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A Rubric to Evaluate Critical Science Education for Sustainability

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Abstract: Social and environmental problems are increasing, as is the urgency that they be addressed in educational institutions to form critical, responsible and active citizens. In this training process, the dialogue between science education and education for sustainability is crucial if we want to understand socio-environmental problems in complex and uncertain contexts, which is why we define Critical Science Education for Sustainability (CSES). In addition to reflecting on which contents and methodologies are most appropriate in CSES, it is also necessary to reflect on the development of assessment instruments that allow diagnosing and evaluating the practice, materials and educational activities from such a perspective. Only with an appropriate instrument and suitable diagnosis can we make decisions to transform education and move towards CSES. This article presents an investigation based on the Delphi method with the participation of 37 international researchers, which resulted in a rubric, the Science, Technology and Society Assessment Tool. A rubric is a kind of evaluation tool that can assess education programs using qualitative or quantitative descriptors. This rubric is meant to analyze and guide critical science education in the context of teaching, policies and educational programs that favor sustainability.

Keywords: critical science education; education for sustainability; evaluation; rubric; science education; sustainability; complexity

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1. Introduction

In recent decades, several initiatives have expressed interest in addressing the socio-environmental crisis that challenges the limits of our planet, such as Agenda 21, designed at the Rio 92 Conference, or Agenda 2030, established in 2015, a more current universal and collective commitment organized around 17 Sustainable Development Goals (SDGs) that seek a balanced approach to the economic, social and environmental dimensions of sustainable development. Despite these initiatives, however, tackling the crisis remains a priority on public agendas, and education remains a key element for coping with the upcoming challenges and achieving the necessary changes.

When we are faced with global and cross-cutting problems that the media and/or educational institutions often address from a non-scientific, simplistic or uncritical point of view, likely generating dogmatic opinions, denial or blind credibility in the population, we realize how important it is to develop scientific education, guided by a critical and reflective perspective, able to help in the analysis of narratives that circulate in society and identify the processes of discourse alienation (whether scientific, economic, political or cultural) that make it impossible to establish an effective education for citizenship and life sustainability at the individual, collective and planetary levels.

It is undeniable that we are living in a world of fake news, post-truths and scientific denialism, and that the COVID-19 pandemic has brought many uncertainties and a greater upsurge in contemporary civilization crises.

We find that public opinion, mediated by social networks, increasingly appreciates evocations of beliefs, emotions and personal experiences rather than sets of data from sheer reality. Explanations that support what people want to be true, and that are able to keep one's beliefs and values intact, are worth more than facts or evidence that disprove such values or beliefs.

For Edgar Morin, the crucial realization behind the impacts we suffered during the pandemic is that everything that seemed separable is actually connected, because a sanitary catastrophe truly involves the totality of everything that is human. The knowledge we have gathered in a fragmented, sub-specialized, decontextualized way has not been able to help us interpret, confront, select, organize and discern worthy information to diagnose situations and guide our decision making with greater predictability, focusing on the quality of life on the planet [1].

Denialism is not synonymous with disinformation, but rather the result of disputes among interest groups that seek to camouflage their motivations and ambitions by making up scientific controversies and exposing an alleged lack of consensus in science. Denialists represent different groups and are driven by various interests, but they have political opportunism and inconsistency in common. In denialist trends, such as terraplanism, for example, there is a "cognitive dissociation: evidence and facts clash with subjective values or beliefs, so the denialist chooses an alternative narrative to explain reality" [2].

For Bruno Latour [3], the denial of facts, as is the case with climate change issues currently neglected by authoritarian governments, as well as "fake news and post-truth, does not mean that we are less capable of reasoning". For scientific facts to be accepted, a world of respected institutions is needed, and for that, there must be a common ground shared by science, social institutions and government authorities. Those against vaccines will not be convinced by a new article in The Lancet, and facts do not exist independently of people's beliefs. As facts do not stand up by themselves, instruments and institutions are required to sustain them.

Vilela and Selles [4] discussed scientific denialism based on Bruno Latour's provocation on whether "we may have 'exceeded the dose' in our criticism of science". The authors' intention in accepting Latour's provocation was also"to reaffirm the need for a political engagement that empowers teachers and learners in the educational trajectories carried out in schools and in non-formal spaces of scientific education. Our defense follows the path of a non-alienating educational dynamics, in order to make subjects more aware of the limits of science and more alert about the complexity of social pressures that produce denialism" (p.1741).

The authors support a democratic way of schooling; hence, they highlight the importance of considering the subjects' "narrative" as a learning context that takes into account the appreciation of knowledge deriving from the students' own living experience, and the acknowledgement of the power of understanding their place in the world. They support "politicization and criticism of science, prudence in pedagogical practices, accepting to negotiate knowledge with other ways of attributing meaning to the world" (p. 1741). They point to the importance of pondering "whether our scientific education, as an action supported by academic production in its field, is in fact being done by us for ourselves, and that perhaps we are also failing to convey it to others" (p. 1742).

Gatti [5] considers that the crisis reveals the urgent need to think about the planetary and civilizational question and calls for new values and a fight for life. In this sense, education has everything to do with the preservation of life in all its aspects, whether social, environmental, scientific, cultural, political or others. It is the function of education to provide conditions for new generations to build life values based on knowledge, and, in this way, to give meaning to learning and enable the creation of a new awareness and attitude towards life, relationships and society.

It is therefore imperative now, more than ever before, that we demand a critical scientific education that goes hand in hand with education for sustainability. Several authors believe in the need for dialogue between disciplines [6,7] and the need to connect science teaching and education for sustainability [8–10] to favor their learning and allow the content to be contextualized to complex and uncertain situations [11–13].

