Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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To cite this article: Walter Sciarretta and Italo Testa 2024 *J. Phys.: Conf. Ser.* **2727** 012020

Investigating the relationships between students' reasoning in Socio-Scientific Issues and knowledge about scientific inquiry and modelling

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Abstract. In this paper, we investigate the relationships between students' reasoning about socio-scientific issues and their knowledge about scientific inquiry and modeling. To this aim, we developed a teaching-learning sequence for Italian high school students (10th grade) during which the students were familiarized with the basic aspects of scientific inquiry and modelling and then confronted with the controversial scenario of the closing of a steel manufacture plant in Italy. The results show that students' knowledge of models and the scientific inquiry does not seem adequate to achieve a sufficient level of competence in socio-scientific reasoning. Implication for teaching practice about physics-based socio-scientific issues will be briefly discussed.

1. Introduction

This work describes a didactic approach based on the so called "Socio Scientific Issues" (SSI). SSI are ill-defined, reality-based, didactical contexts characterized by contrasting views on which consensus has not yet been reached from a scientific point of view [1]. A common trait of SSI is the involvement of students in some kind of personal decision-making process. In SSI approaches, students do not play the role of spectators of technology wonders or passive learners of science contents, but rather that of active society citizens who (will) decide about complex issues. Such decisions necessarily take into account not only the science involved but also moral and ethical aspects. Examples are local environmental controversies, alcoholism, human cloning, and the use of genetically modified food.

In this paper, we will deal with SSI in the Italian context. Some examples, among the most debated ones in the Italian national media in the last 15 years, are the use of nuclear power plants or waste-to-energy plants, global warming and, more recently, COVID-19 vaccination. Although the attention on the national media has been useful to familiarize Italian citizens with the existence of controversial issues in science, the inclusion of SSI teaching approaches in the Italian curriculum is still very slow. Only recently, in 2020, a new subject "Citizenship Education" has been introduced at middle and high school level. The main topics addressed in this subject are: Italian Constitution and State organization; environmental education, protection of cultural heritage; digital citizenship. Despite this new subject can potentially feature the discussion of socio-scientific issues, science teachers usually do not discuss controversial scenarios in their curriculum hours devoted to Citizenship Education. To address this issue, we present in this paper a pilot study of the implementation of a SSI-based Teaching-Learning Sequence

(TLS) aimed at improving high school students' Socio-Scientific Reasoning (SSR), namely their ability to apply contents learnt in the science syllabus to discuss about SSI. This pilot study will inform subsequent design phases of the TLS in order to include it in the wider teaching of Citizenship Education at middle and high school level. The content addressed is scientific inquiry and modeling, which is present in the Italian syllabus for scientific subjects, as biology, chemistry and physics. The specific research question of the study is: *"What is the relationship between students' SSR when discussing a physics-based socio-scientific scenario and their knowledge of scientific inquiry and models?"*

2. Theoretical framework

An extensive literature has proven that to make informed decisions about SSI, it is not sufficient to know disciplinary contents, but it is also necessary to consider social, economic and moral aspects [2]. A possible way to frame the use of content knowledge learnt at school in socio-scientific argumentation is the so-called "Threshold Model for Content Knowledge Transfer" (see Figure 1), which describes the relationships between SSI argumentation and content knowledge [2].

