

Good Practice Report

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Lessons learned from a case study on teaching the socioscientific issue of ethanol, used as an ingredient of sanitizers, to promote students' learning of and about chemistry during the COVID-19 pandemic

<https://doi.org/10.1515/cti-2023-0028>

Received June 12, 2023; accepted September 12, 2023; published online October 4, 2023

Abstract: During the COVID-19 pandemic, the unexpected lockdown of schools brought many challenges to redesigning the teaching and learning of chemistry at the secondary schooling level. The demand for online teaching under COVID-19 conditions was, however, also an opportunity to reflect on introducing new content, pedagogies, and media. This paper reflects on the implementation of a chemistry lesson plan focusing on the socio-scientific issue of ethanol used for hand sanitizers in Italy. Ethanol is possibly the most common ingredient of hand sanitizer lotions and provides an authentic context for the learning of and about chemistry. The objective was to promote students' awareness of the deep interconnections between science, society, ethics, and the environment through a socio-scientific issues-based approach.

Keywords: chemistry education; socio-scientific issues; ethanol; online teaching; COVID-19

1 Introduction

Education in schools should provide students as future responsible citizens with education to become able to play an active part in society and to make informed decisions (Sjöström & Eilks, 2018). This also concerns science education since science and technology permeate so many aspects of our everyday life and society. All citizens in a society have to make decisions each day concerning their lifestyles and consumption. If this should be done based in an informed way knowledge from science and technology is needed. The decisions of students as future citizens will have an impact not only on the quality of their life but also on their health or the environment. Knowledge in and about science is important as well as the capability to use it in any relevant context to make informed and critical choices.

One curriculum framework to understand the interplay of science and society is socio-scientific issue-based (SSI) science education (Sadler, 2011). SSI-based teaching uses authentic and controversial issues from society for teaching and learning of and about science in general, or chemistry in particular. One critical SSI during the COVID-19 pandemic was the use and availability of hand sanitizer lotions. One main component of hand sanitizers is suggested to be ethanol (WHO, 2010). It was, however, that with the beginning of the pandemic availability of hand sanitizers as such, or ethanol to prepare them became scarce. This issue was taken up in grade-10 chemistry teaching as an SSI to promote learning about the chemistry of alcohols, their use in hygiene products, and what

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this meant to society in times of a pandemic. The lesson plan is described and experiences in its application in grade-10 online chemistry teaching during the pandemic are presented.

2 Background

The term Scientific Literacy (SL) has been used since the 1950s to stress the importance to have both the knowledge of science and the capability to use it in everyday situations (Hurd, 1958). Since 1999, PISA has contributed to the diffusion of the concept of SL as a political goal (OECD, 1999, 2017). Various concepts of SL have been formed through time (e.g., Bybee, 1997; DeBoer, 2000; Roberts, 2007, 2011) that take into account the importance of both knowledge and its use in a context. In 2018, Sjöström and Eilks reflected on the evolution of different visions of SL, starting from Roberts' (2007) suggestion of two different visions of SL. In the discussion by Sjöström and Eilks (2018), Vision I privileges cognition, starting from the acquisition of science content knowledge and after that taking into account their applications. It can be regarded as “pipeline science” with one aim of preparing students for careers in science and technology. Vision II focuses on context-based learning in science to facilitate students to make sense of the importance that the science content learned has in the different aspects of everyday life. It could be regarded as: “Science for all”. A third vision of SL is more oriented toward critical thinking or “Critical Scientific Literacy” (Hodson, 2009, 2011), it implies cultural and humanistic components and can be regarded as “Science for transformation”. Vision III asks for reflections on the deep interconnections between science, society, politics, ethics, economy, environment, and cultural implications. It is highly related to the humanistic approach in the tetrahedron model presented by Mahaffy (2004). Figure 1 shows the representation of the three visions of SL and the different levels of the relevance of the humanistic aspect (Sjöström et al., 2020). Vision III is deeply connected to SSI-based educational approaches, which integrate science learning into authentic, relevant, and controversial issues from society. SSI-based learning is suggested to help challenge students' interest in science and to promote their higher-order cognitive skills, like the capabilities of critical thinking (Marks & Eilks, 2009).

