In: Contextualizing Teaching to Improve Learning
Editors: L. Leite, L. Dourado, A. S. Afonso et al.
ISBN: 978-1-53611-845-2

Chapter 10

CONTEXTUALIZED SCIENCE TEACHING AND THE STS APPROACH

Isabel P. Martins[1,*] and Alcina Mendes[2]
[1]CIDTFF, University of Aveiro, Aveiro, Portugal
[2]Ílhavo School Cluster, Ílhavo, Portugal

ABSTRACT

Science subjects occupy a prominent place in the school curriculum. Each of them has a specific syllabus with goals established by grade levels. In all of them, students are expected to understand concepts, principles, laws, and theories and to know how to apply them in real or hypothetical situations. Research in the field of the didactics of the diverse sciences, all over the world, has provided guidelines for teaching approaches aimed at developing the scientific and cultural literacy of students, to foster their fondness for learning science and to develop critical citizenship competences. The STS approach provides a framework for contextualizing science teaching in order to promote a vision of science, as a way of thinking and understanding instead of confining it to a body of conceptual knowledge. Scientific education is a political issue, while science education is a public good and must be considered a basic right for all citizens. Contextualized science teaching, through STS approaches, is a way to improve the comprehension of the natural world and its potential for creating new goods. Research in science education has been producing knowledge that grants the understanding of problems and that supports decisions that can lead to a science teaching that is adjusted to current challenges. In this chapter we present the ideas and points of view of research focusing on STS and on contextualized science teaching that has been undertaken all over the world. This in itself is a reflection of the importance given to the learning outcomes that contextualized science teaching guided by the STS approach has achieved, as well as the challenges that are involved in designing and implementing teaching strategies for this purpose.

Keywords: contextualized science teaching, STS approach, didactics of science, scientific literacy

* Corresponding Author Email address: imartins@ua.pt.

Introduction

This chapter aims to provide those involved in science education (teaching, learning and evaluation) from a research or a training perspective with some ideas and guidelines that have been developed, through research on contextualization and on Science-Technology-Society (STS) approaches in different parts of the world, and the way they relate to each other. In fact, *Contextualized science teaching and the STS approach* may be of interest to teachers, authors of curricula, programs and didactic resources, science teacher trainers, those responsible for educational policies, researchers in science education and all those who promote a public understanding of science.

The importance of research that provides guidelines for the field of education is well known and is reinforced by the number of international reports on the subject. For this reason it is necessary to explain the meaning of the results of research in this area, as well as to look at the ways in which these proposals can be put into practice by user-communities and how the ideas can be communicated through interlocutor network members on a national and international level.

The problems that have been identified and studied in science education, particularly in the formal school context, are not new. There has always been concern with and attempts to improve the learning outcomes, as measured by formal evaluations on a national level, as well as in international comparative studies. However, the goals and objectives to be achieved in education systems have evolved over time having been mainly driven by the recognition of an evolution in the societies themselves and of the emergence of new profiles of social agents. From learning based on specific subject content and canonical sayings structured according to logical hierarchies of concepts, we have evolved into the development of competences allowing us to exercise a critical and responsible citizenship in a world, where instability and the unpredictable proliferate. Such skills and competences do not exclude the importance of disciplinary knowledge but rather give it a new meaning.

The didactics of science, thus, are emerging as a field of knowledge to interpret problems and justify strategic proposals for organizing teaching, learning and assessment practices, as well as to inform the development of appropriate educational resources required to achieve the goals of science education. This latter intentional purpose is considered to be the political dimension of didactics. In order to look at the didactics of science from such a critically reflexive perspective, it is necessary to value the active participation and inquiry of students in both teaching and learning situations. In this case, science teaching should be conditioned by three dimensions: the scientific knowledge in the field of didactics; the social importance at local, national and global levels, which is attributed to knowledge associated with both science and technology; and the impact that knowledge and individual practices will have in building fairer and more egalitarian societies. Moreover, what has most distinguished science teaching of today from science teaching of the past (in non-higher education) is the teaching approach rather than the concepts themselves. This is reflected in the design of curricula and programs.

This chapter therefore fits into the field of didactics of science, as it provides a reflection on educational guidelines for the teaching and learning of science, while focusing on non-higher education with particular emphasis on contextualized teaching and the STS perspective.

Let us take the following principles as a starting point:

- Science education is not just a subject that is only of interest to teachers. Since many sectors of activity are concerned about this topic, though from different distinct perspectives and especially since the results of international comparisons (TIMSS and PISA) it belongs to the educational agendas of many countries.
- Scientific literacy for all is a right of all members of democratic societies. However, the desirable individual level of scientific literacy is variable depending on the professional activity and other social roles of individuals.
- Interest in science learning depends on many factors outside the school environment and to assume that all students are motivated in the same way is a complete mistake.
- The quality of science education is intrinsically linked to research. It is research that provides theoretical guidelines, combines knowledge and experience from different countries and allows questions to be asked before, during and after innovative teaching experiences.

TEACHING AND LEARNING SCIENCE

Concepts and Contexts

Education is full of terms and distinct words with similar meanings. Sometimes the same terms are used with different meanings. Moreover, words and language from everyday life are used in academic communication settings and professional practices without worrying about explaining the specific meaning of how that word is being used with the interlocutor. For example, science teaching recommends the need for students to know how to conceptualize and how to contextualize. But what do 'context' and 'contextualization' mean? This is a central question in terms of the current chapter applied to science education.