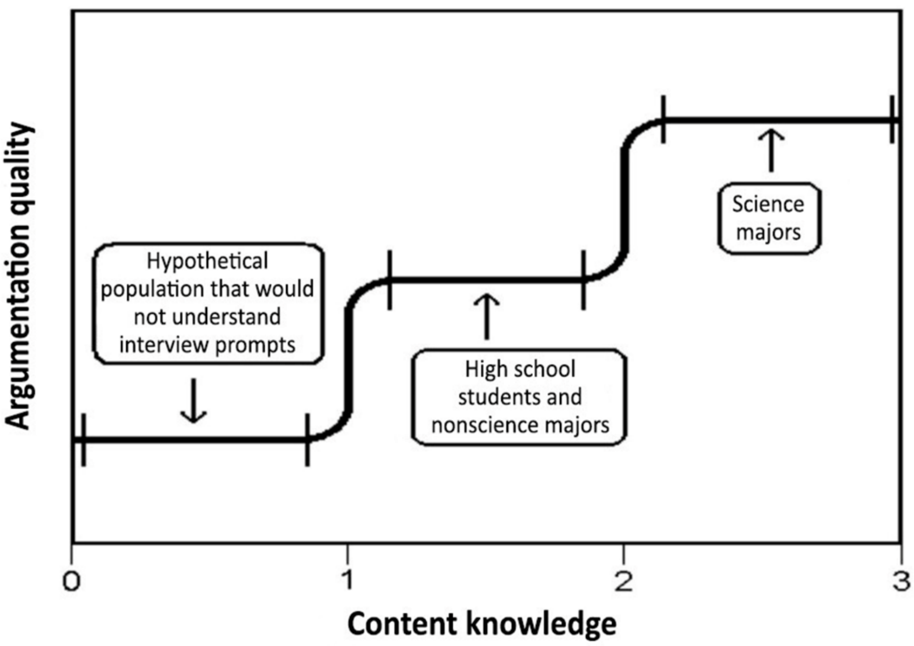

Figure 1. Threshold model for content knowledge transfer, adapted from [2].

The model, building on previous studies [3-5] predicts a not linear dependence of the quality of students' arguments about SSI on their knowledge of scientific contents. In particular, the model features on the content knowledge axis (*y-axis*) three "thresholds", namely specific "values" of content knowledge at which significant increases on the argumentation quality axis (*z-axis*) are likely to be detected. The threshold 1 distinguishes a "little or none" from a "basic" level of content knowledge, needed to at least discuss the issue. Threshold 2 discriminates the "basic" from an "advanced" level of content knowledge, which may help producing high-quality arguments. Hence, to pass Threshold 2, students should possess robust enough schemes of the involved concepts. Finally, Threshold 3 separates the "advanced" level from the knowledge expected of professional scientists. An important prediction of the model is that the argumentation quality of two students does not significantly differ if their content knowledge level falls between two thresholds.

In this study, we adopted a model in order to describe SSR (see Figure 2). The model features four interacting dimensions: complexity, perspective taking, inquiry and skepticism [6]. Complexity concerns the ability to recognize that SSI have no simple solutions. Perspective taking refers to the ability to examine SSI from different, often divergent perspectives. Inquiry, includes the ability to investigate SSI designing experiments and scientific inquiry. Skepticism concerns the ability to examine potential biased information about SSI. The simplest relationship between the four dimensions can be described as follows: identifying the complexity of a SSI scenario helps recognizing confounding perspectives that generates skepticism on the use of existing data and leads to the need to conduct more research in order to collect additional data [7].

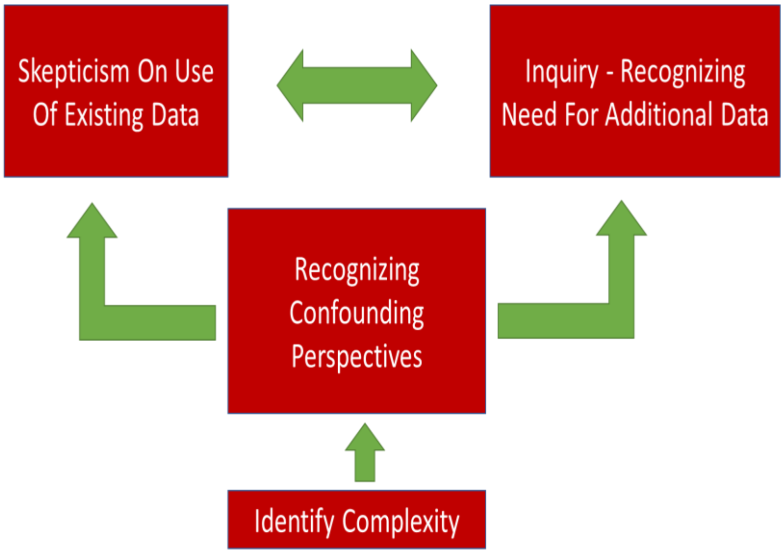

Figure 2. The interacting dimensions of the socio-scientific reasoning construct. Adapted from [6].