Knowledge of science and chemistry is important as well as the capability to use it responsibly and autonomously to solve problems. The presence of science and technology in almost every aspect of our life is so massive that Hoffmann (1990) stated that the lack of scientific knowledge is undemocratic. Nevertheless, citizens usually have negative and suspicious attitudes toward chemistry. Students do not like chemistry and repute it too difficult (Rochard, 2007). SSIs and authentic problems have been proven to be useful to motivate students and to engage them in discussions about chemistry and the interconnections between science and societal aspects (Eilks, 2002).

The capability to use knowledge to solve problems responsibly and autonomously is the focus of competence-based curricula. From 2007 (MIUR, 2010; MPI, 2007), Italian curricula became competence-based and started addressing the framework of the competencies for lifelong learning set by the EU (2006). The Italian Chemistry

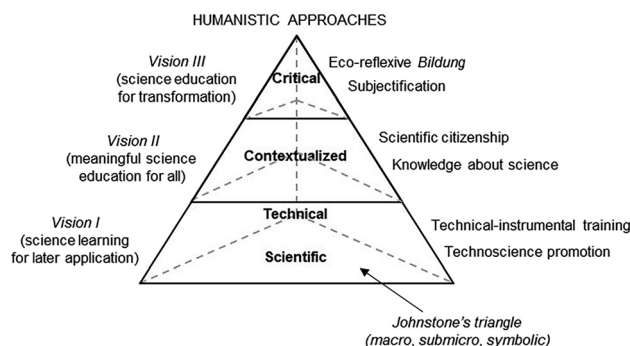


Figure 1: Different visions of scientific literacy and related core aims of learning (Sjöström et al., 2020).

Guidelines for the Technical Institute (an upper secondary school with technical orientation) state that chemistry teachers should support the students to reach learning outcomes that enable them “to use the cultural and methodological tools acquired to place oneself with a rational, critical and responsible attitude towards reality, its phenomena and its problems, including the purposes of lifelong learning” (MIUR, 2010, p. 78).

The PISA 2018 outcomes (OECD, 2019) show that Italian students have a lower performance in science (468) than the OECD average (489). The score indicates even a decline from PISA 2015 in which the Italian students’ score was 481 and the OECD average was 491 (OECD, 2019). To overcome the scarce outcomes of PISA in many European countries, the EU (2018) released a new recommendation to enhance key competencies for lifelong learning: “In the knowledge economy, memorization of facts and procedures is key, but not enough for progress and success. Skills, such as problem-solving, critical thinking, ability to cooperate ... are more essential than ever before in our quickly changing society”, and state that “new ways of learning need to be explored”. The Italian curricula were changed accordingly and are up-to-date. But, probably, the practice in many classrooms is not yet, in Italy and beyond (Genisa et al., 2020).

An analysis of the implementation of SSI-based learning (Genisa et al., 2020) shows that SSI-based science education is emerging in many countries, but not yet in Italy. To align the learning approach to the curricula and society’s needs, the use of SSIs for education can be helpful (Hofstein et al., 2011). SSI’s use for teaching aims to promote critical thinking and general educational skills for preparing students for active social participation (Holbrook & Rannikmäe, 2007; Sadler, 2011). The educational goal is to enable the students as future citizens to make informed and critical choices about issues in which science is not the only aspect to be considered. In this perspective, students must learn not only the scientific bases but also they have to be prepared and trained in thinking about social, economic, environmental, and ethical aspects deeply intertwined with science and technology (Eilks et al., 2018).

3 Lesson plan design and intervention

3.1 Selection of the topic

The criteria and justification for selecting the issue of ethanol use in hand sanitizers were guided by the framework suggested by Eilks et al. (2013) for reflecting socio-scientific issues in teaching. During the COVID-19 pandemic, every student used hand sanitizers that contain ethanol. The topic was therefore authentic and relevant for the students. It allows for open discussion and deals with chemistry. The criteria given by Sjöström et al. (2015) are shown in Table 1 and operated to the example of ethanol in hand sanitizers.

3.2 Objectives of the lesson plan

The SSI-based learning lesson plan on ethanol usage in hand sanitizers was designed to meet the Italian chemistry curriculum of the second year of the Technical Institute (10th grade, age 15–16). Due to the COVID-19 pandemic, the lesson plan was structured to engage students in a 100 % online learning environment. The main goals of this teaching intervention were to fulfill the competence-based chemistry curriculum, to motivate the students during the pandemic, and to allow all students to take an active part in the learning process, overcoming the sense of insulation that the sudden school closure introduced.

