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RESEARCH ARTICLE

Education for sustainable development, nanoscience, and chemistry education: A small scale survey among a sample of Italian chemistry teachers

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Abstract
This survey explores the experience and perceptions toward Education for Sustainable Development (ESD) of a sample of Italian chemistry teachers attending a professional development course. In Italy, chemistry lessons could include learning about sustainable development issues, but it is unclear to which extent ESD in chemistry lessons is operated. Additionally, ESD became a central part of the Italian interdisciplinary teaching subject of Educazione Civica (EC) which might be translated as citizenship education. In EC, all science subjects are involved, including chemistry, where lessons are taught by chemistry teachers. This survey inquires about the potential incorporation of ESD and also nanoscience into chemistry lessons in general and in EC in particular from the viewpoint of Italian chemistry teachers. The focus is on teachers' attitudes to including ESD and nanoscience in their lessons and potential difficulties in implementing them.

Keywords
chemistry education, education for sustainable development, citizenship education, nanoscience, teacher attitudes

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State of the literature
- Education for Sustainable Development (ESD) is a worldwide accepted goal for education in general, and for secondary and tertiary science education in particular.
- Teacher education and their attitudes are central to implementing ESD in schools.
- Different studies suggest that teacher education is not sufficiently focused on implementing ESD in certain countries.

Contribution of this paper to the literature
- The paper explores the perception of Italian chemistry teachers on implementing ESD in the case of Italy.
- It describes to which extent Italian chemistry teachers feel prepared to implement ESD and nanoscience into their teaching and into a new school subject called Educazione Civica (EC) which might be translated as citizenship education.
- Directions for further educational reforms are suggested.

Introduction
The media often refer to sustainability and sustainable development and the terms have become usual in everyday life. The concept of sustainable development (SD) was introduced on a broad political scale in 1987 by the report of the Brundtland Commission "Our Common Future" (Word Commission on Environment and Development [WCED], 1987). The perspective presented in the foreword was to set "A global agenda for change" (WCED, 1987) to allow economic growth considering the protection of the environment and a decent development of the society. The connections, and mutual interdependence between prosperity, a healthy environment, and the life of the people came into focus. The Brundtland Commission released a definition that remains one of the most widespread and accepted: SD is a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, 3.27).

Considering that the resources of our planet are limited and that the health of human beings and the environment are intertwined, cooperation is indispensable to pursue SD. In 1992, the Agenda 21 stressed the importance of Education for Sustainable Development (ESD) "Education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues" (United Nations Conference on Environment and Development [UNCED], 1992, 36.3). In 2015, the Agenda 2030 set 17 Sustainable Development Goals (SDGs) (United Nations [UN], 2015). Among the SDGs is SDG no. 4 (Quality Education) which claims in its target 4.7:

> By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development.

In 2017, the Italian Ministry of Education (Ministero dell'Istruzione, dell'Università e della Ricerca [MIUR]) in cooperation with the Alleanza Italiana per lo Sviluppo Sostenibile (Italian Alliance for the SD [ASviS]) propagated learning about and for the SDGs with contests for all

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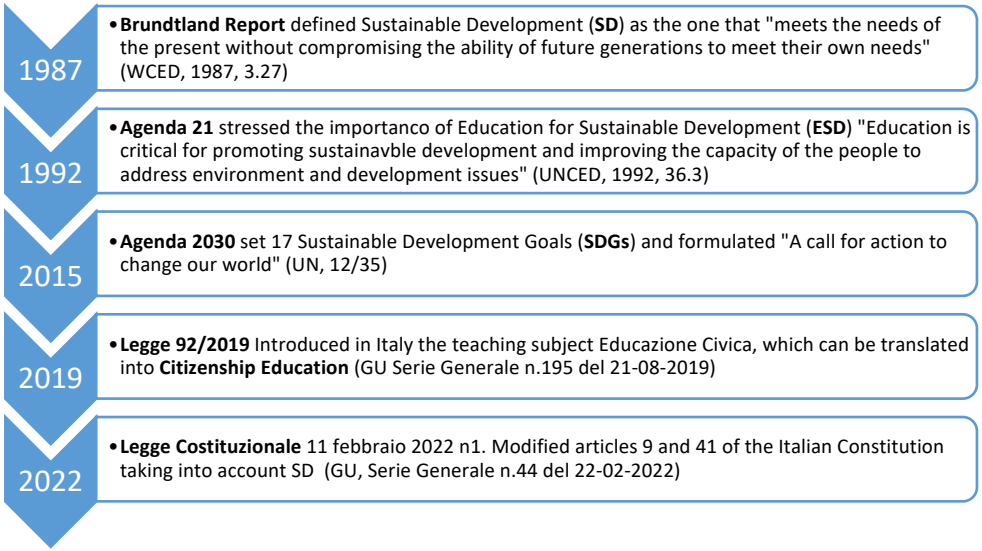

Figure 1. The timeline of the SD introduction in Italian education and constitution

school levels (MIUR-ASviS, 2017). In September 2020, a law (Legge 20 Agosto 2019, n.22) introduced a new subject in all levels of Italian schools, from kindergarten to secondary school. The subject is called Educazione Civica (EC), which might be translated as citizenship education. The nature of EC is suggested as being interdisciplinary and transversal. It has three thematic cores: the Constitution, SD, and digital citizenship. Teachers of the different school subjects should cooperate in teaching EC for 33 hours per school year, dedicating to it part of their scheduled teaching time from their subjects. The educational policy suggested that science subjects should address the thematic core of SD within EC (MIUR, 2020). In doing so, educational policy aims at paying more attention to SD as a central goal of the education of future citizens.