By undertaking this challenge, we, a group of science education researchers from Latin America and the Iberian Peninsula, committed to Education for Sustainability and guided by theoretical references from the Science, Technology, Society, Environmental approach (STSE) educational perspective and the Complexity Paradigm, conducted a research project to understand which skills, competencies, practices and knowledge are considered fundamental for the development of a scientific, critical and reflective education, according to the view of specialists in the field. From such findings, we build an evaluation tool to analyze and guide practices and processes for training teachers, develop teaching materials and prepare educational programs within the scope of scientific education and education for sustainability.

This article presents the methodology and the results obtained in a STSE research project carried out between 2018 and 2021. Specifically, it shows an evaluation instrument, elaborated in the form of rubrics and built with the intention of analyzing and guiding critical scientific education in the context of teaching, policy making and preparation of educational programs and which, in turn, favors education for sustainability. The article proposes this evaluation rubric and discusses its relevance through the criteria of objectivity, relevance, reliability and validity.

2. Importance of the STSE Perspective and the Complexity Paradigm for Critical Science Education for Sustainability

When inquiring about which curricular guidelines should be followed to implement a critical scientific education focused on Education for Sustainability, we will certainly come to more than a single answer. As Martins [14] (p. 16) points out, over time, many arguments have been adopted to answer the questions about who and what science teaching in our schools is aimed at. The discussion of "for whom" often leads to a decision affected by the political bias of each country, and is made by the public/political power in charge of defining the school curriculum. Conversely, the purpose, or the "for what" aspect of science teaching, has taken different forms at different moments in time. The prospect of a science education that contributes to scientifically educated individuals capable of intervening in democratic societies is, perhaps, overly challenging for the purposes of the school. Even when the principle is agreed upon, questions will remain about what knowledge the school should help each individual to achieve. Is this knowledge dependent on the moment in time, since citizen intervention is always affected by the context?

However, the goal of science education should always include the ideal of building a more just and sustainable society, to help it face and overcome some of the serious issues of contemporary civilization, and for that, as Bazzo reminds us [15], education needs to be more "badly behaved" to break up with a number of outdated procedures which, for the interests of hegemonic groups, have forsaken the fundamental variables of the civilizing process. Moreover, in the specific case of science education, it is necessary to be aware of the camouflaged domination that inhabits the argument of scientific neutrality, given that the demands of historically excluded and silenced peoples are neglected or made invisible by a hegemonic thinking that controls science and technology (S&T) production [16].

There is a strong assumption that science education should provide citizens with a "critical reading of the world", leading them to reflect on their own circumstances as they face the challenges posed by science and technology. Assuming this understanding, however, makes it essential to develop a posture that extends beyond the acquisition of knowledge or information and moves towards the construction of a culture of participation of subjects in the reality in which they are inserted ([17], p. 281).

To promote this type of education, expanding the amount of information about STSE interactions in school curricula is not a sufficient provision. Educating from this perspective should provide students with the ability to establish relationships and acquire problem-solving skills involving environmental, social and economic aspects. Likewise, we should expect the participation of society in the issues involving S&T production processes [18].

In the field of education, the conceptions involving the STSE perspective are polysemic, as they involve different points of view and are supported by different levels of criticality. This can make it closer or further from the development of a critical scientific education focused on the principles of education for sustainability.

To distinguish and understand the various approaches that make up the plurality of the STSE movement [19], three parameters have been identified that tend to express the connections between the STSE triad and scientific education: (i) scientific rationality, (ii) technological development and (iii) social participation.

The focus of scientific rationality is deemed to be on science, and the acceptance of "different rationalities present in the construction of science" (p. 33) does not imply the guarantee of certainties and progress through its rational essence. The first step towards the development of other points of view in the context of teaching is understanding that science has limitations and should not be considered as neutral, salvationist or deterministic, with the acknowledgement that, although rational, science is not solely characterized by logical or empirical principles, and understanding that science is constructed from the controversies and the dialogue between different points of view, a concept that strengthens the connections between STE and ES.

The second parameter, technological development, can be approached in three ways in the educational context, each leading to more or less critical perspectives. The first approach is more focused on technical issues, such as the functioning of a technological apparatus, often starting from a "linear and mechanistic concept of development, in which industrialization is understood as an engine of social progress" (p. 38) solely and exclusively dedicated to enhancing people's well-being. Environmental impacts from waste, residues and pollution are occasionally acknowledged, but in either case, there is only a clear recognition of the situation, without developing a critical and problematizing posture towards it. In a second approach, the authors point to the notion that technological progress is uncapable of meeting the basic needs of a population, since technology is not unbiased, but rather a cultural structure that encompasses the values of a specific group. Finally, we have a third approach, in which technology is thought of within a context; that is, there is an argument that technological development should suit the human and regional characteristics of a certain population.

As for the last parameter, social participation, the authors stress the importance of society's involvement with STSE issues, since contemporary problems involve risks and uncertainties that will not be resolved only by scientific paths. This parameter includes citizens' capability and empowerment to act and transform society towards a more sustainable future.

Therefore, the three parameters discussed lead to a concept of scientific education for sustainability, in which three educational purposes stand out: "(i) perceptions between scientific knowledge and the students' context; (ii) questions on issues related to citizenship and (iii) social commitments in the face of problems not yet established" (p. 42). It is considered that they lead to changes in science teaching and learning processes capable of reaching a more critical perspective.

When considering these same parameters, Santos [20] agrees that STSE education contributes to the development of a critical scientific education, but the author draws attention to the need for discussions to go beyond the reflections made on STSE interrelationships. According to the same author [21] (p.16), thinking about critical scientific education means approaching it from the perspective of a scientific literacy that expands the role of education by incorporating the discussion of values that may question the existing model of scientific and technological development.