The objectives of the lesson plan, shown in Table 2, were combining the improvement of the students’ social skills and capabilities to make choices autonomously and responsibly in the perspective of personal development and the enhancement of students’ knowledge of and about chemistry.

The chemistry content knowledge addressed encompassed mainly stoichiometry, solutions and their concentrations, structure, and properties of substances, molecular models, separation of mixtures, and safety. Reflection about the interconnections between chemistry and society was planned to be promoted.

Table 1: Criteria for selecting Socio Scientific Issues and a possible approach for the topic of ethanol.

Criteria	Description	Ethanol in hand sanitizers
Authenticity	The topic is authentic when is currently reported and discussed by society	With the start of the COVID-19 pandemic, the use of hand sanitizers became intensively discussed in the media (newspapers, television, internet, social media, ...). Reports included that during the pandemic it was difficult to find enough ethanol-based formulation; it became difficult to find enough ethanol at all
Relevance	The topic is relevant, if respective decisions will affect the current or future lives of our students	All over the world, ethanol was requested to prepare hand rub sanitizing lotions. The huge use of ethanol-based sanitizing hand lotion made it difficult to find rubbing alcohol on the market during the pandemic. Ethanol has also other uses, e.g., in industrial and pharmaceutical fields, as a fuel, or component in alcoholic drinks. Decisions were to be made about which application to give priority to
Evaluation undetermined in a socio-scientific respect	The evaluation allows different points of view	There are different opinions about how to prepare ethanol, i.e., from food plants or fossil resources. There are different ways for what to use ethanol, i.e., sanitization, fuel, alcohol drinks, solvents ... there are alternatives for the use of ethanol as a hand sanitizer
Allows for open discussion	The topic can be discussed in an open forum	There are different ways to fight a pandemic. Hand sanitation by ethanol is only one option, or one component in a set of actions, among many others. The use of ethanol in hand rub can prevent the diffusion of disease but also cause skin irritation. The use of stronger sanitizers (e.g., based on benzalkonium chloride) is also possible but might lead to further side effects
Deals with questions from science and technology	The topic concerns itself with a techno-scientific query	Ethanol is probably the most famous alcohol. The structure of ethanol defines its properties and uses. It can be produced by fermentation and other techniques. Its use is multi-faceted in science and technology

Table 2: Aims of the SSI-based learning module on ethanol usage for hand sanitizers.

Objectives of the lesson plan
Motivate the students by discussing an authentic and relevant socio-scientific issue
Promote students' skills to find, select and interpret information and to self-organize learning from the perspective of personal development
Promote students' knowledge of and about chemistry
Promote students' capability to make choices autonomously and responsibly
Enhance students' capability to think about the social, economic, political, ethical, environmental, and scientific interconnections
Enhance students' social and communication skills, i.e., the capability to cooperate, work in groups, and exchange opinions; encourage students to discuss and evaluate different points of view, stimulate students to evaluate pros and cons of different choices

3.3 Structure of the lesson plan

The lesson plan was structured along the SSI-based teaching model suggested by Marks and Eilks (2009). It encompassed five steps: Textual approach, clarifying the chemistry background, resuming the socio-scientific question, discussion, and evaluation from different points of view, and meta-reflection (Table 3).

3.4 Implementation

In Italy, chemistry at the Technical Institute is taught 3 h a week in the first 2 years, and 1 h is usually devoted to practical work. The lesson plan covered nine teaching periods of 60 min each and lasted approximately a month.

Table 3: Structure of the lesson plan and learning activities (guided by Marks & Eilks, 2009).