If we consider that the meaning of a word depends on its use in communicative language (Wittgenstein, 1963, cited in van Weelie, 2001), conceptual learning is 'useless', if it is not understood or if it is not known for what it will be used i.e., what can we 'do' with these new ideas and skills.

The word 'context' is considered to be central in science education research, as its importance is clearly documented in research fields like conceptual change and situated learning (Stein, 1998).

However, the use of the concept of 'context' by educational researchers is far from achieving consensus. It needs to be discussed and clarified as far as both teaching and learning are concerned with that concept.

From a more general perspective and not just in terms of education/training a context represents a situation in which it is possible to give significance to a certain action/term/word. For this reason, when an expression is misinterpreted in everyday language, one says that it was 'taken out of context'. In the case of teaching and learning, the contexts will serve to mobilize students towards situations that are meaningful to them and, therefore, make it easier to interpret new situations afterwards.

The project developed by van Weelie (2001) discusses two didactic principles; namely, conceptualizing and contextualizing. In this study, using the issue 'biodiversity', through the design of learning activities, the students construct useful conceptual definitions and they learn how to use these definitions to find new meanings for the concept in new situations.

According to van Weelie (2001), contextualization means the useful action of interpreting a concept within a specific context. For this reason, it is important to construct meaning, i.e., to conceptualize the key concepts in context and then to go on to use these concepts to interpret new contexts. The re-contextualization of concepts, thus, will reinforce the process of its conceptualization.

Contextualized teaching is not an appanage of the natural and experimental sciences intended for discussion here. Other disciplines regard contextualization as being intrinsic to their fields of knowledge e.g., history, geography, anthropology or literature.

Contextualized Science Teaching and the STS Approach - A Revisited Issue

From the 1980s onwards, there have been many studies and curricular development initiatives emphasizing the importance of incorporating contexts in science teaching. At that time, it was already evident that the lack of student motivation to learn canonical science had had negative effects on the scientific education of young people. The literature put forward several arguments related to this problem. Some of them are empirically supported and suggest the contextualization of teaching, as a way to increase the motivation and learning of students in science (e.g., Hofstein & Rosenfeld, 1996; Mazurova & Slabeycius, 1995; Ramsden, 1997; Shymansky & Kyle, 1992; Stinner, 1995). Researchers, as well as many teachers, were aware that students were not very interested in science disciplines regardless of the development and impact that science and technology have on society. Despite the increased schooling that occurred in many countries, particularly in higher education, there has been a decrease in demand for degree courses in traditional science subjects contrary to what has happened in other emerging training areas. In the 21st century, this decrease had drastic consequences within higher education institutions, universities and institutes. In some cases, it led to the closure or fusion of departments that had produced great scientists and even some Nobel Prize winners in the past. As we will argue later, the perspective of contextualized science teaching is not without limits.

Didactics of science literature published in the late 20th century shows that proposals for contextualized science teaching emerged associated with various scientific disciplines such as biology, physics or chemistry and do not really constitute an autonomous field of research in didactics. This may be illustrated by the following examples of suggested ways to promote the contextualized teaching of science: the mobilization of aspects of history and philosophy of science (Stinner & Williams, 1993; Stinner, 1995); problem-solving and carrying out experimental work (Roth & Roychoudhury, 1993); efficiency of formal and non-formal teaching approaches like visits to parks and museums (Hofstein & Rosenfeld, 1996); using news published in the *media* (Mazurova & Slabeycius, 1995; Wellington, 1994;); analysis of the day-to-day situations of students and an exploration of reciprocal interactions between science-technology-society (Ramsden, 1997). The results of research about alternative conceptions, which were quite influential at the time, also provided strong arguments to support the proposals for contextualized science teaching (e.g., Palmer, 1997).

Proposals for contextualized science teaching that have been published in the literature suggest benefits in terms of motivation of students, understanding the meaning of the concepts taught and understanding the nature of science. They also showed potential in terms of developing citizenship skills. These arguments in favor of contextualizing science teaching (to meet international recommendations) were expressed in the report by the American Association for the Advancement of Science, *Science for All Americans* (Rutherford & Ahlgen, 1989). This document not only states the need to address the motivational problems of students but also stresses the importance of presenting scholarly science in a realistic way by showing both its strengths and limitations just like any other human endeavor used for individual and social purposes.

Due to an appreciation of the social dimension of science learning, particular emphasis is placed upon proposals that explore the reciprocal interactions between Science-Technology-Society (STS), as a way of achieving contextualized science teaching (Ramsden, 1997).

The STS guidelines in science teaching have been widely documented and discussed in the literature published between 1980 and 1990 and also in the decades that followed. In fact they emerged as a specific line of didactics research, which currently accounts for numerous publications and scientific events on the subject and organized communities of researchers (e.g., *Associação Ibero-Americana CTS na Educação em Ciência* i.e., the *STS Ibero-American Association for Science Education*).