Most models of SD stress three dimensions: environmental, economic, and societal sustainability (Purvis et al., 2019). SD and its dimensions have also entered the Italian Constitution. In 2022 an Italian constitutional law amended Article 9, which is part of the constitution's fundamental principles, and Article 44 (Legge costituzionale 11 febbraio 2022, n.1) addressing the three dimensions of SD and the definition released by the Brundtland report (WCED, 1987). A simple timeline of the introduction of SD into the Italian curricula and constitution is shown in **Figure 1**.

In 2020, the MIUR released guidelines to help teachers implement EC. The guidelines stress the educative aims of the subject EC to prepare future citizens to become able to take an active part in societal debates, to make choices and decisions coherent with the SDGs, to identify the complexity of moral, political, social, economic, and scientific issues, and to formulate personal answers (MIUR, 2020, attachment C). The aims are aligned with the Italian curricula that have been based on competencies since 2007 (Ministero della Pubblica Istruzione [MPI], 2007; MIUR, 2010). Competence-based curricula ask for a learning approach that is different from focusing mainly on content knowledge because it focuses principally on what students can do with their knowledge and how they use it with autonomy and responsibility.

To cooperate for SD and make informed and responsible choices, in our society moulded by science and technology, knowledge of science and technology is very important but the capability to consider the social, economic, and environmental implications is crucial. Students must be prepared to understand the basis of science-related issues but they also must be trained to think about the social, economic, environmental, and ethical implications of the application and use of science and technology (Eilks et al., 2018). Such an approach calls for a new teaching approach that could be useful also to motivate students and display the relevance of science for students' lives now and in the future (Stuckey et al., 2013).

So far and despite the importance of science, science subjects are not very popular among students (Rocard et al., 2007). To contrast this attitude different pedagogical approaches have been suggested. Some learning approaches motivate students by involving them actively like active or inquiry-based learning (Bybee, 2009; Rocard et al., 2007). It is also suggested to motivate students by situating learning in meaningful contexts to facilitate them to make sense of scientific implications in everyday life (Gilbert, 2007).

The European Commission promoted and funded several projects to bring students' attention to science and its interconnections with society. One of those projects, Irresistible (http://irresistible-project.eu), developed and released active-learning-based modules to make students reflect on Responsible Research and Innovation (RRI) and its use (Apotheker et al., 2017). A step further could be represented by socio-scientific-issues (SSI) based education that has been proven effective in promoting students' interest in science as well as in stimulating critical thinking and reflections about non-scientific aspects rooted in science (Eilks et al., 2008, 2018; Marks & Eilks, 2009). SSI-based education promotes education through science (Holbrook & Rannikmäe, 2007) for the development of scientific literacy (SL). The SL vision promoted by SSI-based education is mainly the one oriented to critical thinking named "Critical Scientific Literacy" (Hodson, 2009, 2011). The humanistic approach of Mahaffy's tetrahedron model (Mahaffy, 2004) is an important part of this SL vision and focuses on education for transformation (Sjöström & Eilks, 2018, Sjöström et al., 2020).

Among others, SSI education in chemistry aims to promote evaluation and communication skills as well as science learning (Marks & Eilks, 2009). The issues, useful for SSI-based chemistry

learning, must deal with questions from chemistry, and must be authentic and relevant; their evaluation in a socio-scientific respect is undetermined, and the issue allows open discussion (Marks & Eilks, 2009). SSI approaches call the students to tackle issues rooted in chemistry and to consider the potential consequences of related choices on the environment, economy, and society. Students are stimulated also to share, motivate, and evaluate opinions. This is likely what they will have to do as future citizens.

Most of the issues related to SD and cutting-edge chemistry are SSIs. New applications of chemistry and technology quickly enter our everyday lives. Nanoscience, for example, which use is new and controversial, has applications in many fields of daily life and for promoting SD, and schools should prepare students to face the aspects of science that they will encounter as future citizens. Focusing on SD aims to enhance SL by highlighting the connection between society, technology, and science (Hofstein et al., 2011). Already in 1987, Bybee suggested SD issues for inclusion into science teaching to promote SL, like air quality and atmosphere, world hunger and food resources, war technology, population growth, water resources, energy shortages, hazardous substances, human health and disease, land use, nuclear energy, extinction of plants and animals, or mineral resources. (Bybee, 1987, p. 680).