Bonil and Pujol [22] assume the paradigm of complexity when thinking about scientific education in a more critical perspective, as they consider it to be "an ideological philosophical option that offers new possibilities for a conceptual revolution and opens paths for the formation of a citizenship capable of thinking and building a more just and sustainable world, with ethical values, epistemic values and action values" (p. 2).

According to these authors, the paradigm of complexity helps in educational work insofar as it is concerned with making the individual understand the world and acquire criteria to take a stance and participate in its transformation. It acts, therefore, by guiding the subject in thinking about problems and finding solutions within a systemic view of the world, while providing possibilities for more civil action in society.

This brief study of the literature makes it possible to realize that science education conceptions are guided by different theoretical assumptions, each with more or less critical perspectives. However, there seems to be a consensus among authors that the purpose of science education is to provide a more participatory education for citizenship. However, if we seek to promote scientific education from a critical perspective focused on education for sustainability, it is important that we develop new instruments for the evaluation of teaching and learning processes. It is well known that hardly anything will change if the evaluation tools do not change. In this sense, assessment instruments must be conceived from a formative, regulatory and transforming perspective.

3. A Rubric as a Tool to Evaluate Critical Science Education for Sustainability (CSES)

Critical Science Education for Sustainability (CSES) should be an opportunity to reformulate traditional views of education for sustainability associated with a change in attitudes and actions. In this sense, CSES must steer approaches to education for sustainability that lead to reflections on the contents themselves and how they are organized, as well the most appropriate methodologies to train citizens who understand the complexity of the environment [23–26]. For that, evaluating the training programs is essential, because, as Sanmartí affirms, if evaluation does not change, nothing will change, and to promote changes, it is necessary to start by changing the paradigm about what we mean by evaluating in education [27].

The need to offer tools for evaluating the design of educational projects, programs and activities from the perspective of CSES becomes an important contribution if we, as an educational community, wish to evolve in our reflection on the teaching practice. Assessment instruments must be conceived from a formative and transformative point of view and, in this sense, rubrics are outstanding instruments because, although initially conceived exclusively for assessing teachers, they increasingly acquired an instructive character linked to the students' expectations [28]. Moreover, they allow describing different qualitative levels of performance that can favor self-assessment and metacognitive reflection [29].

The use of rubrics as tools for analyzing the design and content of programs is still little explored, but it is nevertheless endorsed by the effectiveness demonstrated in other areas, particularly in view of the following elements already highlighted in the literature:

- Rubrics are assessment systems based on referenced criteria or standards, which serve as guidelines or references when complex concepts, such as educational quality, are to be established.
- They accept both quantitative and qualitative approaches, which enables more accurate diagnoses.
- They determine different achievement levels of the established criteria or standards, which also helps in making more accurate diagnoses.
- These are resources that can, and should, adapt to the material educational contexts in which they will be applied.
- Their creation is, or should be, the result of a consensual collaborative work by a professional collective committed to educational quality [30] (p. 123).

The main purpose of using rubrics to evaluate programs is the possibility of sharing clear evaluation criteria, with different levels of achievement, specified through qualitative or quantitative descriptors.

When carried out collectively, the elaboration of rubric design contributes to the clarification of the key aspects to be prioritized according to the objectives of each program, thus reducing ambiguities and/or different understandings and giving rise to a consensus that will favor the implementation of new educational paradigms.

The use of rubrics, in turn, enables a better understanding of the learning objectives and the detection of the presence or absence of such objectives in educational programs, thus contributing to the recognition of aspects to be revised and providing bases for constant improvement.

For these reasons, "rubrics are acknowledged as useful resources for designing educational programs, since their conceptualization, and subsequent application, is able to detect the degree of alignment of the programs, which favors the identification of possible gaps" [31] (p. 4).

There seems to be a consensus that rubrics are important instruments for evaluating a given field in education, and they are considered both a resource for comprehensive and formative assessment [27] and an instrument for reflection, guidance and evaluation of educational practice itself that allows the subject to become aware of their own learning and, therefore, to modify their conception and redirect their behavior into a more sustainable path. Therefore, developing assessment tools is a challenge and an opportunity to move towards the Education for Sustainability approach [32].

4. Materials and Methods

4.1. Design, Context and Participants

As previously mentioned, this article presents part of the results of a broader investigation whose objective was to identify, with a panel of specialists, how the scientific and education community understands the existing assumptions, issues and challenges to basic education and teacher training, in order to promote Critical Science Education for Sustainability (CSES).

To develop this qualitative research, we adopted the Delphi method [33], as it constitutes a valuable technique for identifying demands, needs and trends in a given field of knowledge and contributing to studies on educational assessment, planning and policy development. The fact that the method brings together a set of opinions from geographically separated experts without face-to-face interaction [34] helps to eliminate influences from dominant persons in the group, and makes it effective for promoting reflection and elaborating guidelines that lead to dense results about complex and wide-ranging topics. Although it cannot predict the future, the Delphi technique can help us understand the probability and impact of future events, since a group of experts can identify problems and risks from related assumptions and hypotheses.

The method consists of a set of questionnaires that are answered by the specialists in an individual and sequential manner. After gathering their opinions in the first questionnaire, the results are collected and returned to the participants. New rounds of questionnaires and feedbacks are carried out in order to establish a kind of dialogue between the participants and gradually build a collective response to reach consensus on a given issue.

The panel of specialists in this research was made up of 37 researchers in science education and education for sustainability from Latin America (Argentina, Brazil, Chile and Colombia) and Europe (Portugal and Spain). Although these experts are anonymous and do not know each other, they share a context and a way of understanding science, sustainability and science education. Specifically, their cultural, contextual and academic background share the vision that science is constructed as a representation of a social moment in which a multitude of economic, political and cultural aspects converge. At the same time, the experts also share the dynamic vision of scientific knowledge and its way of evolving thanks to the convergence of different disciplines and the active role of the subject—be they a scientist or a citizen.

