of the features of these plastics, such as their resistance. As justification, reference is made to the long time period required for a plastic to degrade. A final conclusion is also provided.

A further aim is that students are able to prepare counterarguments to other data.[38] One example of this is the following dialogue, which occurred during the debate between the owner of the surgical products factory and the environmental scientist:

> *If we ban single-use plastics, in the case of hospitals faced with the current COVID situation worldwide, it would be almost impossible to carry out many operations to improve patients' health as plastic materials need to be used. Although this is fairly serious in a hospital, there are other situations that could become even worse. For example, it would be madness to use our hands to select fruit in a fruit shop when plastic gloves can be used.*
>
> Argument by the owner of a surgical products factory

> *It's true that in some places, such as hospitals, plastic materials need to be used. For example, if syringes were made out of glass they would need to be sterilised, and they are more hygienic when made from single-use plastics. However, plastics are not needed in shops as nobody can guarantee that the plastic or glove that you are going to use to store the food hasn't been touched by someone else. The only thing you need to do is wash the fruit well when you get home. Therefore, plastics don't need to be used in shops.*
>
> Counterargument of the environmental scientist

As can be seen, the first argument was easy to refute as only COVID-based evidence was provided, with no justification or conclusion. In contrast, the counterargument provides a justification by comparing the advantages of plastic syringes with their glass counterparts and another regarding the use of gloves when shopping. It also includes a solution to the problem addressed in the fruit shop as a conclusion.

A comparison of the different arguments and counterarguments will allow students to reach their own decision about this problem. Arguing about issues that relate to chemistry and society allows students to question the validity of arguments, reject ideas not based on evidence, and detect argumentative fallacies.[17]

To summarize, the main arguments supporting the ban were based on the environment and the protection of ecosystems or

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Figure 4. "Word cloud" showing the keywords used by the students during role-playing.

animals. In the meantime, the arguments against the ban focused on COVID-19 or the economy. The "word cloud" (Figure 4) illustrates the most frequently used terms during role-playing, such as "plastics", "people", "economy", "materials", or "company", showing the relationship between chemistry and society.

SCHOOL SETTINGS

This activity was carried out as a pilot study with 26 students (59% girls and 41% boys) in grade 8 (13−14 y) at a secondary school in Málaga (Spain) studying the obligatory chemistry subject, which begins in this school year in the Spanish curriculum. The activity was performed online during the confinement period of the COVID-19 pandemic in April 2020; therefore, the use of face masks, gloves, and other single-use plastic materials was very widespread. This activity can be adapted to an in-person and/or online setting.

METHODS

Data Collection

The instruments used to collect data for each research question (indicated in brackets) were the following:

- Question regarding reaching a decision about the problem.
- Questionnaire concerning perceptions of role-playing and chemical knowledge acquired.
- Questionnaire about emotions experienced during the activity.

The question regarding reaching a decision about the problem was administered before and after role-playing (tasks 1 and 4) (RQ1).

The questionnaire concerning perceptions of role-playing and chemical knowledge acquired was administered at the end of the activity. With regard to role-playing, students were asked to score the activity from 0 to 10 points and to indicate positive and negative aspects of the activity (RQ2). With regard to their perception of the chemical understanding acquired, students were asked to give a score between 0 and 10 before and after role-playing and also to answer the open-ended question "I have learned..." (RQ2).

In the questionnaire about emotions they were asked to choose one of the seven points on a differential semantic scale (very, fairly, somewhat, indifferent, somewhat, fairly, very) the extremes of which were 10 opposing emotions (afraid−calm, stressed−relaxed, worried−unconcerned, insecure−confident, displeased−happy, suspicious−confident, unhappy−happy, bored−enthusiastic, unsatisfied−satisfied, uninterested−interested)[39] (RQ3).