The Programme for International Student Assessment (PISA) studies, since 1999, contributed to disseminating the concept of SL (Organisation for Economic Co-operation and Development [OECD], 1999, 2017). Many national and international initiatives have been launched to propagate the importance of promoting SL and related competencies, like critical thinking, and the capability to consider the mutual influence of science, society, ethics, environment, and governance. Nevertheless, in Italy, the teaching approaches remained quite traditional and the science outcomes of Italian students were below the average in international surveys, like PISA 2018 (OECD, 2019).

The debate after each of the PISA studies called for new learning approaches, but many teachers often tend to teach the way they were taught (Phelps & Lee, 2003). That is why teachers need support and professional development to implement new pedagogies. The limited knowledge of new learning approaches like the one based on SSI and their scarce use in Italy (Genisa et al., 2020) could be the reason for the unsatisfactory outcomes. The poor interaction between the socio-psycho-pedagogical experts and the chemistry ones was addressed as a problem that impinges on Italian teachers' education (Borsese, 2016). Some opportunities to appreciate the importance of the SSI-based educative approaches and ESD in science and chemistry education were offered to the teachers in Italian language through publications (Holbrook et al., 2015; Venturi, 2018), webinars, and lectures by associations for teachers' professional development like Centro interuniversitario di Ricerca Educativa Sulla Professionalità dell'Insegnante (CRESPI, 2020) and by national contests (MIUR-ASviS, 2017). It is not clear yet at which stage Italian chemistry teachers are on their way toward a renewed pedagogy. This is why this survey investigates the knowledge and attitude of Italian chemistry teachers toward SD in general and nanoscience in particular.

Sample and Method

Participants

This study was based on an online questionnaire distributed in 2021 to participants at two professional development workshops of the Didactic Division of the Italian Chemistry Society (DDSCI). The workshops had in common the purpose of stimulating teachers' interest in chemistry education research and best practices. To foster the integration of the different levels of chemistry education, in 2021 the two workshops had the first part in common and then they followed separate paths one dedicated to school and the other to university level. The topic selected in 2021 was "Nanosciences in Basic Chemistry Teaching - A Challenge and an Opportunity". Nanoscience is considered increasingly important in many applications for SD and, therefore, it is starting to have significant repercussions in chemistry teaching at all levels of education.

At the two workshops, answers were collected from 35 participants who voluntarily answered the questionnaire before the workshops started. Most of them had a degree in chemistry (n = 25) and were teaching chemistry (n = 22) at secondary or tertiary levels. The details of their educational background, affiliation type, teaching experience, gender, and age are shown in **Table 1**.

Questionnaire

The questionnaire encompassed two parts. The first part concerned the teachers' knowledge and views on SD and some related aspects like ESD, the 17 SDGs of the Agenda 2030, and EC. The second part was about the issue of nanoscience and its connections to ESD, SDGs, and EC.

To help the participants focus on the questions, and to provide a common background, the questionnaire reported the definition of SD released by the Brundtland Report (1987). In the questionnaire, the three-dimensional model of SD (Purvis et al., 2019) was recalled, and the 17 goals of Agenda 2030 were shown.

The questionnaire was pretested with four teachers to allow for debugging and checking the comprehensibility of the items. The final version of the questionnaire consisted of 16 questions, 9 in the first part about SD and 7 in the second part about nanoscience. The questions of the first part investigated the following aspects:

1. The source from which the participants got information about SD (multiple choice)
2. The knowledge of the three-dimension model of SD (Yes/No)
3. The source from which the participants got information about ESD (multiple choice)

Table 1. Background of the participants (n=35; missing numbers: no answer)

Aspect	Profile	Number of Teachers
Gender	Female	25
	Male	10
Age	25–35	7
	36–45	6
	46–55	13
	>55	9
Educational Background	Degree in Chemistry	25
	Degree in Science	9
Teaching level	University	5
	Upper Secondary	24
	Lower Secondary	3
	Other	3
Years of Teaching Experience	<5 years	9
	5–10 years	7
	10–20 years	9
	>20 years	9
Current Subject Taught	Chemistry	22
	Science	9
	Other	2
Formally Qualified as a Teacher	No	9
	Yes	25

4. Whether the participants saw the potential to address the three single dimensions of SD during chemistry lessons (No, Scarcely, Yes)
5. Whether the participants saw the potential to teach ESD in chemistry course (Yes/No)
6. The educational level at which they feel sensible to start ESD (multiple choice)
7. To evaluate the importance of connecting chemistry education with ESD (1 to 10 scale)
8. To evaluate the importance of connecting chemistry education with the SDGs (1 to 10 scale)
9. To select topics useful to address ESD (open).

The second part of the questionnaire focused on nanoscience, the topic addressed by the two workshops. The questions investigated the participants' sources of knowledge about nanoscience and their view of the topic as potential chemistry content to address ESD. The questions regarded the following aspects:

10. The participants' source of knowledge about nanoscience (multiple choice)
11. At which education level they have taught topics related to nanoscience in chemistry courses (multiple choice)
12. Whether the participants saw concepts/contents that are usually present in a basic chemistry course and that could be connected with nanoscience (open)
13. The topics, that are not usually present in a basic chemistry course, but should be taught while addressing nanoscience (open).
14. To give an example of a topic useful to address SD and its three dimensions and suitable items while teaching nanoscience (open)
15. To give an example of a topic useful to address EC and the study of constitution, SD, and digital citizenship while teaching nanoscience (open)
16. To consider the SDGs and to evaluate if they could be addressed in a chemistry course (1 to 10 scale)

Analysis

The open-ended questions were analysed qualitatively (Mayring, 2000). The closed questions were subject to descriptive statistics.