3. Methods

3.1. Instructional context

In order to answer our research question, we first designed a 15-hour (TLS) for 10th grade student about the closing of the ILVA plant, the biggest steel production site in Italy, located in Taranto (Puglia region). The owners of plant were charged by the local court for culpable and intentional disaster, poisoning of foodstuffs, willful omission of precautions against accidents at work, aggravated damage to public property, dumping and spillage of dangerous substances and air pollution. The charge was supported by several scientific studies that suggested that the plant had actually polluted the air, causing severe health issues in local population over the last 20 years. The scenario is controversial since the plant employs about 11,000 workers so the closing of the plant would cause tremendous economic damages. For such reason, a referendum held in Taranto asking if the citizens would agree with the closure of the plant did not reach the required participation of half the population of Taranto.

To help students use sound arguments from the content knowledge viewpoint in SSI discourse, we designed the activities of the TLS so that the construction of students' arguments could resemble the construction of physics knowledge. In such a way, we aimed to provide students with suitable instruments that could enhance the reliability of their arguments.

The TLS starts with the reading of the controversial decision by the State Council judges to keep the ILVA plant open, despite evidence of health problems of citizens living near the plant. Then, the students are introduced to basic features of scientific modelling and scientific inquiry, with the aim to identify relevant variables that can model the plant functioning (e.g., second principle of thermodynamics) and methods to collect data about the pollution of the plant. Then, the students are familiarized with the

Italian laws about pollution and the system of laws that regulate the emission of plants. During this phase, the students are familiarized with how judges make use of scientific data to take their decisions and how scientific inquiry can be used to collect data useful for the court's decisions. In particular, prior court decisions about the ILVA plant are presented to students in order to understand how the judges have supported their decisions in light of the presence (or absence) of scientific evidence. Finally, the students engage in pair-work where they are asked to support their own decision about the ILVA plant. A short presentation was then produced by the whole class in order to resume the main points emerged from the pair-work.
The TLS was implemented online due to the COVID-19 pandemics. Overall, 78 high school students (41 females, average age = 16 years old) were involved in the study. The activities were carried out outside the regular school schedule. Each activity lasted about 3 hours.

3.2. Assessment tools
To evaluate the students' argumentation quality after participating to the TLS activities, we adapted to the ILVA scenario the "Quantitative Assessment of Socio-Scientific Reasoning" (QASSR) instrument [4]. The adapted instrument features 54 items. Each item featured a claim on which the students were asked to express their level of agreement on a five-steps (from 1 = completely disagree to 5 = completely agree) Likert scale. The 54 items were categorized according to the 4 dimensions of the SSR: *complexity, perspective taking, inquiry and skepticism* (see Table I). Example items for each of the SSR dimensions are also reported. For each SSR dimension, we calculated the overall average rating, so that the students' overall score ranged from 4 to 20.

Table 1. Description of the adapted QASSR.

Dimension	Number of items	Example items
Complexity	12	*"The ILVA case is difficult to resolve because we have limited scientific evidence. If we had more, it would be easier."* *"The case of ILVA is easy to solve because the factory pollutes and therefore it must be closed."*
Perspective taking	6	*"It is very likely that the citizens of Taranto and the representatives of the steel company will collaborate and reach a shared solution."* *"The representatives of the steel company and the residents of Taranto have access to different information"*
Inquiry	17	*"I can't make a decision on ILVA because I'm not sure about the economic and scientific details underlying the operation of the factory, and therefore I would have to do more before I can make an informed decision."* *"I would be able to decide on ILVA because I have reasonable certainty that the benefits of ILVA outweigh the risks. ILVA brings money into the local economy and supplies low-cost steel, both of which are important for living a comfortable life"*
Skepticism	19	*"I expect the results obtained by the ILVA team of scientists to be the same as those obtained by the team of scientists hired by the citizens of Taranto because science is objective"* *"I expect the results obtained by both teams to be different because ILVA has much more money pay for a better scientific team, making their results more reliable."*

To assess students' content knowledge about models and scientific inquiry, we used two questionnaires:

1. A closed version of the widely adopted Views About Scientific Inquiry (VASI) survey [8], featuring 10 two-tier questions where the maximum score was 20.