Data Analysis

The decisions adopted regarding the problem before and after the role-playing (RQ1) were grouped into three categories:

- Decision in favor of banning single-use plastics: Included responses in which this viewpoint was taken in a clearly reasoned and justified manner.
- Decision against banning single-use plastics: Contained responses expressing arguments supporting this position.
- Undecided: For those responses in which a clear decision was not evident or both positions appeared.

These categories were represented in a Sankey diagram and the Chi-squared statistical test was applied.

For the questionnaire regarding perceptions about role-playing (RQ2), the positive and negative evaluations were analyzed separately. In both cases the responses were grouped into different categories and the percentages calculated.

The learning perceived by students (open-ended question "I have learned...") (RQ2) was analyzed by categorizing the responses provided. With regard to the perception of understanding before and after, the mean scores and variation between these two time points were analyzed.

The data obtained concerning the emotions experienced by the students (RQ3) were analyzed by calculating the percentages for each point on the scale for each emotion.

FINDINGS

Findings about Decision Making (RQ1)

Table 2 shows the decision making about banning single-use plastics before and after role-playing.

Table 2. Decision Making at the Two Time Points

Decision	Supporting the ban (%)	Against the ban (%)	Undecided (%)
Before role-playing	94.4	5.6	0.0
After role-playing	72.2	22.2	5.6

Initially, the vast majority of students (94.4%) were in favor of banning single-use plastics. However, this decision dropped to 72.2% after participation in the role-playing, with 22.2% being against such a ban and some students remaining undecided. Despite these changes in opinion, the Chi-squared test showed that there were no statistically significant differences ($\chi^2 = 2.119$; $p > 0.05$) between the two time points.

The Sankey diagram in Figure 5 shows the maintenance and changes in opinion of the students at these two points. It can be deduced from the diagram that the majority of students (77.8%) maintained their original opinion after role-playing, with only 22.2% changing their decision. These changes in opinion were from in favor of a ban to against or undecided, but never from against to in favor. After the role-playing, two types of students are against the ban: those initially already in this position (5.6%) and those who have shown a change of opinion after the debate (16.6%).

The reasons given by students when they were asked to argue their change of decision from in favor to against are given below:

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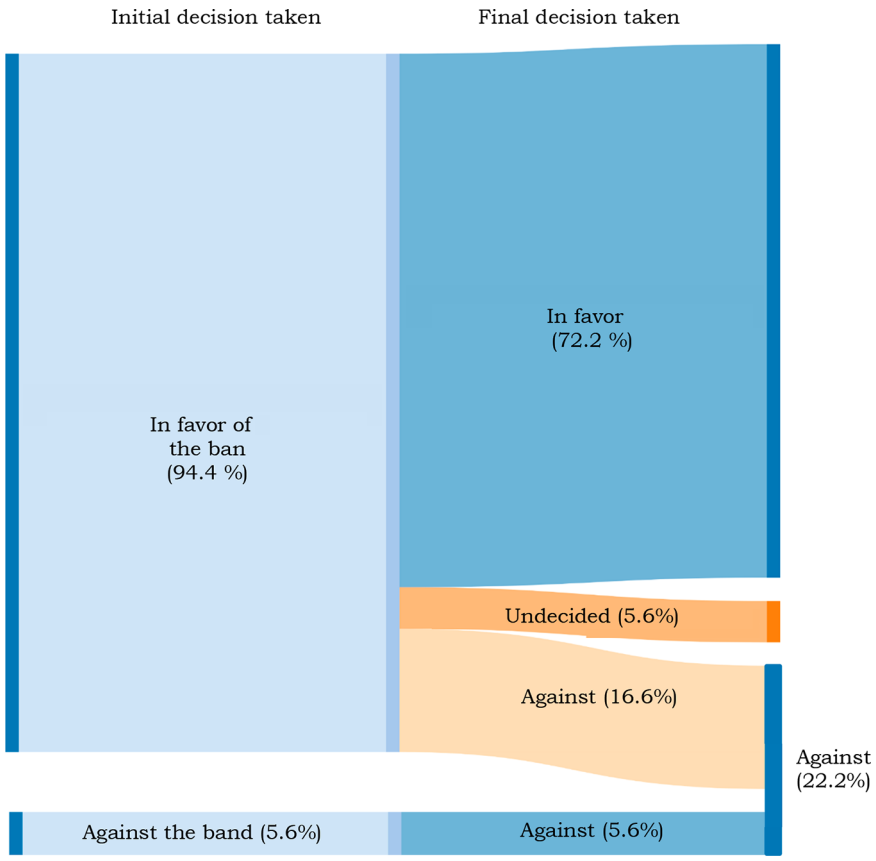