The proposals to contextualize the teaching of science guided by STS approaches made during the last decades of the 20th century have supported large scale curriculum projects, which involved the conception of new programs and/or educational materials and these have had a great influence on the scientific education of generations of students in many different countries. Let us take the following examples: SISCON (Science in a Social Context, 1983, UK); SATIS (Science and Technology in Society, 1986-91, 1993, UK); PLON (*Project Leerparkket Onwikkeling Natuurkunde*, 1986, 1988, Netherlands); ChemCom (American Chemical Society, 1980, 1988, 1992, USA); BioCom (National Science Foundation, 1992-1999, USA); CEPUP (Chemical Education for Public Understanding Program, 1991, USA); SALTERS (The Salters Approach - Chemistry, Physics and Biology, 1989, 1990-92, 1992-94, University of York Science Group, UK).

These projects and the results of their implementation have been the focus of several studies and have had an extensive dissemination within the academic community, which led (in the following decades) to a large impact on curricula decision-making and resources for science education in various European countries, like Portugal and Spain, and other non-European countries like Canada, Australia and Japan.

The proposals for the contextualization of science teaching guided by STS acknowledge a conception of curricula and a way of organizing teaching activities that require explicit and reciprocal relationships between science, technology and society with which we agree. These relationships represent dimensions that are inseparable in the lives of all individuals regardless of their level of schooling. With STS in mind, the exploration of daily situations and scientific-technological applications should be the basis for the conception of contextual approaches to teaching and learning. In this way, curriculum proposals should be centered on the socio-scientific issues of today, so that the students can learn the concepts by understanding their relevance to everyday life. This perspective would have consequences on teaching and, in some cases, it has been shown that the selection of topics pre-empts the concepts that are studied i.e., the contexts themselves determine the contents to be developed (Britton, 1997).

The teaching approaches that follow STS guidelines may involve, as referred to in the literature, a wide range of teaching strategies including, among others, the oral presentation of concepts, the promotion of problem-solving activities and/or a diversity of practical work (laboratory-oriented, experimental, research and synthesis of information, etc.). It is also recommended that there should be a qualitative exploration of situations, which are traditionally considered non-academic but rather more personal or social but relevant for students, in order to question and understand them. Small group discussions are considered to be an essential learning strategy, as is the use of role plays, presentations using a range of different media, creative writing or other types of activities that actively allow the students to engage in and explore the selected context and to learn the concepts that are essential for their understanding (Aikenhead, 1988). In our point of view, this diversity of approaches will have a common central idea: the contextualization of the didactic situation.

It should be noted, however, that the identification of questions by (or with) students plays a crucial role in the definition of STS learning pathways (Akcay & Yager, 2010; Hand, Lawrence, & Yore, 1999), as it is a way of motivating the students to formulate answers to the questions that were initially asked.

One of the most shared versions in the specialized STS education literature is reported by Aikenhead (1994) who discusses the links between science-technology-society from different isolated or combined perspectives, as being:

> "a technological artifact, process or expertise; the interactions between technology and society; a societal issue related to science or technology; social science content that sheds light on a societal issue related to science and technology; a philosophical, historical, or social issue within the scientific or technological community." (p. 52-53).

STS education is based on the assumption that learning science should go beyond scientific instruction, if the goal is to allow individuals to develop a scientific understanding of the world by approaching some problem situations from past or present times. This educational vision will provide each and every person with a more humanistic perspective of science by showing them the multiplicity of relationships that exist between science, technology and society. It should be noted that this vision is related with the concepts of scientific culture and literacy. The social relevance of education in science and technology cannot be ignored nor simply brushed aside. Scientific education is a right that everyone should have and students should be exposed to learning science from an early age. In democratic societies, citizens have the right to express themselves on decisions about political power. To be able to have this social competence, people need to be knowledgeable and able to express informed opinions. Learning science through STS approaches will allow people to attain a much broader view about the importance of scientific knowledge. Thus, we argue that within an integrative STS vision the contextual situation, which embodies the topic/problem under analysis, is a point of departure but it does not end there. It could and should be revisited and reinterpreted throughout the teaching experience and, then, at the end, it should be possible to evaluate the extent to which the expected answers have been found or not and eventually new and relevant questions will be generated.

For several authors, contextualized science teaching and the STS approach are expressions referring to perspectives of science education considered to be equivalent in trying to get students more interested in the learning of science and to improving the image *of* and attitudes *towards* science (Bennett, Lubben, & Hogarth, 2007). For others (e.g., King, 2012) the context based-approach finds its place among a large number of perspectives of science teaching like STS, problem-based learning and project-based science. From our point of view, the STS approach gives a humanistic meaning to science education and it guides the choice of the contexts to be selected.

Contextualized Science Teaching

Research into science education over the past two to three decades, as well as various international organizations, warn of the need to break away from teaching models based on a neutral view of science and concerned with purely factual learning. A recent statement made by the National Science Teachers Association (NSTA Board of Directors, 2010) advocates the teaching of science and technology in the context of societal and personal issues from pre-school age to higher graduation (K-16). They consider that contextualized teaching will be a way to ensure that all students will have the ability to use what they have learned in making decisions involving science and technology at personal, societal and global levels. If students are to achieve this goal, identification of relevant knowledge and attitudes is required. Afterwards the NSTA recommends training that should incorporate debate and analysis of controversial societal issues that are proposed mainly by students themselves.