2. The Views About Scientific Models (VASM) questionnaire developed from our prior studies about models and modelling [9]. The VASM features 15 questions with three alternative choices (“Yes” – “No” – “Partial”). Correct answers, i.e., “Yes” to a correct claim, “No” to an incorrect claim, “Partial” to a partially correct claim, scored 2 points, “Partial” answers to correct or incorrect claims were given 1 point, wrong answers, i.e., “Yes” to an incorrect claim, or “No” to a correct claim, were scored as 0. The maximum score was 30.
   Example questions are:

   “The main role of scientific models is to simplify the reality, facilitate the calculation and highlight the properties of the reality in which we live.” (correct answer: NO)
   “The main role of a scientific model is to represent a phenomenon and make predictions about its future evolution.” (correct answer: YES)
   “The scientific laws are an abstract instrument for analyzing reality built starting from the observation of the reality itself.” (correct answer: Partial)

To answer our research question, we first grouped the students according to the obtained QASSR score (using quartiles of the total score) and then compared the combined VASI and VASM score for the obtained groups using multiple one-way analysis of variance (ANOVA).

4. Results

Cronbach’s alfa for the QASSR instrument was 0.84. Average score was 12.6±0.9 (st.dev.) out of 20. Distribution of students’ scores is reported in Figure 3.

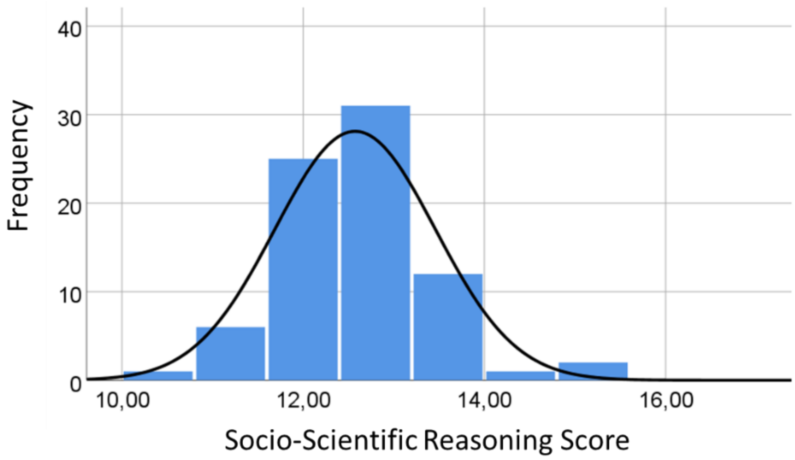

Figure 3. Distribution of QASSR scores obtained by our sample

After having combined the score for the VASI and VASM instruments, average score was 25.0 ± 4.1 (st.dev.) out of 50 (see the distribution of scores in Figure 4).

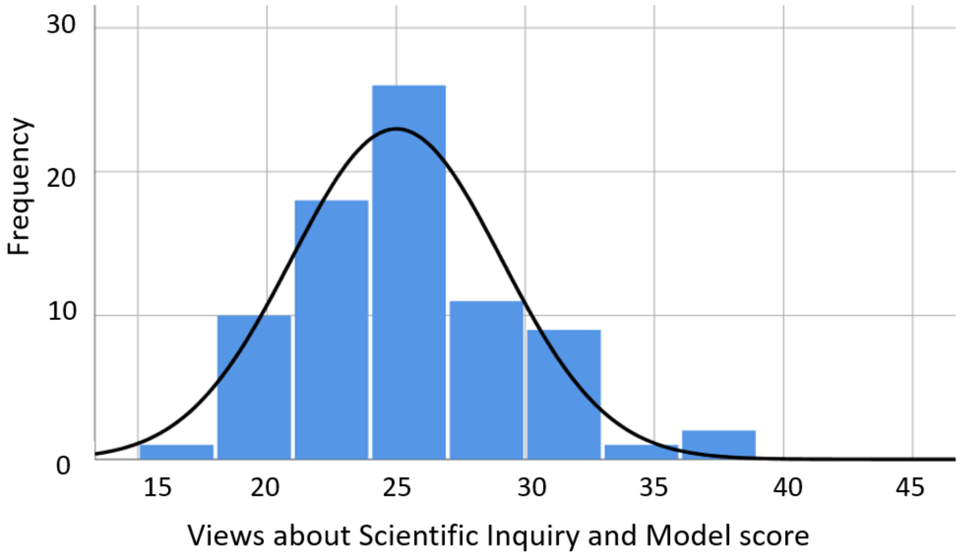

Figure 4. Distribution of the VASI and VASM combined score

For the sake of brevity, we report in the following only students' answers to a typical question of the VASI questionnaire.