Figure 5. Sankey diagram showing maintenance or change of decision before and after role-playing.

I've changed my opinion because single-use plastics currently protect you better, and as a result, you probably don't get infected.

Advisor

The speech given by the disposable surgical products factory character made me change my opinion as it's true that hospitals, veterinary clinics, etc., need them.

Advisor

I saw ideas more clearly in my companions' debate, and I learned things I didn't know before.

Advisor

As can be seen, two of the three arguments are related to COVID-19 and the third to the power of conviction of the ideas debated.

The only student to change their decision from in favor to undecided stated:

What made me change my decision was having a position in the debate contrary to the opinion I held initially. That's why I'm now undecided.

Owner of the disposable surgical products factory

As can be seen, the need to find information to defend a position with which the person was not initially in agreement may raise reasonable doubts about the final decision.

As indicated in other publications[11] on problem-based activities relating to chemistry and society, most of the students showed a pro-environmental stance, able to justify these decisions with issues such as the environment or ecological wholesomeness. However, we also found undecided students or could find advantages and disadvantages to both positions without opting for either of them.

Initially, a strong position of students in favor of a ban on single-use plastics would be expected, considering that students' opinions are influenced by television and social media, in addition to recent publicity movements about reducing plastic consumption and eliminating single-use plastics. Undoubtedly, carrying out this activity during the pandemic provoked more positions against the ban than we expected. Nevertheless, the quality of the arguments stands out, evidencing great previous information gathering.

Findings Regarding the Perceptions of Students about Role-Playing and Their Understanding Concerning Plastics (RQ2)

Students gave the activity 8.4 points out of 10, which is considered to be very positive. Table 3 presents students' perceptions of the activity.

The majority of students (54.5%) considered the staging of the role-playing to be the best aspect of the activity, with this being taken to mean the possibility to debate about plastics. Fewer students (22.7%) considered learning about the chemistry of plastics alone, or listening to arguments from other companions, to be the best aspect, whereas 47.4% stated that there was no unfavorable aspect of note. To a much lesser extent, students highlighted the inability to participate in the staging due to being an advisor (15.8%) and a lack of time for advisors (15.8%) or the group work (15.8%). This latter aspect was also given as a positive aspect, although to a slightly higher degree (18.2%), thus appearing to highlight the importance of the correct selection of group members by the teacher and a good distribution of the tasks as, in some cases, this may cause

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Table 3. Perceptions of the Best and Worst Evaluated Aspects of the Activity

Category	Percentage (%)
Positive Evaluations	
Staging of role-playing	54.5
Chemical understanding of plastics	22.7
Group work	18.2
No response	4.5
Negative Evaluations	
No unfavorable aspects	47.4
Advisers unable to debate	15.8
Lack of time for advisers	15.8
Group work	15.8
Others	5.3

some disagreement and other significant advantages. It should be noted that the only chemistry-related aspect was among the positive evaluations given.

The perception of the understanding concerning plastics increased by 2.4 points, from 5.7 (before role-playing) to 8.1 points (afterward) out of 10.

Table 4 lists the categorization of students' perception of their learning, showing that they perceived to have learned about chemistry (70.4%) and about scientific skills (29.6%), especially how to debate and argue about chemistry based on evidence.