Results

Participants' Sources of Information and Perception of SD and ESD

The main source of information about SD were journals and other media (35.5%), followed by professional development courses (26.5%), and university courses (20.6%). None of the participants stated they got SD-related information from pre-service teacher preparation (**Figure 2**).

Three-quarters of the participants (75.8%) claimed not to know any model for SD and only 24.2% declared to know a model of SD. The sources of information about ESD were mainly journals and other media (33.3%), followed by professional development courses, educational articles, and conferences (26.7%). Only 10% learned about ESD in chemistry courses during their teacher education (**Figure 3**).

The majority of the respondents (94.0%) were positive about the possibility of addressing environmental aspects as part of ESD in the chemistry lessons. More than half of the participants were open to addressing societal (62.5%) and economic (56.3%) issues as well with a third of the participants considered scarcely addressing societal (34.4%) and economic (40.6%) aspects (**Figure 4**).

All participants thought it was possible to integrate chemistry education with SD issues. The participants considered it important to connect chemistry education to ESD, all of them ranked it higher than 7 on a 1–10 scale (**Figure 5**). They also estimated it very important to connect chemistry education to the SDGs and ranked it 7 (8.8%) or higher (91.2%) on a 1–10 scale (**Figure 6**).

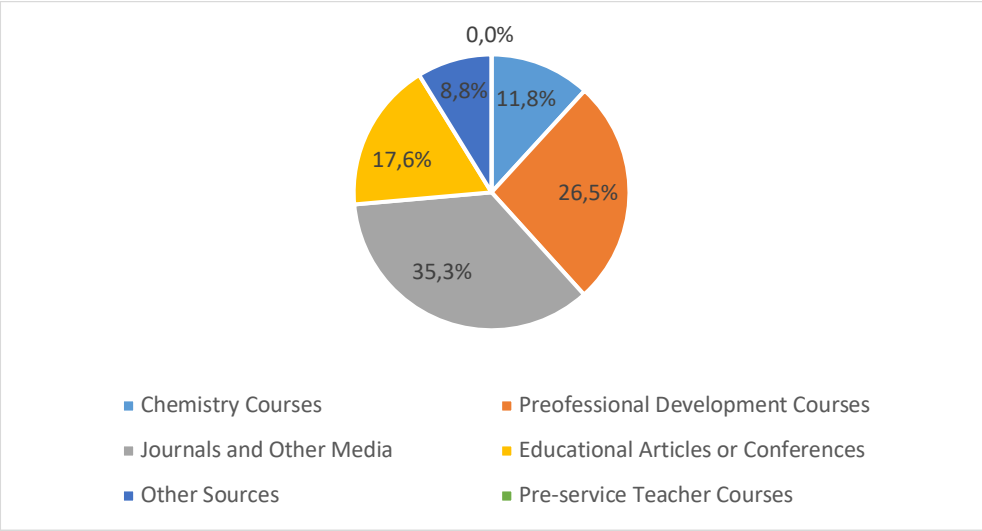

Figure 2. Teachers' sources of information about SD

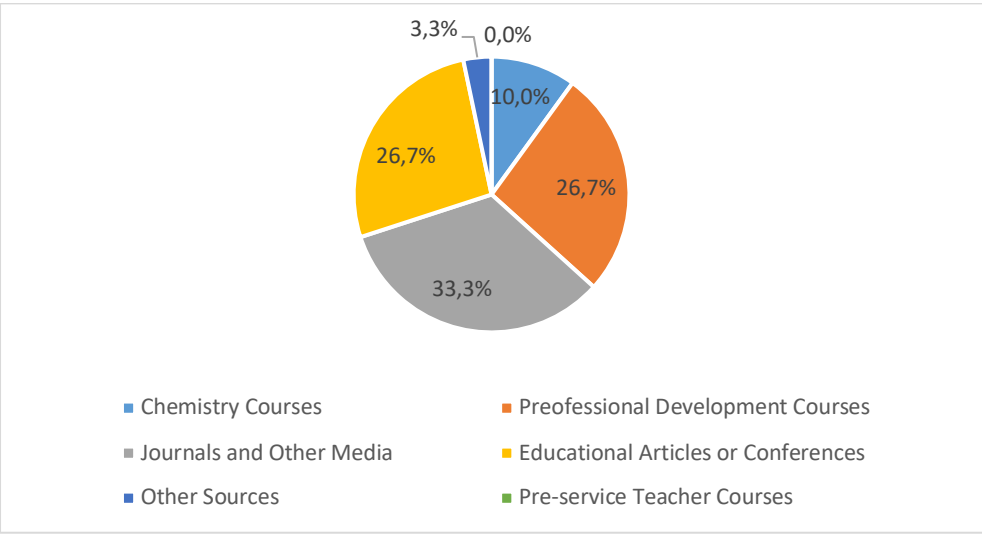

Figure 3. Teachers' sources of information about ESD

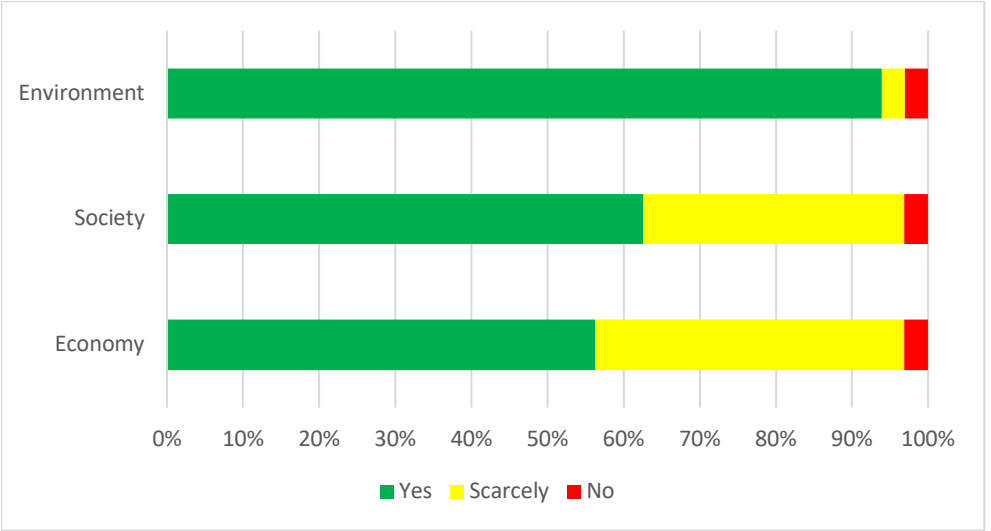

Figure 4. Teachers' attitudes towards the possibility of addressing the different dimensions of SD in chemistry lessons

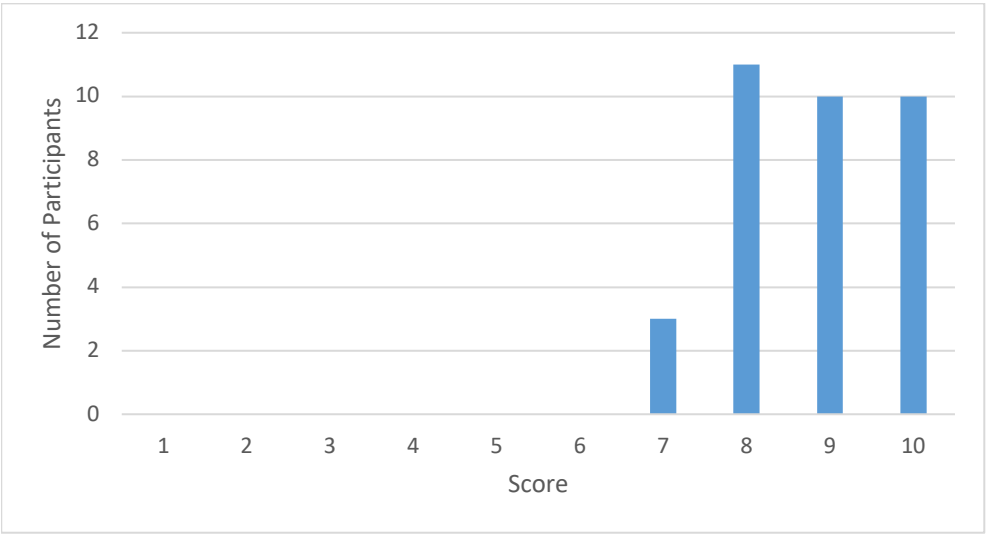

Figure 5. Teachers' ranking of the importance of ESD in chemistry education

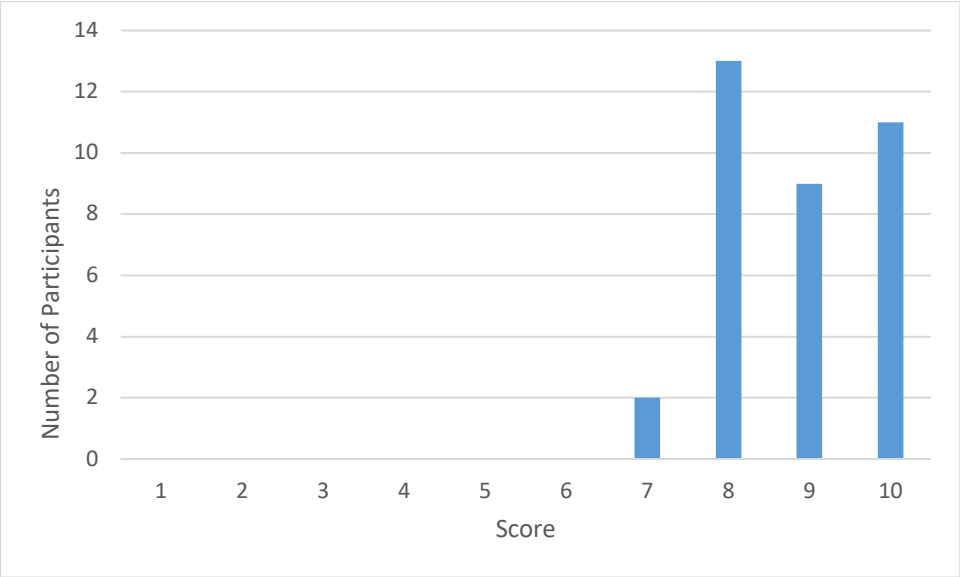

Figure 6. Teachers' ranking of the importance of connecting chemistry education to the SDGs