Table 2. Average scores in the QASSR dimensions according to VASI + VASM score quartiles

QASSR Dimensions	VASI + VASM score quartiles	N	Average score	St. Dev.	*F*
Complexity	*First*	20	3.22	0.37	0.344[a]
	Second	27	3.24	0.51	
	Third	13	3.16	0.41	
	Fourth	18	3.31	0.30	
Perspective Taking	*First*	20	3.04	0.20	0.557[a]
	Second	27	3.10	0.35	
	Third	13	3.21	0.45	
	Fourth	18	3.09	0.31	
Inquiry	*First*	20	3.14	0.28	0.349[a]
	Second	27	3.14	0.29	
	Third	13	3.27	0.29	
	Fourth	18	3.26	0.35	
Skepticism	*First*	20	3.07	0.32	0.540[a]
	Second	27	3.02	0.32	
	Third	13	2.97	0.27	
	Fourth	18	3.11	0.24	

[a] *df = 3; 74, p > .05*

The correct answer to the question *"Do you think that the scientific inquiry can follow more than one methodology?"* is "Yes" and most of the students (about 70%) answered correctly. However, most of these students did not choose the correct justification, which is "*we can follow more than one methodology because we can collect data about a phenomenon by making observations or by designing*

an experiment and controlling the variables". The majority of the answers, on the contrary, stated that the answer to the first tier is yes because one methodology is the deductive method and another one is the inductive method. Some other students answered "No" to the first question justifying their answer by saying that the only correct method is the scientific method by Galileo Galilei.
The one-way ANOVA (Figure 5) shows no statistically significant difference in the VASI + VASM scores between students of different levels of ability according to SSI reasoning as measured by the QASSR instrument (see Table 2). Overall, students with better scores in the VASI+VASM questionnaires performed slightly better in the overall QASSR questionnaire (Figure 6). However, the effect is overall not significant, $F(3;749) = 0.471; p > .05$, thus the predictions of the threshold model are only partially confirmed.

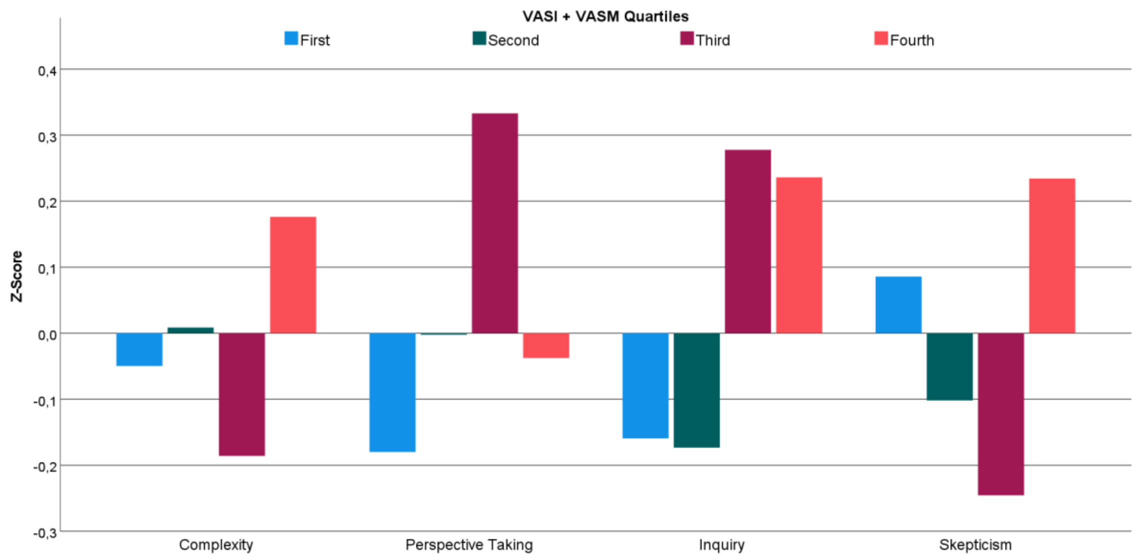

Figure 5. Average Z-score for each dimension of the QASSR according to the VASI + VASM score quartiles