4.2. Data Collection and Analysis

Three rounds of questionnaires were applied in order to identify aspects that the specialists considered fundamental for the development of a critical, reflective and complex education.

The first questionnaire was elaborated from a comprehensive study of the recent literature on the subject. It sought to identify the attributes, assumptions and characteristics of the conceptions of scientific education from a critical perspective [35].

After each round of questionnaires, the researchers performed the analysis of the specialists' responses. Any dissonant tendencies or opinions, as well as their justifications, were examined, systematized and compiled to be subsequently sent back to the group. After learning the opinions of the other members and the group's overall response, each participant had the opportunity to refine, change or defend their answers and send them back to the researchers, who could redesign the new questionnaire based on the new information. This process was repeated until a consensus was reached [36].

Content analysis of the specialists' answers made it possible to identify the senses and meanings and establish connections between the formal (syntactic) and the significant (semantic and pragmatic) level of the content. The content analysis resulted in metatexts that convey the meanings expressed by the specialists through articulations of meanings produced and organized during the interpretive process.

As a last step, we performed the percentage analysis of agreements and disagreements in the statements validated by the experts.

This set of analyses made it possible to identify and systematize the characteristics that science teaching activities must have from a critical perspective while aiming at sustainability (Table 1).

Table 1. Characteristics and descriptors of CSES teaching.

Characteristics	Descriptors
1. Development of emerging themes in society.	Consideration of a critical didactic perspective. Development of transformative actions based on socio-scientific issues and everyday problems. Encouragement of decision making and acting.
2 Encouragement of critical and creative thinking.	Development of argumentation, investigation skills and use of different languages. The use of evidence to justify ways of acting and making decisions. Critical reading of information and discourses that reveal inequalities or social asymmetries in opposition to contrary discourses.
3. Proposition or development of an interdisciplinary approach.	Contents, themes and projects incorporate creative, unusual relationships between scientific disciplines and other fields of knowledge. Interaction between different dimensions (cultural, historical, political, economic, ethical and aesthetic).
4. The construction of positions is favored.	Spaces and opportunities for the construction of creative individual or collective positionings are opened. Positions are based on dialogue and confrontation of arguments, facts, opinions, attitudes and practices of social, scientific and technological relevance from different groups of people and/or institutions.
5. Specific methodological approaches are proposed.	Wide and tolerant view of knowledge that includes student opinions. Scientific research methodology. Metacognitive skills. Formation of collective processes and teamwork. Urban space is used as an educational context. Formulation of stimulating questions and creative practices.

Table 1. *Cont.*

Characteristics	Descriptors
6. The curriculum is organized from the perspective of education for citizenship.	The study plan is structured more by thematic axes related to the real problems of society than by concepts. A flexible, open organization allows for the inclusion of demands and needs of the school community. The curriculum favors the development of multiple competences to form critical, participating citizens, questioners of society's consumerist logic, empowered to solve problems and to participate in decision-making processes.
7. Construction of scientific and technological knowledge.	Consideration of the roles of history, philosophy and sociology of science in the construction of knowledge. Enumeration of the different procedures and purposes of S&T. Presumption of S&T interdependence and autonomy.
8. Connections between science and technology and their representations that circulate in society.	Incorporation of evidence of the correlation between processes and results in scientific production.
9. Understanding S&T as contextualized practices.	Recognition of different dimensions (political, economic, social, cultural and environmental) in the complex understanding of world phenomena.
10. Characterization of S&T as a social construction.	S&T construction regarded as a producer of senses and meanings in specific historical and/or ideological contexts. S&T production is positioned around power relations issues (economic, ethnic/racial, gender) in the construction of knowledge.
11. Non-neutrality of science and technology and/or science education.	Presentation of critical discourses on S&T interests and recipients. Incorporation of inequality as a problem in appreciating the knowledge produced. Emphasis on the non-neutrality and indeterminacy of S&T and/or scientific education.
12. Conscious and critical participation in the development of society.	Learning includes a conscious and critical participation in the construction of knowledge, values or experiences that take into account the concepts of sustainability, equality and social justice.
13. Citizen participation in issues involving knowledge of technoscience.	Learning incorporates the use and evaluation of the science and technology perspective for citizen participation in issues related to S&T knowledge. Participation in research agendas is promoted.
14. Analysis of science and technology impacts.	The teaching–learning process includes analyzing the impacts of S&T on current and/or future decision making. This analysis includes the concepts of risk, precautionary principle and controversy.
15. Construction of identity, sense of belonging to the community and development of values.	Consideration for the construction of identity and sense of belonging, and the development of values such as responsibility, solidarity and collaboration.
16. Reflection on democratic and emancipatory perspectives for individual choices.	Incorporation of different points of view concerning social and environmental problems, with space for individual expression.

Aiming at the construction of an instrument to evaluate CSES, the data in Table 1 were converted into a rubric to reflect, guide and evaluate educational practice [36–38]. Simultaneously, a quality scale was proposed in order for the rubric to allow the valuation of programs, activities or projects from the CSES perspective. The five-level scale was adapted from the proposal by Zarzueta and Herrera [38], in which each level contains different characteristics for qualifying the CSES criteria.

- Level 0—Not present: At this level, the CSES criteria are either absent or do not contain the fundamental elements to favor CSES. Some information and/or practices may exist, but the criteria are not presented or are presented in a confusing or misinterpreted way.

- Level 1—Beginner: This level does not favor CSES, as it shows a lack of understanding or omission of the main elements that favor CSES. Little information is offered, and practices may present errors or misuse of CSES concepts and terms.
- Level 2—Apprentice: An acceptable level of CSES introduction. Although there is inaccurate, partial or incomplete incorporation of the criteria, this does not pose a threat to understanding and training. Offers acceptable practices, but can be improved to advance towards CSES.
- Level 3—Advanced: A desirable level of incorporation of CSES-promoting criteria. Answers are rather comprehensive and the information and practices are strongly related to the specified criteria.
- Level 4—Expert: An exceptional presence of the different key aspects of CSES criteria. Offers excellent information and practices concerning the specified criteria, making it possible to promote the effective development of critical, reflective thinking and a systemic and articulated view of problems, aiming at the construction of alternative scenarios and practices in accordance with CSES precepts.