When discussing the importance of context in learning science, van Rooyen (1994) suggested that different levels of contextualization should be considered: an *extrinsic* level, which could be based on something like a newspaper article, a book or a social problem in which the concepts being studied could take on a real significance for the students and an *intrinsic* level, which is important for the perception of the students and which can be divided into three sub-levels described as *macro*, *meso* and *micro* levels. These will be presented below using examples from biology teaching.

The *macro contextualization* level is about the relationships that can be established between concepts and human experiences. Therefore, if students are studying concepts related to proteins, they should be able to relate those concepts to aspects of their own lives. For example, with regard to composition of food, this means recognizing that meat, milk, fish and eggs are rich in proteins, as opposed to fruits or tubers. The level of *meso contextualization* is about the need to permanently maintain bridges between the different topics being studied, thus, avoiding excessive compartmentalization within the subject. For example, this would be achieved by relating human nutritional needs to the trophic networks that can be established in an ecosystem, even if these issues are studied in different school years. The level of *micro contextualization* has to do with understanding specific components of the concepts. For example, learning about the concept of cell organelle (mitochondria or chloroplast) requires learning about its order of magnitude by discussing measurement units used in microscopy and relating them to the units of measurement that are familiar to students.

This detailed way of conceptualizing contextualization in terms of levels and sub-levels emphasizes important aspects to consider in contextualized science teaching. Taking this conceptualization model as a reference point, it can be argued that these - the majority of the contextualized science teaching proposals presented in the literature - refer to an *extrinsic* level and/or to the *macro contextualization (intrinsic)* level suggested by van Rooyen (1994).

Contributions from several studies indicate that understanding a concept is not restricted to the knowledge of its objective meaning i.e., the way in which a specific discipline structures facts in the form of 'definitions'. Another rather important issue is the subjective meaning of the concept i.e., how the individual organizes knowledge and uses it for different situations. This involves tacit processes of memory associations, phenomena, theories, actions, settings and situations, where the designation of the concept has been included previously. Therefore, one cannot accept that a student has understood the meaning of a concept just because she/he manages to repeat a definition or the words used in the explanation by the teacher.

Analyzing some of the current teaching challenges identified by supra-governmental-based organizations like UNESCO, OECD or the European Union (EU), one concludes that all of these organizations make explicit recommendations to contextualize the teaching of science. In some documents, contextualized science teaching is advocated under the form of guidelines that require the teacher to create conditions for the learning of scientific concepts to be associated with real life experiences of the students, to contemporary social issues or to the historical and social aspects, which shaped the genesis of that knowledge (European Commission, 2004; Eurydice, 2011). It is suggested that in the processes of constructing and implementing the curriculum, policy makers and teachers should keep in mind that it is essential to articulate the study of the concepts with the personal and social interests of the students *in* and *about* science, through encouraging curiosity about real situations, analyzing historical descriptions of the contexts of discovery and exploring reciprocal interactions emerging between science, technology and society (Fensham, 2008; Gauthier, 2006; Jenkins, 2003; OCDE, 2006; UNESCO, 2006).

The nature of the science curriculum, which has repercussions on the teaching approaches to be adopted, has been a topic of discussions over the last two decades. In particular, there have been discussions about whether the curricula should be academic or 'popular' goals-oriented; if it should be standardized in each country (national curriculum) or regional (at least partially); if it should be neutral with regard to value judgments or promote debates on socio-scientific issues and in this case, which topics should be chosen; if curricula design should follow the traditional model of providing students with basic/canonical knowledge (scientific instruction) or rather develop personal and social competences in and about science (scientific education); and if the curriculum should be conceived by and follow the current political power ideology or follow the results and findings of scientific research (Roberts & Ostman, 1998). None of these options is exempt from positive and negative aspects and so they need to be balanced.

Several authors have addressed orientations for teaching science based on contexts. We would like highlight the proposal made by John Gilbert (e.g., 2006; 2014), who identifies what is understood by 'context', what is the purpose of this orientation for science teaching, how a context with educational interest should be chosen and which 'models of contextualized teaching' could be considered.

Referring to previous work, Gilbert (2014) argues that the choice of a context should take its educational value into account based on the following four criteria: (1) it is of real or potential interest to the students and, therefore, they will be motivated to understand it; (2) it will facilitate the interaction between teachers and students; (3) it is appropriate to introduce the specific terminology of the new concepts to be covered; and (4) it is conducive to the mobilization of the prior knowledge of the students.

Another question, which is worth raising, is concerned with how teaching strategies could be organized. Of course, there are different ways of conceiving contextualized teaching, which depend on issues like: the nature of the topic, the difficulties of students in demonstrating previous thought about the topic, alternative conceptions that students have on basic topics and the unwillingness of students to counter positions. However, Gilbert (2014) describes four main models of teaching science in context. Nevertheless, he considers that it is not legitimate to use such labels in cases that do not meet the four criteria. The four models can be summarized as follows:

- *Model 1: Contexts as applications of concepts taught traditionally*. This model has to do with an absolutely traditional teaching perspective based on the exposition of the concepts one by one, where the contexts are only there as an opportunity for applying concepts that have been presented previously. Moreover, those applications are not the focus of the learning evaluation. Generally, this teaching model does not meet the stated criteria and only engages students, who are already interested in science.
- *Model 2: Contexts as applications introduced during the teaching of concepts*. The main focus of attention still is teaching concepts in a traditional way but the applications start to be introduced particularly through idealized exemplary cases, albeit with little or no relation to real situations. It is used by teachers who defend traditional conceptual teaching, but who also believe they can increase student motivation this way.
- *Model 3: Contexts as guides for the development of individual cognitive activity*. In this model learning is seen as the result of the stimulation of the cognitive activity of each student. Teacher-student interaction one-to-one is the most valued way of stimulating the cognitive activity of the students. The whole class and the interactions among students are not valued, because learning is considered to be an individual process involving the mental and individual capacities of each learner. The context works as an environment for developing individual cognitive activity.
- *Model 4: Contexts as a means of understanding a diversity of real cases*. In this model - the only one that meets the four defined criteria - the teacher and the students work collaboratively to explore contexts, which promote teacher-student and student-student interactions. For this practice to work effectively it is necessary that the teacher has a deep understanding of the concepts and contexts to explore. Moreover, using current real-life cases demands that the teacher undergoes a permanent process of training in order to keep up-to-date with the contents, as well as with the socio-scientific arguments used by the mass media with regard to the selected contexts/topics.

By promoting the exploration of open problematic situations and building from the ideas of the students, the teacher may be able to adopt several teaching sequences and may be faced with several interdisciplinary challenges.

With regard to the sequence of the teaching process, the contexts should be understood not only as a starting point and a thread to guide the learning activities to be performed but also as a point of arrival concerned with the understanding of the context itself.

Implications of Contextualized Science Teaching Using the STS Approach

Several advantages have been cited in favor of contextualized teaching, when compared with other teaching perspectives. These include the lightening of overloaded curricula, stronger articulation with other concepts and other contexts, greater student motivation for learning science and even development of competences of critical thinking and argumentation (Gilbert, 2006; King, 2012). However, this issue is still under discussion and it is not certain that all of the questions about it have just one straightforward answer. Here are some of the questions that have been raised (Essays, UK, 2013): Do everyday contexts really improve the learning of science? And do they (also) improve the attitudes towards science? Do the outcomes of contextualized teaching depend on the type of students?

Based on a systematic review of more than sixty studies about contextualized science teaching, Bennett et al. (2007) list the main results of the participation of students in projects designed for this purpose, when compared to conventional courses; namely, that there was a very relevant improvement in the attitudes of students towards scholarly science and/or to science in general; that there was a significant increase in students choosing to study chemistry, physics or biology in higher education after following the Salters Project; that comparative studies carried out in three countries (Australia, Sweden and the UK) showed that attitudes towards learning science were strongly influenced by the perception of the students of the relationship of science to reality, technology and the future; that achievement on learning physics (in Germany) improved, when socio-scientific themes were addressed, as compared to using practical activities; that there was moderate evidence that contextualized teaching decreases the difference in attitudes towards science in terms of gender; and that evaluation results in conventional chemistry tests were weaker in the case of contextualized teaching. The latter result was to be expected because teaching in context should have different evaluation criteria than conventional teaching methods.

Despite the different conceptualization of the concept of 'context-based approaches' and 'STS approaches' that may underlie the different studies reviewed by Bennett et al. (2007), the evidence presented sustains the view that contextualized teaching does not lead to a decrease in the understanding of science and that it may cause considerable benefits in attitudes towards scholarly science.

As far as the practical implications involved in implementing contextualized teaching are concerned, more attention should be given to three issues: teacher training, the evaluation of school learning and the choice of contexts.

The training of teachers capable of fulfilling Model 4, as defined by Gilbert (2014), is highly demanding. There must be a stronger commitment of teacher trainers, so that all areas of initial teacher education (theory and practice) contribute to equip teachers with the necessary competences to meet these demands. It is not plausible to imagine that a teacher, who never learned how to exploit contexts during his/her training, whether at an *extrinsic* or *intrinsic* level, will know how to do this in the future. In many cases, teacher training institutions will have a long way to go before this goal can be achieved. In-service teacher training programs should also follow that path.

The assessment of student learning is another aspect that deserves attention. The evaluation model has to be compatible with the teaching and learning model. Opting for contextualized teaching means that assessment has to be distinct from the conventional method. One of the fundamental questions related to learning in context is about the capacity to use what has been learned into new contexts and this requires decontextualizing the concepts to re-contextualize them. To successfully manage the knowledge of doing the 'transfer' (Gilbert, Bulte, & Pilot, 2011; Gilbert, 2014) is not a linear process and it will depend on the contexts involved, the initial context and the current context. The success of contextualized teaching will thus be conditioned by the performance of the student in this process. Putting it simply, we can differentiate three types of transfer: *near transfer* (the concepts involved in the interpretation of the new context are similar to those used in the first context); *further transfer* (the concepts involved in the new context are different in small details from those used in the first context); *far transfer* (the concepts needed for the interpretation of the new context require an appreciable broadening of those used in the first context).

In all cases, the final re-analysis of the context that was used as a starting point is essential to guarantee that the student is able to put what has been learned into perspective, when facing other new situations. This step is particularly relevant because it should also ensure that the new learning is disconnected from the specificity of the context used to construct it. It allows the context to be relativized - the *de-contextualization* phase - contributing for the abstraction and transferability of what has been learned to new situations.