Steps	Description	Learning activities
Textual approach and problem analysis	The textual approach was based on authentic texts found in journals, newspapers, and websites about ethanol, its production, and uses to engage the students in the analysis of the aspects involved	<ul style="list-style-type: none">- Brainstorming about ethanol- Discussion about the different uses of ethanol- Pre-test on the perception of the different aspects involved in the evaluation of production and use of ethanol- Students read authentic material, released by different agencies, about ethanol production and uses. A jigsaw classroom on the different aspects was used to share and discuss the information
Clarifying the chemistry background, e.g., in a laboratory environment	Clarification of the chemistry background was done by linking new knowledge on ethanol with prior acquired knowledge from school and laboratory work before the lockdown. Students deepened their chemistry content knowledge and knowledge about aspects other than science	<ul style="list-style-type: none">- Reinforce the knowledge about the structure and properties of ethanol- Creating a molecular model of ethanol- Learning about the production of ethanol- Discussion about different uses, i.e., fuel, alcoholic drinks, and denaturated ethanol- Learning how to prepare a sanitizing hand lotion from a solution of ethanol WHO (2010)- Group work: Design, creation, and presentation of deliverables, e.g., Power-point presentation, label, spot, video, or song (max. 60 s), to promote a sanitizing lotion based on ethanol for its use during the COVID-19 pandemic- Group work: Creation and exposition of a presentation about the uses of ethanol and its impact on the environment and society
Resuming the socio-scientific dimension	Students were asked to consider how science and society speak back to each other concerning the production and uses of ethanol. Students had to elaborate on ideas and opinions about the different kinds of ethanol mixtures and their uses, health and alcoholism, taxation of alcohol for drinks, production of sanitizing lotions and their affordability in different socio-economic situations, the use of soil for bioethanol production, the benefit for the economy and risk of soil exploitation, or the price increase of food were discussed	
Discussing and evaluating different points of view	Students discussed evaluating different points of view about the use and production of ethanol. They exchanged ideas and opinions about the processes to obtain ethanol and its uses	<ul style="list-style-type: none">- Discussions about the outcomes
Meta-reflection	Assessment and self-assessment: Likert items, open questions, and rubrics for the presentations were the tools used to evaluate the outcomes. Students were encouraged to think about the learning module. They discussed and evaluated what they learned about ethanol and its uses	<ul style="list-style-type: none">- Discussion of the module outcomes- Post-test on the perception of the different aspects involved in the production and use of ethanol- Likert items on the lesson plan pedagogy- Open questions about the learning module

Table 4: Correspondence between the role of the group member and the material to review.

Role	Material	Source	Conclusion	Presumed background
Coordinator	Journal article Zanelli (2009)	Italian Chemistry Society	Consider all the possible aspects involved in taking the controversial decision about the production and use of bioethanol (economy, legislation, politics, environment, society, science ...)	Information about science, technology and society
Secretary	Newspaper Ballone (2007)	Local foundation for preserving nature	Avoid extensive cultivation in agriculture for producing bioethanol to protect the environment	Information about the impact of extensive agriculture (environment exploitation, air pollution), and social risks (higher cost of food, ethical considerations)
Ambassador	Advice for school ENI scuola (2022)	Italian Society for Energy and Oil	High costs of production, impact on CO ₂ emissions, waste production, rising costs of food	Information about biofuels usage
Technician	YouTube videos Abbotto (2020a), (2020b)	Academic	Create cooperation between industry and scientists to produce hand sanitizers	Information concerning the availability of ethanol for the production of hand sanitizers
All students	Website advice Italian Istituto Superiore di Sanità ISS (2014)	Health medical research center	Alcohol and individual and social risks	Information on health issues

Table 5: Guidelines for the creation of the presentation.

Workgroup assignment
<p>Create a short presentation (maximum 8 slides) to communicate:</p> <ul style="list-style-type: none"> – Who/what is involved in the production of ethanol – Who/what is involved in the different uses of ethanol – Clarify the pros and cons of ethanol production – Clarify the pros and cons of the different uses of ethanol – List the sources of information (references) in a separate slide <p>Attention: the maximum number of slides includes the slide with the composition of the group, roles, class, institute, year, and the one with the references. The group will choose the presenter of the work during the video lesson. The presentation will last 8 min</p>

The time for homework was not included. The students were used to working in groups with roles following the jigsaw classroom method (Kagan, 1994); the new aspect was working online. The students had to create a deliverable to convey the results of their investigation and their reflections. Table 4 shows the description of the assigned work and in Table 5 are the guidelines released.

4 Methods

The case study reports only the aspects related to the SSI approach. The content knowledge assessment combined exercises, tests, oral examinations and deliverables developed at home during the lockdown. The deliverables were assessed using a rubric that has been shared with the students before they started to work (Ambrogi et al., 2008).