5. Results and Discussion

The main contribution of this research is the construction of the Science, Technology and Society Assessment Tool, called the FACTS rubric [39] for the Portuguese acronym (Ferramenta avaliativa ciencia, tecnologia and sociedade) (Table 2), that allows evaluating policies, programs and activities of Critical Science Education for Sustainability (CSES).

Table 2. Science, Technology and Society Assessment Tool for CSES.

AXES		CRITERIA	LEVEL 4 (EXPERT)	LEVEL 3 (ADVANCED)	LEVEL 2 (APPRENTICE)	LEVEL 1 (BEGINNER)	LEVEL 0 (NOT PRESENT)
AXIS A—Teaching and Learning Processes	1	**Development of emerging themes in society**	Adopts a critical didactic perspective aimed at the **development of transformative actions**, through the approach of socio-scientific issues **and problems from the surrounding reality**, encouraging decisions and actions by students.	Adopts a critical didactic perspective through the approach of socio-scientific issues, encouraging decisions and actions by students.	Adopts a critical didactic perspective through the approach of socio-scientific issues.	Uncritically presented, without problematizing socio-scientific issues or worrying about the students' decision making or actions.	Absence of emerging themes in society.
	2	**Encouragement of critical and creative thinking**	Based on: **(i)** the development of argumentation, investigation and use of different language skills; **(ii)** the use of evidence to justify ways of acting and making decisions; **(iii)** critical reading of information and discourses that denote social inequality or asymmetries, with the construction of discourses contrary to such positions.	Based on **two** of the three items below: **(i)** the development of argumentation, investigation and use of different language skills; **(ii)** the use of evidence to justify ways of acting and making decisions; **(iii)** critical reading of information and discourses that denote social inequality or asymmetries, with the construction of discourses contrary to such positions.	Based on **one** of the three items below: **(i)** the development of argumentation, investigation and use of different language skills; (ii) the use of evidence to justify ways of acting and making decisions; **(iii)** critical reading of information and discourses that denote social inequality or asymmetries, with the construction of discourses contrary to such positions.	Encouragement of critical and creative thinking without taking into account any specific items indicated in the previous levels.	Critical and creative thinking are not encouraged.
	3	**Proposition or development of an interdisciplinary approach**	Contents, themes and projects incorporate creative, unusual relationships between scientific disciplines **and other fields of knowledge, including at least four dimensions** (cultural, historical, political, economic, ethical or aesthetic).	Contents, themes and projects incorporate creative, unusual relationships between scientific disciplines **and other fields of knowledge, including at least one dimension** (cultural, historical, political, economic, ethical or aesthetic).	Contents, themes and projects incorporate creative, unusual relationships between scientific disciplines, **including at least one dimension** (cultural, historical, political, economic, ethical or aesthetic).	Contents, themes and projects incorporate relationships between scientific disciplines.	Does not develop contents, themes or projects with an interdisciplinary approach.

Table 2. *Cont.*

AXES		CRITERIA	LEVEL 4 (EXPERT)	LEVEL 3 (ADVANCED)	LEVEL 2 (APPRENTICE)	LEVEL 1 (BEGINNER)	LEVEL 0 (NOT PRESENT)
	4	**The construction of positions is favored**	Favors the creation of spaces and opportunities for individual, collective and creative affirmation, and the construction of positions **based on dialogue and confrontation of scientific and technological arguments, facts, opinions, attitudes and socially relevant practices coming from different groups of people and/or institutions**.	Favors the creation of spaces and opportunities for individual, collective and creative affirmation, and the construction of positions **based on dialogue and confrontation of scientific and technological arguments, facts, opinions, attitudes and socially relevant practices**.	Favors the creation of spaces and opportunities for individual, collective and creative affirmation, and the construction of positions **based on dialogue and confrontation of scientific and technological arguments**.	Favors the creation of spaces and opportunities for individual, collective and creative affirmation, and the construction of positions.	Does not favor the construction of positions.
	5	**Specific methodological approaches are proposed**	Emphasizes the experimental component of the natural sciences, adopting at least **four** of the following teaching and learning methodologies: **(i)** a tolerant view of knowledge to include the view of students; **(ii)** the investigative modes of science; **(iii)** metacognitive skills; **(iv)** the formation of collective processes and group work; **(v)** the use of urban space as an educational context; **(vi)** the encouragement for questions and creative practices.	Emphasizes the experimental component of the natural sciences, adopting at least **three** of the following teaching and learning methodologies: **(i)** a tolerant view of knowledge to include the view of students; **(ii)** the investigative modes of science; **(iii)** metacognitive skills; **(iv)** the formation of collective processes and group work; **(v)** the use of urban space as an educational context; **(vi)** the encouragement for questions and creative practices.	Emphasizes the experimental component of the natural sciences, adopting at least **two** of the following teaching and learning methodologies: **(i)** a tolerant view of knowledge to include the view of students; **(ii)** the investigative modes of science; **(iii)** metacognitive skills; **(iv)** the formation of collective processes and group work; **(v)** the use of urban space as an educational context; **(vi)** the encouragement for questions and creative practices.	Emphasizes the experimental component of the natural sciences, adopting at least **one** of the following teaching and learning methodologies: **(i)** a tolerant view of knowledge to include the view of students; **(ii)** the investigative modes of science; **(iii)** metacognitive skills; **(iv)** the formation of collective processes and group work; **(v)** the use of urban space as an educational context; **(vi)** the encouragement for questions and creative practices.	Does not prioritize the adoption of specific methodological approaches for teaching and learning science.