In our opinion, one of the reasons that could explain the weak performance of many students in the PISA tests could be related to the discrepancy between the types of evaluation questions (national and school tests) in their particular countries and the types of questions that are used in the international PISA test, which adopts a contextual framework for the questions. In effect, the questions asked in the PISA test were related to specific contextual situations in which students should be immersed to answer them. To successfully answer the questions it was not enough to give an explanation reproducing canonical concepts. This led to the internationally assumed assumption that PISA is not suitable for evaluating and/or comparing curricula.

As far as *choosing contexts* is concerned, the question is very complex. It should be accepted that it is not possible to find topics that will interest all the students in the same way, which compromises the first criterion proposed by Gilbert (2014). The most likely option will be to alternatively consider the interest of the students in the class and have them all understand and accept this choice. Furthermore, the interests of the students will vary over the years, which means that teachers will have to permanently prepare new contexts, even though there has been no change in the formal curriculum. The choice of contexts should be based on themes that are socially relevant within the Education for Sustainable Development goals and inter-relationships between science, technology and society. Such societal issues should allow students to gain an understanding and depth of knowledge in terms of competences and attitudes that will enable them to become participative citizens. The didactical use of contexts that allows students to explore STS interrelationships establishes a privileged way of promoting the scientific education of students by allowing them to identify, analyze, understand and think critically about questions that affect the quality of life of people, as well as the sustainability of their actions (Fensham, 2008; Lyons, 2006; Osborne & Dillon, 2008). In this sense, the selection of contexts should guarantee that students analyze the reciprocal interactions that science establishes with other areas of knowledge and with technology and society. Also, it should allow them to understand the nature and relevance of scientific knowledge, as well as to develop the skills required for reasoning and critical thinking (American Association for the Advancement of Science, 1993; Gunel, 2008; National Research Council, 2013; Rocard et al., 2007).

As we have seen, the choice of contexts to form a basis for a science curriculum involves the need to consider the interests of students and their previous competences, which eventually also involve their future plans and the expectations of society. However, over and above these dimensions (personal and social), which are more directly related to the characteristics of the students, the choice of a context for teaching science also involves a didactic dimension that is inherent to the professional knowledge of the teacher.

The relevance of a context for teaching science depends on whether are not its exploration turns out as adequate for the study of new concepts i.e., providing teaching sequences that are effective to meet the learning outcomes. In operational terms, the relevance of a context does not just derive from the attributes of the chosen socio-scientific situation, it is also essential that it allows for the specific terminology and the target concepts to be used. Moreover, the relevance depends on how a situation might be didactically transformed into a teaching context. This means that it depends largely on the teacher, on his/her training, teaching experience and professional competence.

In summary, the educational value of a contextualized science teaching approach results mainly from the way a real-life situation of socio-scientific nature, which is interesting from a personal and/or social perspective to the students, will be explored didactically by the teacher by taking into consideration the characteristics of the students and the conceptual, procedural and behavioral concepts prescribed by the curriculum. This requires making decisions related to the way of problematizing the context, the flexibility in the teaching sequence or the nature of teaching and evaluation strategies, for example.

The selection and didactic transformation of real socio-scientific situations to develop a contextualized teaching of science demands a reflexive and critical attitude from the teacher. Here are some of the questions that may be asked by teachers: Up to what point do I know and manage to activate the interests of my students though the selected contexts? To what extent can I conciliate the interests of the students and the educative relevance that I identify in some real-life situations? What didactic resources do I need and do I have in order to adequately explore a given situation? What kind of collaboration do I have and/or can I ask for? What risks are involved in the exploitation of new and emerging situations?

Mobilizing emerging real and highly mediated situations may seem tempting for the purpose of contextualizing science teaching guided by an STS approach. Besides, the media coverage of these kind of situations and their inevitable arrival into the classrooms often happen before the teacher has had the chance to access the necessary scientific details to fully understand them.

Let us recall, for example, two socio-scientific cases that were both major news items: the birth of the first cloned sheep, Dolly, in 1996 and the earthquake with a magnitude of 9 followed by the tsunami in 2011 in Japan. In the first case, the scientific publication in the journal *Nature* was made only a year later in 1997 and in the second case, a detailed scientific description of that phenomenon could not have preceded its occurrence. Both situations were very widely publicized on television and in newspapers and magazines and they generated waves of non-scientific opinions - some of which were of an alarmist or even catastrophic nature, which worried communities, families, students and science teachers. Both cases would have been excellent opportunities for science teachers to teach their students to develop appropriate images of the work of scientists and of the processes they use to construct and disseminate scientific knowledge. When these situations occurred, it would have been difficult to turn them into educationally relevant teaching contexts according to Model 4 proposed by Gilbert (2014).

However, some years later, the case of the cloning of Dolly and the case of the earthquake of magnitude 9 in Japan had become potential contexts for the STS oriented teaching of biology and geology respectively. This possibility occurred, when teachers were able to access the scientific foundations that were deemed necessary to understand the phenomena at hand in a scientifically consistent way. This is an essential condition, when it comes to analyzing with the students the diverse and unforeseen opinions about the events and the impact that they had on society. A broad and strong scientific preparation of the teacher is necessary for didactic processes, which allow for the exploration of real-life contexts in a STS perspective, to be well conducted and educationally valuable, as this requires adapting the teaching process to the age of the students and to what they need to learn.