Table 2. Topics selected as useful to teach operating ESD (number and % of teachers mentioning)

No.	Category	Description	N	%
1	Chemistry contents	Any response related to chemistry contents or chemistry contents from the curriculum, i.e. organic chemistry, the periodic table, green chemistry, energy	9	50.0
2	Chemistry and Environment	Any response related to both chemistry and the environment	3	16.7
3	Environment	Any response related to pollution, environmental exploitation, or recycling only considering the matter conservation	2	11.1
4	Environment and Economy	Any response related to the environment and economy	2	11.1
5	None of the previous	Any answer that was vague not mentioning any topic	2	11.1

When asked to suggest potential topics useful to teach operating ESD in chemistry education 18 out of 35 participants provided answers. Half of the mentioned topics referred to contents from the chemistry curriculum, while the other half referred to other aspects like the economy or the environment (**Table 2**). Some of these answers addressed multiple aspects, i.e. "Acids and bases, thermochemistry, organic chemistry (polymers) because they could give an idea of how substances can interact with the environment", "the limitation of available resources; many raw materials are already running out - the social justice that must be the basis of their use - the alteration of the ecosystem". Nearly half of the teachers, however, did not mention any ideas of how to connect ESD and chemistry education.

Table 3. Topics usually taught in chemistry that the participants consider suitable to be connected to nanoscience

No.	Category	Description	N	%
1	Chemistry contents	Any answer related to chemistry content, i.e. chemical bounds (3), structure/property (3), organic chemistry (2), solutions, metals and non-metals, kinetic, catalysis, …	11	64.7
2	Chemistry and Environment	Any answer related to chemistry, environmental education, and environmental sustainability	4	23.5
3	None of the former	Any answer that stated no idea or is not in the previous categories	2	11.8

The participants reputed appropriate to start addressing ESD at early stages. Most considered primary education the most suitable level to start from (65.7%), followed by lower secondary (25.7%). Few (8.6 %) suggested leaving the start to upper secondary education.

Participants' Knowledge and Attitude Toward Nanoscience

Concerning the educational level at which the participants first got information about nanoscience for their chemistry courses 50% answered that they never heard about it and the other 50% heard of it at the university level. Concerning the teaching of nanoscience more than two-thirds of the participants had never taught nanoscience (70.6%), while some (29.4%) had taught nanoscience either at the high school or university levels.

When asked to select topics or contents that are usually present in chemistry courses and that could be related to nanoscience only 17 out of 35 participants were able or willing to provide ideas (**Table 3**). Examples of the three different categories of answers were: "Solutions, catalysers, intermolecular bonds"; "Molecular structure, organic chemistry, environmental chemistry" and "I don't know". Then the participants were asked: "If you think that nanoscience could be taught in a basic chemistry course which topics that are *not usually* listed in the traditional chemistry syllabus would you address?". Out of 35 participants, 16 provided an answer (**Table 4**), e.g. "Application of nanomaterials to develop the technologies necessary to pursue and obtain products that are economically, ethically and environmentally sustainable, principles of circular economy, civic education, ethics."

The results concerning the 14 answers to the question*: "If you think that a learning module on nanoscience could be useful to address the issue SD and its three dimensions: society, economy, and environment,*

Table 4. Topics not usually taught in chemistry that the participants consider suitable to be connected to nanoscience

No.	Category	Description	N	%
1	Applications	Any answer related to applications, technology, production, and recycling	9	56.2
2	Chemistry contents	Any answer related to chemistry subject contents	3	18.7
3	Ethics	Any answer related only to ethics	1	6.3
4	No idea	Any answer that states no idea	2	12.5
5	Not suitable	Any answer that considered nanoscience not suitable in basic chemistry courses	1	6.3

Table 5. Topic reputed suitable to address SD in lessons on nanoscience

No.	Category	Description	N	%
1	Yes	Any answer positive with no suggestion, i.e. "*Yes but I do not know which topic to teach or how to teach it*"	7	50.0
2	Environment	Any answer related to the environment, waste disposal, recycling	5	35.7
3	New technologies	Any answer related to new technology	1	7.1
4	Circular economy	Any answer related to the circular economy	1	7.1

Table 6. Topic reputed suitable to citizenship education with lessons on nanoscience

No.	Category	Description	N	%
1	Yes	Any answer positive but with no suggestion	7	46.7
2	Sustainable Development	Any answer related to sustainable development	3	20.0
3	Nanotechnology	Any answer related to nanotechnology applications	2	13.3
4	Energy	Any answer related to energy	1	6.7
5	Social and economic wellness	Any answer related to the socio-economic wellness	1	6.7
6	Digital citizenship	Any answer related to digital citizenship	1	6.7

what topic would you address?" half of the answers were positive but with no concrete idea behind. Only seven out of 35 participants provided positive answers with a justification (**Table 5**).