Table 2. *Cont.*

AXES		CRITERIA	LEVEL 4 (EXPERT)	LEVEL 3 (ADVANCED)	LEVEL 2 (APPRENTICE)	LEVEL 1 (BEGINNER)	LEVEL 0 (NOT PRESENT)
	6	**The curriculum is organized from the perspective of education for citizenship**	The curriculum is: **(i)** structured less by concepts and more by thematic axes related to real problems of society; **(ii)** flexible and open to allow the inclusion of demands and needs from the school community; **(iii)** committed to building multiple competencies to form critical, participatory citizens who question society's consumerist logic and are empowered to solve problems and participate in decision-making processes.	The curriculum includes **two** of the following aspects: **(i)** structured less by concepts and more by thematic axes related to real problems of society; **(ii)** flexible and open to allow the inclusion of demands and needs from the school community; **(iii)** committed to building multiple competencies to form critical, participatory citizens who question society's consumerist logic and are empowered to solve problems and participate in decision-making processes.	The curriculum includes **one** of the following aspects: **(i)** structured less by concepts and more by thematic axes related to real problems of society; **(ii)** flexible and open to allow the inclusion of demands and needs from the school community; **(iii)** committed to building multiple competencies to form critical, participatory citizens who question society's consumerist logic and are empowered to solve problems and participate in decision-making processes.	The curriculum is structured **both** by concepts and by thematic axes related to real problems of society.	The curriculum is not structured by thematic axes related to real problems of society, nor does it seek to break with the hegemonic and fragmented perspective of knowledge.
AXIS B—Views e Perception of S&T in Society	7	**Construction of scientific and technological knowledge**	The construction of scientific and technological knowledge by students: **(i)** takes into account the roles of the history, philosophy and sociology of science; **(ii)** builds relations among the different procedures and purposes of S&T; **(iii)** presupposes the dependence and independence of the different procedures and purposes of S&T, from a technoscience perspective.	The construction of scientific and technological knowledge by students emphasizes **two** of the following aspects: **(i)** takes into account the roles of the history, philosophy and sociology of science; **(ii)** builds relations among the different procedures and purposes of S&T; **(iii)** presupposes the dependence and independence of the different procedures and purposes of S&T, from a technoscience perspective.	The construction of scientific and technological knowledge by students emphasizes **one** of the following aspects: **(i)** takes into account the roles of the history, philosophy and sociology of science; **(ii)** builds relations among the different procedures and purposes of S&T; **(iii)** presupposes the dependence and independence of the different procedures and purposes of S&T, from a technoscience perspective.	The construction of scientific and technological knowledge by students is presented solely through the identification of procedures.	The construction of scientific and technological knowledge by students does not take into account any of the aspects mentioned.
	8	**Connections between science and technology and their representations that circulate in society**	Establishes connections between science and technology and their representations that circulate in society, **highlighting** the correlations between the processes and results of scientific production.	Establishes connections between science and technology and their representations that circulate in society, **considering** the processes and results of scientific production.	Establishes connections between science and technology and their representations that circulate in society, **considering only** the results of scientific production.	Presents examples of science and technology representations that circulate in society, **without establishing connections** with the processes and results of scientific production.	Does not comprise connections between science and technology and their representations that circulate in society.

Table 2. *Cont.*

AXES		CRITERIA	LEVEL 4 (EXPERT)	LEVEL 3 (ADVANCED)	LEVEL 2 (APPRENTICE)	LEVEL 1 (BEGINNER)	LEVEL 0 (NOT PRESENT)
	9	**Understanding S&T as contextualized practices**	Acknowledges S&T as contextualized practices in **at least four** of the following dimensions: political, economic, social, cultural and environmental, enabling a more complex perception of the phenomena.	Acknowledges S&T as contextualized practices in **three** of the following dimensions: political, economic, social, cultural and environmental.	Acknowledges S&T as contextualized practices in **two** of the following dimensions: political, economic, social, cultural and environmental.	Acknowledges S&T as contextualized practices in **one** of the following dimensions: political, economic, social, cultural and environmental.	Does not acknowledge S&T as contextualized practices.
	10	**Characterization of S&T as a social construction**	Regards S&T as a social construction, a **producer** of senses and meanings in specific historical and/or ideological contexts, in which questions of power relations (economic, ethnic-racial, gender) affect the production of knowledge.	Regards S&T as a social construction, a **producer** of senses and meanings in specific historical and/or ideological contexts.	Regards S&T as a social construction **situated** in specific historical and/or ideological contexts.	Defines S&T as a social construction, **without highlighting** any specific historical and/or ideological context.	Does not regard S&T as a social construction.
	11	**Acknowledging the non-neutrality of S&T and/or science education**	Presents critical discourses about the interests and targets of S&T, questioning inequality in the appreciation of knowledge, and **emphasizing** the non-neutrality and indeterminacy of S&T and/or scientific education.	Presents pertinent, though **inaccurate**, critical discourses on the non-neutrality of S&T and/or scientific education.	Presents **uncritical** discourses on the non-neutrality of S&T and/or scientific education.	Presents **only statements** related to the non-neutrality of S&T and/or scientific education.	Does not emphasize the non-neutrality view of S&T and/or science education.
AXIS C—Citizenship/Action	**12**	**Conscious and critical participation in the development of society**	Provides learning that enables a conscious and critical participation in the development of society from the construction of knowledge, values or experiences that take into account the concepts of sustainability, equity and social justice.	Provides learning that enables a conscious and critical participation in the development of society from the construction of knowledge, values or experiences that take into account **two** of the following concepts: sustainability, equity and social justice.	Provides learning that enables a conscious and critical participation in the development of society from the construction of knowledge, values or experiences that take into account **one** of the following concepts: sustainability, equity and social justice.	Supports a conscious and critical participation in the development of society from the construction of knowledge, values or experiences, although not based on any of the concepts of sustainability, equity or social justice.	Does not encourage conscious and critical participation in the development of Society.
	13	**Citizen participation in issues involving knowledge of technoscience**	Provides learning that makes it possible to employ and evaluate the perspective of **both** science and technology for citizen participation in issues involving scientific-technological knowledge, and encourages participation in research agendas.	Provides learning that makes it possible to employ and evaluate the perspective of **either** science **or** technology for citizen participation in issues involving scientific-technological knowledge.	Provides learning that makes it possible to employ **or** evaluate the perspective of science **and** technology for citizen participation in issues involving scientific-technological knowledge.	Provides learning that makes it possible to employ **or** evaluate the perspective of science **or** technology for citizen participation in issues involving scientific-technological knowledge	Does not encourage citizen participation in issues involving knowledge of technoscience.