With regard to chemistry, 37.0% of students noted aspects concerning the relationship between chemistry and society and the importance of single-use plastics as regards protecting us in the current health situation, or their effects on the economy. Furthermore, 25.9% alluded to the effects of chemistry on the environment, whereas 7.4% mentioned some properties or characteristics learned about plastics.

Finally, the students' perceptions suggest that role-playing promotes learning about aspects of chemistry such as the degradation of plastics and the importance of chemistry for society or contamination and the environment, indicating an enhanced understanding of chemistry.

Findings about Emotions (RQ3)

The emotions experienced during role-playing were valued very highly as all students tended to indicate positive emotions from each pair provided, with the most favorable option (very) of all these pairs being given percentages of between 37% and 53% (blue color in Figure 6). The emotions relaxed, calm, confident, glad, or satisfied obtained the highest percentages (close to 50%). These positive emotions experienced indicate that this activity enhanced the motivation and interest of students toward the problem of plastics.

Interestingly, the highest-rated positive emotion was relaxed (53%), and the negative emotion was worried (21%). It is probably indicative of the attitude of the two types of citizens we can find in society toward plastics: people with little concern (relaxed) or a lot of concern (worried).

The gamification elements associated with role-playing may be responsible for some of the emotions indicated: enthusiastic and happy due to the motivation of the game, suspicious due to its competitive drive, or worried about arguing and counter-arguing in public adequately as the main rule of the game.

STUDY LIMITATIONS

The sample size used in this study can be considered to be a limitation as regards the reproducibility of the results in a larger population. As such, our aim in future studies is to implement this role-playing in other groups of students. Despite this, the sample is considered to be appropriate for a pilot study to investigate the potential of this type of activity in the classroom as it requires all students to participate actively in the activity, which would not be viable with larger groups.

A second limitation, which we were able to partially overcome, concerns the online format which had to be used for this activity, due to reasons beyond our control (COVID-19), during a period of home confinement when schools were closed and classes were taught remotely. The virtual teaching format caused some problems and imbalances in the activities, such as a lack of Internet connection for some students or the difficulties encountered when moderating the speakers and debates remotely, which would have been markedly enriched if carried out in person.

One final aspect to be revised concerns the role of advisors, who demanded a greater intervention during staging.

CONCLUSIONS AND IMPLICATIONS

This paper presents the results of an activity that allows grade-8 school students to develop critical thinking skills by way of argumentation and decision making regarding social aspects related to chemistry in a real life context, namely the use of plastics.

The data obtained in this study appear to suggest that role-playing and, more specifically, staging of a debate, are well received by students and that they promote learning about aspects of chemistry such as the degradation of plastics, the importance of chemistry for society or contamination and the environment, as seen from the perceptions stated by the students, which indicate an enhanced understanding of chemistry (RQ2). Moreover, the positive emotions experienced indicate that this activity enhanced the motivation and interest of students in this topic (RQ3).

Although the majority position as regards this problem was initially in favor of banning the use of plastics, it was found that role-playing caused students to think again about the problem,

Table 4. Categorization of the Learning Perceived by Students

Category	Example	Percentage (%)
About Chemistry		
Chemistry and society	"Single-use plastics are needed, especially against COVID."	37.0
Chemistry and the environment	"I have learned a lot about the consequences of plastics for the planet, such as contamination or the death of animals."	25.9
Properties of plastics	"I have learned many characteristics of single-use plastics, such as that they do not degrade like paper or cardboard and remain in the oceans for longer."	7.4
About Scientific Skills		
Debating and arguing about chemistry	"I have learned to debate much better and to develop counterarguments in only a short time with the help of the rest, and sometimes without it."	29.6