Three tools were used to evaluate the teaching intervention. A pre-post questionnaire was used to see whether the students' views on the SSI of using ethanol in hand sanitizers changed in terms of making the students more sensitive to the different dimensions that had to be taken into account when evaluating socio-scientific questions. A five-step Likert questionnaire was used asking for how important the following dimensions are to decide how to use ethanol: economy, politics, science environment, ethics, society, and

governance. The dimensions were taken from the framework of the EU-funded project Irresistible (2013). The scale was from 1 (irrelevant) to 5 (very important). Mean values were calculated and compared.

A second questionnaire was used after the intervention to find out the students' perception of online learning integrated with longer phases of group work assignments. Also here, five-step Likert scales were used from 1 (strongly disagree) to 5 (strongly agree). Statements given were: Working in groups online was more difficult; working in groups online was more fun; working in groups online was a waste of time; by working in groups online I learned more; by working in groups online I learned a better use of the ICT; working in groups online was unfair to students with difficulties in getting the Internet; and working in groups online was helpful to the students with difficulties in getting the Internet connection. The answers were subject to descriptive statistics.

The Likert questions were accompanied by three open questions. The open questions regarded the students' opinions about the new learning methods.

- What are the main things that you have learned during the chemistry lessons about ethanol usage?
- What do you think of the chemistry lessons and the work about ethanol we have done during the last weeks?
- What did you like most about the chemistry lessons about ethanol?

According to Mayring (2000), the open questions analysis was qualitative. The answers were coded following categories derived from data.

5 Sample

Twenty seven students from a 10th-grade class (age 15–16) in northern Italy participated in the teaching intervention, and 19 students answered the questionnaire voluntarily.

6 Findings

Before the SSI-based learning module, the majority of the students considered science very important/important (83 %) to evaluate the use of ethanol. A much lower number of students (47 %) considered environmental aspects very important/important. The students' evaluations of the economy were almost equally distributed between very important/important (34 %), neutral (33 %), and irrelevant/not important (33 %). The students' evaluation of society was slightly lower, they reputed it important/very important (33 %), neutral (28 %), and irrelevant/not important (39 %). Few students reputed governance (12 %), ethics (11 %), and politics (6 %) as very important/important. A large number of students considered politics irrelevant (56 %) (Figure 2 left).

After the intervention (Figure 2 right), the economy resulted as the component with the major percentage of evaluation as very important/important (84 %), followed by environment and science both with 79 %. No one reputed science is irrelevant and 58 % reputed it very important. A growing number of students considered society important or very important (37 %) and the number of irrelevant/not important decreased (27 %). The

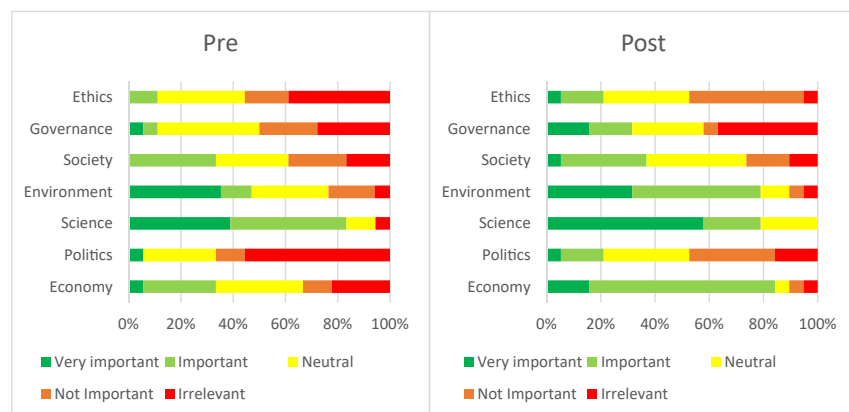


Figure 2: Results of the Likert questionnaire used to investigate the students' perception of dimensions for evaluating ethanol usage.