In view of the arguments discussed above, we suggest that the choice of a context should take a *fifth* criterion into consideration in addition to the four defined by Gilbert (2014): the educational relevance of the context requires that scientific explanations of phenomena inherent to a socio-scientific situation need to be developed by the scientific community and understood by teachers. If this condition is not fulfilled, then there is a risk that the didactic exploitation of the context will only be addressed on an immediately emotional level without really touching the scientific dimension of the event or situation encompassed by the context.

Science teaching is not intended to make students become scientists nor to train them to be scientists. All citizens - including future scientists - need to know about issues that other scientists care about and, in particular, about some of the practical implications involved. Certainly, for such understanding to take place it will be necessary to know concepts, laws and theories but, if we want students to understand their importance and relevance, then we will need to approach them in personal and social settings. The question of motivating their curiosity and interest in knowledge is a key question for teachers and policy makers. However, if we aim to achieve this goal, we will need to have flexible curricula and teaching methodologies designed to meet the needs of different types of students by taking into account that the schools of today have children and young people with very distinct cultures and capabilities.

The training of teachers and educational policy options will always be crucial for educational development. What matters, thus, is that they are supported by scientific research. The same applies to curricula design.

Educational objectives are always a political choice and have an underlying ideology about education and its goals. Even though there is an extensive bibliography available on guidelines, practices and curriculum proposals, the legislative diplomas regulate teaching, training and curriculum at all levels of schooling and, thus, they influence the work of teachers according to that political choice. To deem that this is irrelevant to the options of teachers is unrealistic. Only exceptional teachers with highly motivated students will be able to overcome the limitations and constraints of the official syllabuses. This realistic but in no means fatalistic view of formal education does not aim to undervalue the importance of studies, which are validated empirically, as these could become a reference for all those wishing to support curriculum innovation based on contextualized teaching. What we want to emphasize here is the importance of the existence of educational policy guidelines to support teaching, learning and evaluation practices based on scientific research and oriented towards the scientific literacy of the students.

CONCLUSION

Throughout this chapter, we have tried to emphasize the importance of teaching science within relevant social contexts based on the work of several authors. Underlying this perspective is the importance of training students for the conscious exercise of citizenship, where scientific knowledge is an essential element. Science is part of heritage and one of the most important intellectual achievements of human kind. For this reason, it is considered as a part of culture in its widest sense. Science is a human activity and much more than a structured body of validated knowledge that has been (re)constructed over time, so it is a way of thinking and understanding. Therefore, learning science in schools or elsewhere is much more than just the understanding of so-called canonical contents.

Nowadays, science teaching should not follow an earlier tradition, although we can still teach today concepts that have been established for over a century. We are all aware that the interests of young people of today are not the same as those of previous generations. Furthermore, the teaching that is practiced today cannot be the same as to that which current teachers were submitted, when they were students. How can we proceed then, if a lot of disciplinary knowledge continues to be fundamental and - for that reason - important? One of the possible paths to follow, which is supported here, is the teaching of contextualized science on current topics with STS issues. This does not mean that it does not address contexts related to the history of science but that the daily-life context of students cannot be undervalued. But, as explained previously, for contextualized teaching to work as a way for more and better science education for students, very substantial investments are required in curricula and training of teachers and, in particular, in their motivation and commitment to continue to learn throughout their professional lives.

Contextualized science teaching is a didactical approach. The STS orientation for science teaching is a theoretical perspective framing curricula, programs, didactic resources and teaching strategies.

Scientific culture is dependent on many factors but it will always depend on education and in particular on the science education to which each individual has access. This does not mean that education within a school context is the only determining factor, as each one of us learns beyond school. However, the school environment is undoubtedly one of the richest in which to develop a taste for further learning, even if most of it is still unknown. One of the greatest things that schools of today can provide for young people in the field of science education is to help them understand the essence of scientific thought, its ability to see things from different perspectives, to look for explanations for natural and social phenomena and to predict the occurrence of others. To do this adequately at every age level is the great challenge facing teachers today. Innovating science education should be a permanent concern for teachers and authors of curricula and teaching resources, as well as policy makers. Teaching science in context, in spite of the recognized limitations, is a way of improving the understanding of the importance of scientific knowledge *in* and *for* Society.

ACKNOWLEDGMENTS

This work is financially supported by National Funds through FCT - Fundação para a Ciência e a Tecnologia under the project UID/CED/00194/2013.

REFERENCES

Aikenhead, G. (1988). An analysis of four ways of assessing student beliefs about STS topics. *Journal of Research in Science Teaching, 25*(8), 607-629. doi:10.1002/tea.3660250802

Aikenhead, G. (1994). What is STS teaching? In J. Solomon, & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp.47-59). New York, NY: Teachers College Press.

Akcay, H., & Yager, R. (2010). The impact of a science/technology/society teaching approach on student learning in five domains. *Journal of Science Education and Technology, 19*(6), 602-611. doi:10.1007/s10956-010-9226-7

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: a synthesis of the research evidence on the effects of context-based and STS approaches to science teaching, *Science Education, 91*(3), 347-370.

Britton, E. (1997). Sciences, technologie, société [Science, technology and society]. *Revue Internationale d'Éducation, 14*, 61-66.