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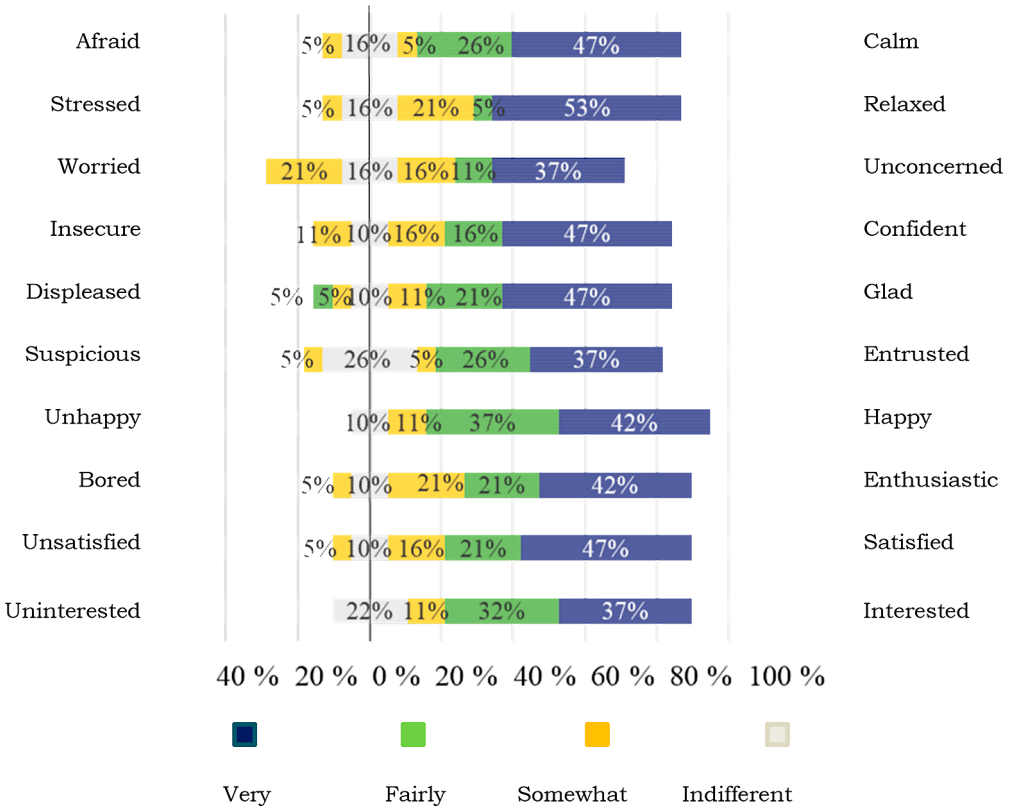

Figure 6. Emotions experienced by students during role-playing.

as some students changed their decision to against or undecided. The arguments given to not ban them were based on the health situation or the importance of being well-informed, a task they assumed when preparing their role or advising it and when evaluating the evidence-based arguments and counterarguments given by their companions (RQ1). The marked influence of confinement due to the pandemic means that students were more critical with both banning and environmental contamination, becoming aware of the dichotomy between the importance of chemistry for society and the potential environmental issues it may cause. Thus, the students have addressed the complex situation of the problem of plastics in society. On the one hand, plastics have helped to improve our health or sanitation. However, on the other hand, plastics are causing major environmental problems. The changes of opinion, which are considered to be revealing, did not result in any statistically significant differences in the sample analyzed.

These preliminary findings highlight the importance of including this type of activity in the chemistry classroom to improve students' argumentation skills and decision making as future citizens with regard to problems in which chemistry is involved, thereby improving their critical thinking. Moreover, they also highlight the difficulties faced by students when considering problems from all viewpoints as, in this case, students mainly focused the debate about plastics on the aspects of environmental and health protection, given that they form part of the essential materials used during the pandemic (face masks, gloves, protective equipment, etc.), with little attention being paid to other aspects, such as the consequences of degradation on human health.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.1c00580.

Notes for the instructor (PDF) (DOCX)
Student handouts (PDF) (DOCX)
Questionnaire concerning perceptions of role-playing and chemical knowledge acquired (PDF) (DOCX)
Questionnaire about emotions experienced during the activity (PDF) (DOCX)

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