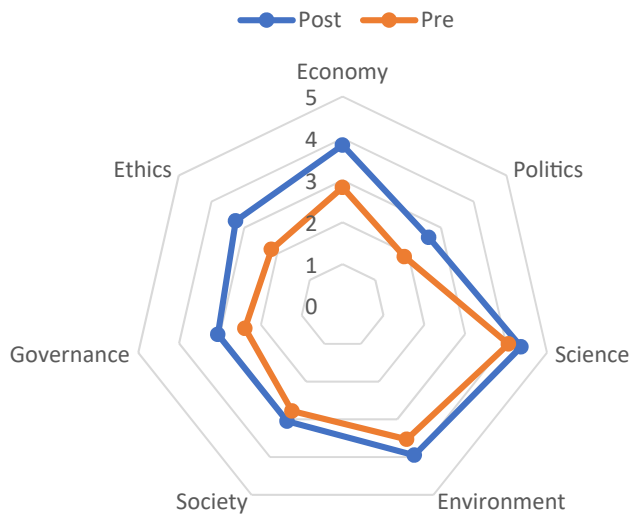


Figure 3: Mean values of the students' pre-post evaluation of the different aspects involved in the use of ethanol.

consideration of very important/important increased for governance (32 %), ethics (21 %), and politics (21 %) (Figure 1b). A comparison between the means of the evaluations before and after the SSI-based learning module is presented in Figure 3. It shows that only the consideration of science was almost equal before and after the intervention. All other dimensions were seen as more important than before the intervention.

The second questionnaire investigated the students' perception of online working in groups (Figure 4). The majority of the students strongly agreed/agreed (84 %) that the online group work improved their ICT skills. A majority of the students (58 %) strongly agreed/agreed in evaluating it as helpful for the students who had difficulties in getting the Internet, but a large part of them (48 %), strongly agreed/agreed in valuing it as unfair. A majority of the students strongly disagreed/disagreed considering the online group work a waste of time (58 %) or more difficult (53 %). A consistent part of the students was neutral (43 %) when considering if they learned more by working in groups online and one out of five strongly agreed/agreed (21 %).

The answers to the first open question about the main things students learned during the intervention were classified into four main categories: (a) Social skills and personal development, (b) chemistry, (c) new methodology and interconnection between science and society, and (d) none of the previous (Table 6).

The major part of the students stressed the aspects related to social skills and personal development. *"During this period, I learned that, even if you are far away, you can work in a group by working on a single part of the work and then putting all of them together and comparing as a team"; "I have understood the importance of delivering homework on time".* A considerable number of students appreciated the new methodology that motivated them. *"I learned to work differently from what I did before and this allowed me to give a new stimulus to the brain and*

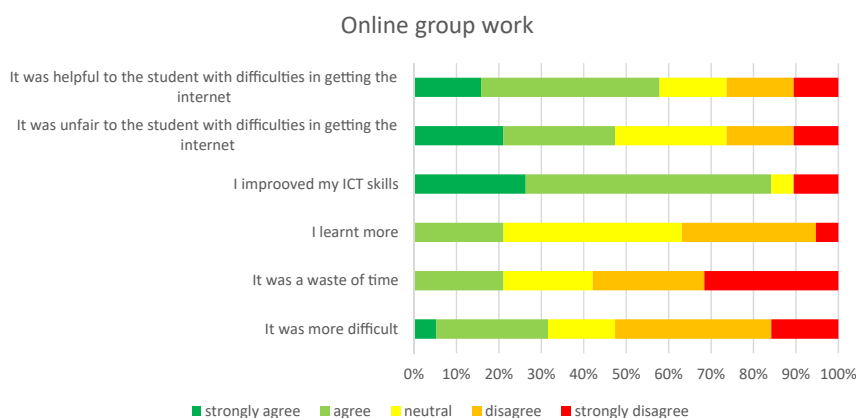


Figure 4: Results of the Likert questionnaire used to investigate the students' perception of the online group work.

Table 6: Categorization of students' answers to the first open question.

Category	Description	Number of students
A	Any response related to cooperation, work-group, personal development	6
B	Any response related to chemistry contents	4
C	Any answer related to the new learning methodology and the socio-scientific interconnections	4
D	Any answer that did not mention the elements of the previous categories	2
a + b	Any answer that combined the elements of the relative categories	3

allowed me to have more desire to study”, and “The work on ethanol is very important because it talks about topicality”.

Concerning the second question “What do you think of the chemistry lessons and the work about ethanol we have done during the last weeks?” there were two main interpretations of this question, (a) focusing on the technical aspects of the teaching methodology, and (b) focusing on personal development. The outcomes are shown in Table 7.

Typical answers were: “The lessons were certainly different from the normal ones but not less engaging”, “They were interesting and we managed to understand the topics even if we were far away”, and “... the teacher has allowed us to reason and to come to a conclusion autonomously”.