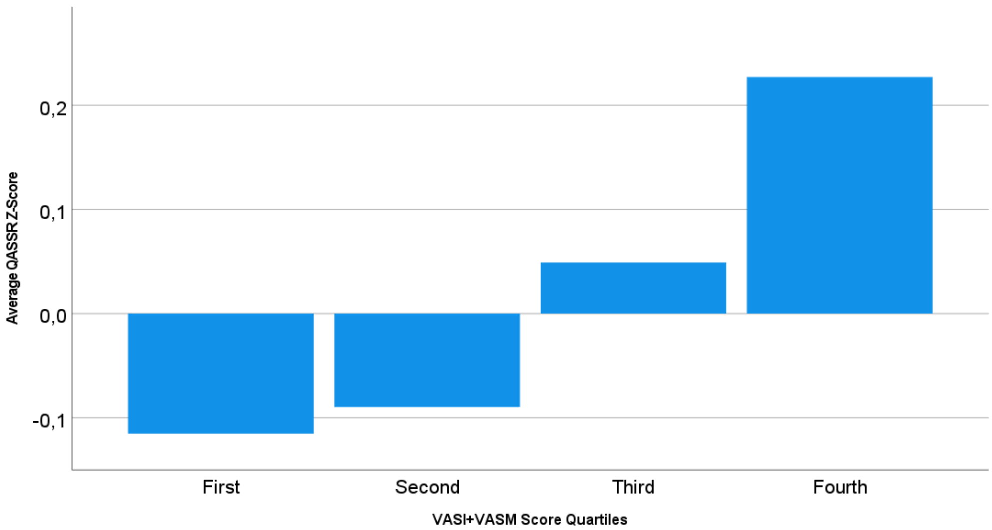

Figure 6. Total SSR score according to the different quartiles from the VASI+VASM

5. Conclusion and further implications

The results show that the threshold model can partially describe students' socio-scientific reasoning about a controversial scenario in Italy, the closing of the ILVA plant. In particular, we found that the students' knowledge of scientific inquiry and models acquired during the designed TLS can affect their socio-scientific reasoning, but such knowledge does not seem adequate to achieve a significantly better ability in socio-scientific reasoning. The obtained results suggest some changes to the TLS to help students apply acquired knowledge about scientific inquiry and models to controversial scenarios. For instance, in the revised version, we included more example of how judges can use scientific inquiry and models to support their court' decisions.

Overall, from an educational point of view, the most important result of this study is the development of instructional materials that can be used in the school subject of "Citizenship Education" to evaluate students' SSR and knowledge about inquiry and scientific models. In this way, we hope to improve students' socio-politically attitudes regarding our society. We are currently designing a small professional development course in which the involved teachers will familiarize with the TLS activities in order to implement them in their classroom. We expect to involve in a future study about 100 students.

References

[1] Zeidler D L 2005 *et al. Sc Ed* **89** 357
[2] Sadler T D and Donnelly L A 2007 *Int. J. Sc. Ed.* **28** 1463
[3] Sadler T. D and Fowler S 2006*Sc Ed* **90** 986
[4] von Aufschnaiter C, Erduran S, Osborne J, & Simon S 2008 *J. of Res. Sc. Teach.* **45** 101.
[5] Sadler T D, Klosterman M L and Topcu M S 2011 Learning science content and socio-scientific reasoning through classroom explorations of global climate change *Socio-scientific issues in the classroom: Teaching, learning and research* ed T D Sadler (New York: Springer) pp. 45-77
[6] Romine W L, Sadler T D and Kinslow A T 2016 *J. Res. Sci. Teach.* **54** 274
[7] Romine W L, Sadler T D, Dauer J M and Kinslow A T 2020 *Int. J. Sc. Ed.* **42** 2981
[8] Lederman J S *et al.* 2014 *J. Res. Sci. Teach.* **51** 65
[9] Danusso L, Testa I and Vicentini M 2010 *Int. J. Sc. Ed.* **32** 871