Essays, UK. (2013). *Context based approaches in teaching of primary science education essay*. Retrieved from https://www.ukessays.com/essays/ education/context-based-approaches-in-teaching-of-primary-science-education-essay.php?cref=1

European Commission (2004). *Europe needs more scientists*. Luxembourg: Office for Official Publications of the European Communities.

Eurydice (2011). *Science education in Europe: national policies, practices and research*. Brussels: Education, Audiovisual and Culture Executive Agency.

Fensham, P. (2008). *Science education policy-making: eleven emerging issues*. Paris: UNESCO.

Gauthier, R. (2006). *The content of secondary education around the world: present position and strategic choices*. Paris: UNESCO.

Gilbert, J. (2006). On the nature of 'Context' in chemical education. *International Journal of Science Education, 28*(9), 957-976.

Gilbert, J. (2014). Science education through contexts: is it worth the effort? In M. Watts (Ed.), *Debates in Science Education* (pp.145-157). Oxon, NY: Routledge.

Gilbert, J., Bulte, A., & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education, 33*(6), 817-837. doi:10.1080/09500693.2010.493185

Gunel, M. (2008). Critical elements for the science teacher to adopt a student-centered approach: the case of a teacher in transition. *Teachers and Teaching: Theory and Practice, 14*(3), 209-224. doi:10.1080/ 13540600802006095

Hand, B., Lawrence, C., & Yore, L. (1999). Writing in science framework designed to enhance science literacy. *International Journal of Science Education, 21*(10), 1021-1035. doi:10.1080/095006999290165

Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Studies in Science Education*, 28, 87-112.

Jenkins, E. (2003). *Guidelines for policy-making in secondary school science and technology education.* Paris: UNESCO.

King, D. (2012). New perspectives on context-based chemistry education: using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education, 48*(1), 51-87. doi:10.1080/03057267. 2012.655037

Lyons, T. (2006). Different countries, same science classes: students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 697-700. doi:10.1080/09500690500339621

Mazurova, J., & Slabeycius, J. (1995) Newspaper articles and physics teaching. *Physics Education, 30*(5), 297-301.

National Research Council (2013). *Next generation science standards: for states, by states.* Washington, DC: The National Academies Press. doi:10.17226/18290.

NSTA Board of Directors (2010). *Teaching science and technology in the context of societal and personal issues.* Retrieved from http://www.nsta.org/about/positions/ societalpersonalissues.aspx.

OCDE (2006). *Evolution of student interest in science and technology studies: policy report.* Retrieved from http://www.oecd.org/science/sci-tech/36645825.pdf

Osborne, J., & Dillon, J. (2008). *Science education in Europe: critical reflections.* London: The Nuffield Foundation.

Palmer, D. (1997). The effect of context on student's reasoning about forces. *International Journal of Science Education, 19*(6), 681-696. doi:10.1080/0950069970190605. 439869

Ramsden, J. (1997). How does a context-based approach influence understanding of key chemical ideas at 16+? *International Journal of Science Education, 19*(6), 687-710. doi:10.1080/0950069970190606

Roberts, D., & Ostman, L. (Eds.). (1998). *Problems of meaning in science curriculum.* New York, NY: Teachers College Press.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). *Science education now: a renewed pedagogy for the future of Europe.* Brussels: European Commission.

Roth, W., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. *Journal of Research in Science Teaching, 30*(2), 127-152. doi:10.1002/tea.3660300203

Rutherford, F., & Ahlgren, A. (1989). *Science for all Americans.* New York, NY: Oxford University Press.

Shymansky, J., & Kyle, W. (1992). Establishing a research agenda: critical issues of science curriculum reform. *Journal of Research in Science Teaching*, *29*(8), 749-778. doi:10.1002/tea.3660290803

Stein, D. (1998). *Situated learning in adult education. ERIC Digest*, (195). Retrieved from Ericae.net website: http://ericae.net/edo/ed418250.htm

Stinner, A. (1995). Contextual settings, science stories, and large context problems: toward a more humanistic science education. *Science Education*, *79*(5), 555-581. doi:10.1002/sce.3730790506

Stinner, A., & Williams, H. (1993). Concept formation, historical context, and science stories. *Interchange*, *24*, 87-104.

UNESCO. (2006). Science, citizenship and values: keystone to a realistic, pragmatic approach to science education: a historical perspective. *Connect - UNESCO International Science, Technology & Environmental Education Newsletter*, *31*(3-4).

van Rooyen, H. (1994). The quest for optimal clarity of presentation. *American Biology Teacher*, *56*(3), 146-150.

van Weelie, D. (2001). Contextualizing biodiversity. In O. de Jong, E. Savelsbergh, & A. Alblas (Eds.), *Teaching for scientific literacy: context, competency, and curriculum* (pp.99-116). Utrecht: CDβ-Press.

Wellington, J. (1994). Using informal learning to enrich science education, In J. Wellington (Ed.), *Secondary science: contemporary issues and practical approaches* (pp.284-294). London: Routledge.

EDUCATION IN A COMPETITIVE AND GLOBALIZING WORLDE

Contextualizing Teaching to Improve Learning

The Case of Science and Geography

Laurinda Leite · Luís Dourado
Ana S. Afonso · Sofia Morgado
Editors

NOVA