Table 2. *Cont.*

AXES		CRITERIA	LEVEL 4 (EXPERT)	LEVEL 3 (ADVANCED)	LEVEL 2 (APPRENTICE)	LEVEL 1 (BEGINNER)	LEVEL 0 (NOT PRESENT)
	14	**Analysis of science and technology impacts**	Includes, in the teaching–learning process, the following concepts for the analysis of science and technology impacts on current decisions and/or projections of future actions: risk, precautionary principle and controversy.	Includes, in the teaching–learning process, **two** of the following concepts for the analysis of science and technology impacts on current decisions and/or projections of future actions: risk, precautionary principle and controversy.	Includes, in the teaching–learning process, **one** of the following concepts for the analysis of science and technology impacts on current decisions and/or projections of future actions: risk, precautionary principle and controversy.	Does not include the concepts of risk, precautionary principle or controversy in the teaching–learning process for the analysis of science and technology impacts on current decisions and/or projections of future actions.	Does not include the analysis of S&T impacts.
	15	**Construction of identity/sense of belonging (inclusion) and values**	Guides reflection, encouraging the construction of identity and sense of belonging, and developing values such as responsibility, solidarity and collaboration.	Guides reflection, encouraging the construction of identity and sense of belonging, and developing **two** of the following values: responsibility, solidarity and collaboration.	Guides reflection, encouraging the construction of identity and sense of belonging, and developing **one** of the following values: responsibility, solidarity and collaboration.	Guides reflection, encouraging the construction of identity and sense of belonging.	Does not present reflections that encourage the construction of identity, sense of belonging (inclusion) or values.
	16	**Reflection on democratic and emancipatory perspectives for individual choices.**	Presents different points of view concerning social and environmental issues, with space for individuals to express their humanity.	Presents different points of view concerning social **or** environmental issues, with space for individuals to express their humanity.	Presents a single point of view concerning social **and** environmental issues.	Presents a single point of view concerning social **or** environmental issues.	Does not present reflections on democratic and emancipatory perspectives for individual choices.

To facilitate its applicability in different contexts, the FACTS rubric is organized into three axes—*Axis A, Teaching/Learning Processes; Axis B, S&T Vision/Production; Axis C, Citizenship/Action*—in which the 16 characteristics and their descriptors are distributed (see Table 1).

The FACTS rubric also features a qualitative rating scale—Expert, Advanced, Apprentice, Beginner and Not Present—which allows for the assessment of different levels of success. These different dimensions and criteria are meant to anticipate, evaluate and improve the design of programs and policies from this theoretical perspective.

This instrument allows different profiles of education professionals (teachers, university professors, educators, technicians, etc.) to apply the rubric according to their interests and practices, provided they wish to evaluate the teaching and learning processes from the CSES perspective (*Axis A*), their underlying vision of science (*Axis B*) and to what extent are actions promoted to transform society (*Axis C*).

At the same time, the three axes as a whole complement each other and make it possible to identify and evaluate not only specific CSES issues, but also provide an integrated view when the issues are considered jointly.

On the one hand, *Axis A* can evaluate the extent to which projects, materials, activities and/or learning connect the contents and their methods with relevant, emerging and current problems, situations or socio-environmental crises that imply interdisciplinary, critical and creative work (Calafell, Banqué) [40]. Likewise, methodologies are activated that place students at the center of learning from the thinking, doing and feeling of science. An example of the articulation that occurs naturally between the intra-axis criteria is the interdisciplinarity framework in education (*Criterion 3: Proposition or development of an interdisciplinary approach*). Even considering the existing models (mono-, multi- or pluridisciplinary, interdisciplinary and transdisciplinary) to solve social and environmental problems, Bonil et al. [41] propose to situate science education within a model of disciplinary dialogue in which the articulation of knowledge from different fields and disciplinary contents will bring students closer, so that they can interpret the physical and social world and act within it. For the authors, disciplinary dialogue favors the understanding of complex phenomena and, by placing dialogic spaces between different knowledge fields, enhances the construction of argumentation by students (*Criterion 2—Incentive to critical and creative thinking*). Furthermore, according to these authors, this skill is necessary to form citizens capable of feeling, thinking and acting in face of the characteristics of the environmental and social phenomena of our time (*Criterion 4—Favoring the construction of positions* and *Criterion 6—Organization of the curriculum aiming at an education for citizenship*). In addition, the development of the argumentation ability provides better conditions to debate and face the contemporary issues that the SDGs raise [42], as it favors the perception of interdependence between the local and global spheres and the necessary understanding of the social, economic and environmental patterns that affect them. On the other hand, *Axis B* complements *Axis A* insofar as to evaluate CSES, it is necessary to associate science teaching and learning to an epistemological view of science. It is therefore important to assess how science is built and which views are dominant, an essential idea to understand how the sustainability of the planet can be taken into account. In other words, assessing the extent to which the approach to science is a historical, cultural and social construction implies that science is not neutral and that it is a political action affected by different social roles and powers (Morin, Mota) [43]. The view provided by *Axis C*, however, is of special relevance to higher education, as it can assess the extent to which programs invite students to build their identity and participate in society, and the emancipatory capacity of such programs. It is an axis that highlights the importance of training good CSES professionals as well as citizens capable of transforming the world (Matauranna) [44].