When asked *"Do you think that a module on nanoscience could be useful for teaching citizenship education, considering its three dimensions: the study of the Constitution, sustainable development, and digital citizenship? If so, what themes would you address?"* 15 participants answered and all were generally positive even if some suggested no further ideas (**Table 6**). Others provided more general ideas, like: "Yes. Applications in everyday life and uses in different fields, i.e. health, environment, electronic…" or "Nanoscience could be included in SD as well as in digital citizenship since it is nanoscience that allowed to reach the current level of digital technology".

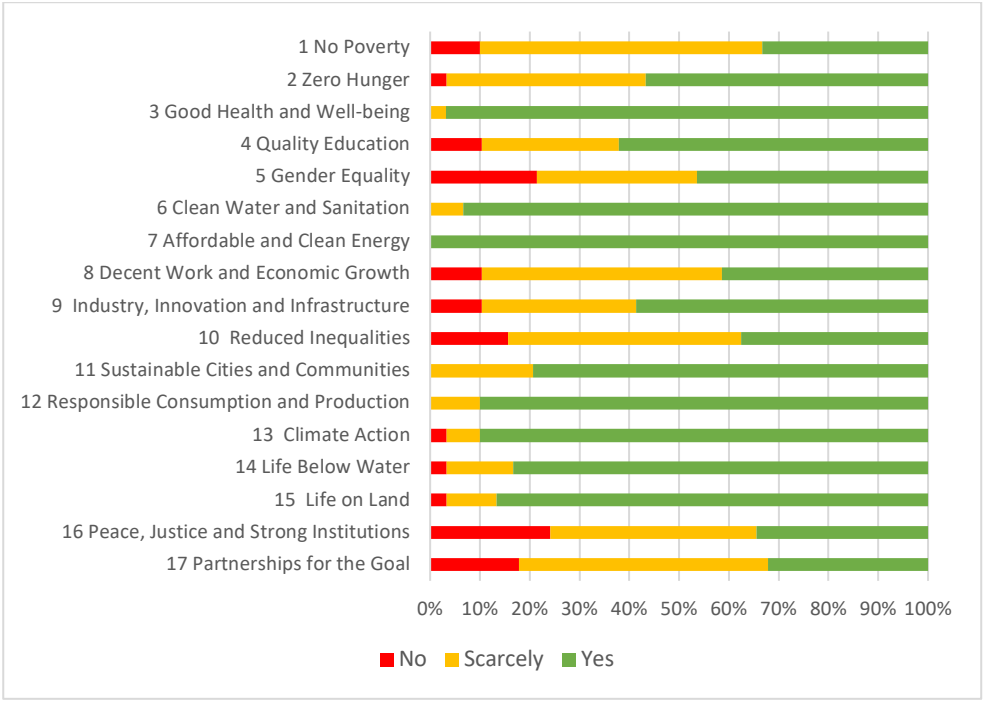

Figure 7. Assessment of the possibility of addressing the SDGs in chemistry courses.

The last question was posed to ask the participants to consider the 17 SDGs and to assess if the single goals could be addressed in chemistry courses. The results are presented in **Figure 7**. Goal no. 7 (Affordable and clean energy) received 100% of positive answers. Many other goals that received high percentages of positive answers, especially those where the relation with science and/or chemistry (and its related products or environmental impacts) is very obvious, like no. 3 (Good health and well-being), no. 6 (Clean water and sanitation), no. 12 (Responsible consumption), no. 13 (Climate action), no. 15 (Life on land), and no.14 (Life below water). No one reputed that goals 3, 6, 7, and 12 could not be addressed in a chemistry course. Although more indirectly related to chemistry, also other goals received more than half of the respondents' positive consideration, like no.11 (Sustainable Cities and Communities), no. 4 (Quality education), and no.9 (Industry, Innovation, and Infrastructure). A bit less was support for no.2 (Zero hunger) although this is a central chemical issue of availability of clean water or fertilizers as well as a responsible use of pesticides. The other goals got less support, but there was no goal not receiving more than 30% full support and less than 25% no support at all.

Discussion and Conclusion

All the respondents considered it important and possible to incorporate SD in chemistry education. However, it seems that both teacher education and continuous professional development did not yet provide the teachers with sufficient knowledge and information about how to integrate SD and ESD into chemistry education. It seems that formal education provides students and teachers with scarce education and training about SD. The majority of them got information about SD and ESD only from articles, journals, and other media.

The introduction of the new subject of EC has not yet been effective in overcoming the difficulties in the implementation of ESD. The aim of the EC implementation is the education of future citizens in a society moulded by science and technology. Many aspects grounded in science have deep implications for society, the economy, and the environment. Teachers in Italy usually have been trained to teach mainly content knowledge, but now they need to be trained to teach also the other related aspects. Chemistry contents and environmental implications were the topics that most of the teachers reputed as useful to teach SD in chemistry courses while society and economy were poorly addressed.