Concerning the question of what the students liked most about the lesson plan, the majority of the students stressed the learning methodology and a consistent amount of them addressed cooperation and personal development (Table 8).

Examples of typical answers were: “For sure the work on ethanol because it was very constructive and it was since a long time since we did not work in a group in which you have to find much information and each one had to put his effort.” “I liked most the lesson at a distance because this made us autonomous.” “At the beginning, the great independence and the opportunity to reason by myself.”

Table 7: Categorization of students' answers to the second open question.

Category	Description	Number of students
A	Any answer related to the new learning methodology	
	1. Different	4
	2. Difficult	3
	3. Interesting	1
	4. The program was carried out	3
	5. Combine 1 + 2	2
B	6. Combine 1 + 3	2
	Any answer related to social skills and personal development	4

Table 8: Categorization of students' answers to the third open question.

Category	Description	Number of students
A	Any response related to cooperation and work-group and personal development	8
B	Any answer related to teaching methodology	7
C	Any response related to chemistry contents	2
D	Any answer that did not mention the elements of the previous categories	2

Concerning the content knowledge assessment no differences were found to those obtained during regular lessons before the COVID-19 pandemic.

7 Discussion

This SSI-based learning module has had positive effects to promote students' attention toward the aspects other than science involved in evaluating the use of ethanol. Before the module, the aspect that the major part of students valued very important or important was science followed by the environment. After the SSI-based module, the economy was the aspect that the majority of the students valued importantly. The total percentage of students who reputed science as very important or important remained similar to the previous but the percentage of students who reputed it as very important increased. In addition, the evaluation of the importance of the environment increased consistently. Governance, politics, and ethics increased in the scale of positive evaluation. The total number of students who considered politics irrelevant or not important was still great, but many students turned their evaluation from irrelevant to not important demonstrating increased attention toward the component. The evaluation of society remained mostly the same but the percentage of irrelevant decreased and the percentage of very important increased. The learning activity brought students to consider the different aspects related to the issue and to think and discuss the relations between science, society, economy, politics, ethics, and the environment. The SSI-based learning module fostered the students' awareness of their social skills and personal development. They appreciated the opportunity to cooperate and exchange opinions about a relevant and topical issue. They became aware of their personal development, especially concerning the capability to organize the work and reasoning with responsibility and autonomy. The students were positive toward the online group work. They perceived it as an opportunity to maintain relationships in difficult moments and to enhance their ICT skills.

8 Conclusions

Although this case study has several limitations, being limited to one learning group only and with feedback from only 19 students some indications can be derived from this intervention. The findings of this SSI-based learning module indicate that SSI-based teaching even if done online has the potential to broaden the students' view when considering questions of science and technology. After the intervention, they see more importance in considering also other aspects beyond science involved in the applications of a science-related issue. The students learned about the chemical properties of ethanol related to its structure and the methods for its production, which are part of the traditional chemistry curriculum. But, they also discussed the different aspects that its uses imply at individual, societal, and environmental levels. The human aspect, which is a relevant part of this approach (Sjöström et al., 2020), resulted to be the driving one. The students learned that the module enhanced their social skills and fostered personal development. They appreciated the opportunity to foster their social skills by cooperating and sharing opinions. Most of them perceived a sense of autonomy and responsibility in organizing independently the work and in reasoning on the different aspects discussed. The students perceived and valued the opportunity to foster their competencies. The education of future citizens should encompass learning content and society-related critical thinking. In our society, molded by science and technology, science content knowledge is important but critical use of it is crucial. Education calls for content knowledge and critical thinking. The first one is usually part of traditional teaching but the second one is not. SSI-based learning helps enhance students' attitude of reasoning autonomously on aspects other than science, i.e., society, economy, politics, ethics, and environment while discussing a science-related issue. Nevertheless, the SSI approach is not common in Italy. The lack of SSI implementation could be due to the lack of teachers' knowledge about it and this brings to consider the importance of investment in corresponding teacher continuous professional development.

Research ethics: Consent from the school authorities was given. All participants took part on a voluntary base.

Author contributions: All the authors have accepted responsibility for the entire content of this submitted manuscript and approved submission.

Competing interests: The authors declare no conflicts of interest regarding this article.

Research funding: None declared.

Data availability: Not applicable.

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