It is evident, therefore, that the criteria described in the FACTS Rubric are interconnected by references of STSE relations and the complexity paradigm from a critical point of view. Another example of interconnection can be observed between criteria *7—Construction of Scientific and Technological Knowledge* of *Axis B* and criteria *1—Development of emerging* *themes in society* and 2—*Incentive to Critical and Creative Thinking* of *Axis A*, with criterion 13—*Citizen participation in issues involving S&T Knowledge*.

For Galvão, Reis and Freire [45], understanding the importance of the nature of science is essential to the context of CSES training, because it is by constructing ways of thinking about it that students will be able to distinguish nuances of the scientific culture itself. Likewise, the use of controversial socio-scientific issues in the classroom helps to build a more tangible image of science and enhances the possibilities of connecting science, technology and society. The authors emphasize that this way of working has important potential in the development of critical thinking, interpretation, argumentation, decision-making and communication skills, and also in the acquisition of knowledge itself.

Auler and Delizoicov [16] strongly support the importance of subjects' participation in the construction of their own knowledge, suggesting the existence of a connection between "educational practice" and "research practice" in the search for an "emancipating and critical-transforming formative process" of the subject (p.293).

Barbosa and Bazzo [46] point out that a viable way to develop participatory attitudes and engagement in contemporary themes is to include debates on science and technology issues in school teaching. Similarly to Bonil et al. [42], the authors emphasize the need to develop a contextualized and interdisciplinary way of teaching, supported by a more progressive and participatory learning strand, in order to increasingly focus on the importance of the critical formation of the human being.

Finally, by analyzing the criteria in a transversal and integrated way, we gather that CSES is conceived as a civil, participatory and emancipatory education with the objective of transforming society. In this sense, the appropriation of knowledge and the construction of a critical reading of reality becomes a fighting strategy for transforming society. CSES is an education that takes science and scientific knowledge as a social and cultural practice and interacts with other cultures, forms of knowledge and values—a scientific education that conveys the value of resistance to overcome obstacles and difficulties, and whose expected criticality is based on a STS teaching that allows students to take a more critical stance towards social issues related to science, technology and society, thus calling for public participation in decisions related to science and the uses and benefits of science products. In this sense, the truth conditions of each scientific fact or theory must show the very limits of science's authority. The relevance is placed on bringing to debate the technical and instrumental rationality of science and the acknowledgement of the different interests associated to human knowledge, with a critical view of the cultural industry and the claim for a broad cultural formation. It must be an education based on scientific knowledge and on practices that affect and interfere directly in everyday life, but, above all, interrelate with social actions that allow the development of a sense of solidarity, cooperation and collaboration towards social equality and respect for the "environmental rights". Therefore, CSES must provide information, develop critical thinking and develop skills and values such as argumentation, investigation, language understanding and use, autonomy, responsibility, solidarity, organization, collaboration, etc. More specifically, the researchers who answered the survey that generated this rubric state some characteristics as fundamental for CSES that has socio-environmental sustainability as a goal. It must be multidimensional, demanding, holistic and relational, committed to the precautionary principle, socially responsible and based on sociocultural change towards sustainability, both to reverse the processes of ecological deterioration of the planet and to achieve equality and justice in the social and global spheres.

6. Conclusions

Based on the results, we can say that the research contributes to the advancement in the field of Critical Science Education and Sustainability Education by proposing an assessment instrument, the FACTS rubric, which has different strengths that make it an objective, relevant, reliable and valid instrument. The rubric is objective because it incorporates three different axes and sixteen criteria organized in a qualitative gradient of five values. It is relevant because it allows assigning value to different types of actions such as educational programs, activities, materials, etc., and can be applied by different agents (teachers, technicians, university professors, etc.). It is reliable because it was developed with the participation of 37 experts undergoing three rounds of intervention in the Delphi methodological modality. Finally, it is a valid instrument because it has been implemented in different seminars to evaluate science teaching materials with students and university courses for future teachers [47].

Another strength of the FACTS rubric is its ability to transform the contexts of science education into a more critical and sustainable position. This is due to the fact that it has been conceived as a formative and normative instrument that can be used before, during or after a learning process and, consequently, its use should encourage educators and students to transform their way of learning and acting in science (Bonil, Calafell) [48].

It has the potential to generate new research, e.g., to analyze academic programs in terms of their integration to sustainability principles and criteria, as well as the curricula of teacher training courses, among others. As the rubric is designed not only to measure knowledge and attitudes, but also to guide practical proceedings, our research team is already working on new application stages. Hence, this research work did not end here, and its findings have been incorporated into outreach projects that aim to transform these results into "good practices" in schools [49].

The sets of criteria highlight the fact that the political engagement of students and their understanding of our current society, the fight against different sources of discrimination and inequality and the support of an interdisciplinary curriculum that prioritizes a contextualized approach to knowledge from its problematization are goals to be achieved by CSES.

It is worth mentioning that the rubric presents a limitation regarding its transferability to other contexts different from Latin America or the Iberian Peninsula. In this sense, its validity could be reinforced should it be implemented in other European or American contexts with a more technocratic vision of science and sustainability

Finally, the FACTS rubric contributes to and enriches the relationship between SE and ES from a dialogic and complex perspective of education assessment that includes the current challenges of the 21st century.

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