The number of answers to the open questions was approximately half the number of the respondents. This could be a signal of difficulties in tackling the topics. Concerning nanoscience, many participants found connections with basic chemistry contents present in the syllabuses and with several applications of nanoscience in various fields and with the environment. When asked about the SD aspects that could be addressed within a chemistry module on nanoscience, they addressed mainly the environment. Nevertheless, when asked about the possibility of teaching SD with a nanoscience-based module most of them mentioned no idea.

The impact of chemistry on the environment is present in every step of goods production, from the gaining of raw materials to the disposal of exhausted products. Pollution is an idea frequently associated with chemistry, but this is only one side of the medal, the one due to chemistry misuse. The other side, the less valued, is the one of disaster recovery and the production of new materials and new applications that enable SD and positively affect the economy and society. Development, to be sustainable, must consider not only the environment but also the social, economic, and ethical aspects that are as well present in every step of goods production. Italian chemistry teachers need support to teach chemistry addressing all three dimensions of SD.

The participants considered positively the possibility to address the Agenda 2030 SDGs in chemistry courses and all of them agreed about goal no. 7 (Affordable and clean energy). Probably because energy is a content present in chemistry curricula. They were also open to other goals that can be easily connected with chemistry contents present in the chemistry syllabuses like purification and separation methods, as well as safety education.

Continuous professional development on SD and ESD should be provided to teachers to help them overcome a marginalized vision of chemistry education focused mainly on chemistry contents and to facilitate them to address SD (Burmeister et al., 2012). Teacher education needs to encompass an SSI-based learning approach that has been proven to be effective in motivating students and enabling them to learn chemistry taking into account social and political implications, a largely neglected field (Hofstein et al., 2011). The use of SSI in science education is not very popular in Italy, as a scoping review pointed out (Viehmann et al., 2024), even though attempts are present (Ambrogi & Eilks, 2023). The development and implementation of SSI-based chemistry modules, which engage actively students with actual and relevant topics rooted in chemistry, could help students to make sense of chemistry and teachers to put into practice the Italian guidelines (MIUR, 2020) bridging the gap between the normative framework and the practice in the classroom.

The limit of this study could be the small dimension of the sample. On the other hand, even if small, the group was representative of the different Italian geographical areas and the different school-teaching levels. Furthermore, the participants, who voluntarily took part, were particularly sensitive to chemistry education and its innovations. The outcomes of this small-scale survey are aligned with those obtained by Smaniotto et al. (2022) in a survey at the Italian mandatory school level. They investigated the teachers' awareness, knowledge and attitude towards SDGs. Their results showed a moderate knowledge of SDGs gained mainly from Internet sources and media. The teachers' attitude towards ESD is positive but the scarce knowledge of ESD and models for innovative teaching approaches could be a barrier. It must be taken into account that the surveys, independently from their scale, had been conducted on groups of motivated teachers who participated voluntarily and probably on a larger scale, including less interested participants, the outcomes could be worse. This brings us to consider that in Italy the integration of ESD and sustainable issues in educational activities needs to be improved. Furthermore, the interest towards ESD seems to decrease from the lower level of schools to tertiary education. Sonetti et al. (2020), made "the first country-wide systematisation of the Italian higher education institutions toward SDGs implementation" (p. 20). In their survey about the strategies adopted by the Italian universities to put into practice education for sustainability, they found that despite the interest being good the knowledge of SD is not. In their conclusions they claimed: "At the present moment, the acquisition of knowledge and competences regarding sustainable development appears as being left to self-information or post-degree education." (p. 14). The attention towards ESD is increasing in Italy. To disseminate the knowledge of SDGs, ESD, and the SSI-based educative approach including people who do not have a good command of foreign languages the availability of material in native language is important. The framework for the European sustainability competence (Bianchi et al., 2022) and material for the implementation of the SSI approach to promote students' scientific literacy (Sá-Pinto et al., 2022) are available in Italian language. Some playful educational activities were created to teach science and sustainability at

primary school (Deganello et al., 2024). The DDSCI in 2022 dedicated the Giuseppe Del Re School for teacher training, to Chemistry for Sustainable Development and Citizenship Education. The slides of lectures and workshops are at the link: https://www.soc.chim.it/it/soc.chim.it/it/divisioni/didattica/DelRe2022. The increasing presence of material to promote a new educational approach to ESD through SSI for teachers gives hope for a positive trend in ESD and chemistry education, but there are other critical points. Studies have been conducted to investigate how the ESD is put into practice. Fioramonti et al. (2021) investigated some experiments on an interdisciplinary approach to sustainability education in secondary and tertiary education in Italy and pointed out that despite ESD being mandatory at all educative levels no resources are dedicated to its implementation, i.e. funding, time in the school schedule, and personnel and this could be an obstacle. We hope that the increasing attention paid by Italy to ESD and SSI learning approaches in science and chemistry education could enhance the quality of educational approaches and consequent results. To reach the goal efforts should be devoted and supported over time.

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