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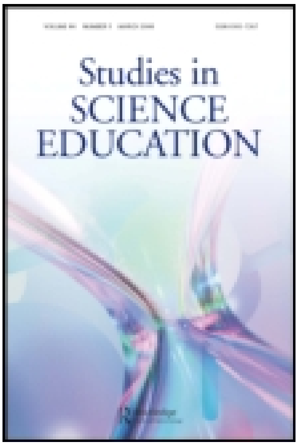

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The meaning of 'relevance' in science education and its implications for the science curriculum

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'Relevance' is one of the key terms related to reforms in the teaching and learning of science. It is often used by policy-makers, curriculum developers, science education researchers and science teachers. In recent years, many policy documents based on international surveys have claimed that science education is often seen (especially at the secondary school level) as being irrelevant for and by the learners. The literature suggests that making science learning relevant both to the learner personally and to the society in which he or she lives should be one of the key goals of science education. However, what 'relevant' means is usually inadequately conceptualised. This review of the literature clearly reveals that the term relevance is used with widely variant meanings. From our analysis of the literature, we will suggest an advanced organisational scheme for the term 'relevance' and provide helpful suggestions for its use in the field of the science curriculum.

Keywords: relevance; scientific literacy; interest; motivation; curriculum; curriculum emphasis; educational reform

Introduction

In recent years, many studies have been conducted and related articles are published which clearly present a gloomy picture with respect to the learning of science, especially at the secondary school level. A key claim is that science education – particularly in Physics and Chemistry – remains unpopular among students (Hofstein, Eilks, & Bybee, 2011; Holbrook, 2008; Osborne & Dillon, 2008). Many of these articles infer that students are insufficiently interested in science learning and/or not motivated by science subjects (Jenkins, 2005; Osborne, Simon, & Collins, 2003). One reason mentioned quite frequently is that learners perceive science and science education as 'irrelevant' both for themselves and for the society in which they live and operate (Dillon, 2009; Gilbert, 2006; Holbrook, 2008). As a result, science teachers are required to make education 'more relevant' in order to better motivate their students and interest them in science subjects (Holbrook, 2003, 2005; Newton, 1988a, 1988b). However, it sometimes remains unclear what exactly is meant by 'making science learning relevant', including both how to attain this goal and which connections (or differences) exist between the following terms: relevance, interest and motivation.

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There is no doubt that science is very important for our World and the society in which we live (Bradley, 2005). Many publications emphasise the importance of science in maintaining the economic wealth of modern societies, thereby justifying both the learning of science as essential for sustainable development in the future (Burmeister, Rauch, & Eilks, 2012) and for active participation in society and societal issues (Roth & Lee, 2004). Based on this, it is automatically assumed that all students need a certain level of scientific knowledge in order to become literate citizens and, thus, to be able to participate in socio-scientific discussions. This is especially important in our increasingly technological world (Hofstein et al., 2011). Many people agree that modern societies need to actively invest a sufficient amount of their educational resources in learners who will eventually embark on careers in science and technology (EC High Level Group, 2004). Today, every country needs scientists to achieve further scientific and technological developments and maintain future economic standards of living (EC High Level Group on Science Education, 2007). However, the question remains: Can we equate the word 'relevance' used to justify science education with the true importance of science in a techno-scientific world, including its related applications with regards to ecological, economical and societal development as described in the rhetoric of most educational policy papers? Debate in science education uses the term 'relevance' quite often and in various ways. It seems that explicit and generally accepted definitions and models of what is meant by 'relevance' are still lacking in science education at both the research and curriculum development levels.

However, it is not only the educational research and practice using the term 'relevance'. It should be noted that very often, education development and implementation are influenced by many different stakeholders from inside and outside the educational arena. These includes: education policy-makers, managers and decision-makers in industry (and other employment places), and scientists in the academia. Clearly, these stakeholders differ in their goals and objectives for influencing teaching and learning science. In addition, the target population (primary or secondary school students who study science), the society (with its needs, socio-economic conditions and culture) in which the students live and operate and the subject matter (for example, disciplinary or interdisciplinary approaches) might influence decision about science curricula. It is suggested that each of the above mentioned groups of stakeholders will try to influence science teaching and each of them with a different understanding of what it means to make science education more 'relevant'.

In addition, it is clear that the shift to relevance-oriented science curricula is frequently based on economic constraints, namely, availability of funds for reforms and its related curriculum development. For example, Eijkelhof and Kortland (1988) in the Netherlands describe a reform in the teaching of Physics: The PLON (a Dutch acronym for *Physics Curriculum Development Project*) project. The project was funded over a period of almost 15 years. This long-term curricular cycle provided continuous feedback to stakeholders (government and science educators) to broaden the goals of physics education towards a more relevance-oriented Science–Technology–Society (STS) curricular approach. However, funds do not only come from the government. In the case of chemistry, quite often future employers such as industry involve themselves in the development of new curricula (e.g. industrial chemistry by Hofstein and Kesner (2006) in Israel and the SALTERS projects in the UK as described in Bennett and Lubben (2006). The funds are coming from the industries with the goal in mind to ensure that in the future, there will be enough employees in their fields. In other words, the involvement in science education and curricular reform is considered by industry to be relevant for convincing students to embark in the future on careers in industry.

This paper is not an attempt to criticise papers in which authors use the term 'relevance' in non-uniform ways. Instead, it intends to clarify the use of this term since this word is frequently used in science education with widely differing meanings and in different contexts. About 25 years ago, Newton (1988a) wrote the following about these situations:

> Science teachers are increasingly exhorted to make their teaching relevant but, in general, the notion of relevance in science education seems fraught with inconsistency, obscurity and ambiguity. (p. 7)

and:

> The notion of relevance is not a simple one. It seems at the least unhelpful and at the worst counterproductive to urge a teacher to be relevant in terms which are abstract and diffuse. It might be useful if some aspects of the notion of relevance were to be clarified. (p. 8)

This paper will evaluate whether the claim made by Newton 25 years ago is still valid. The paper does not intend to give a final answer to what needs to be done to achieve the goal of relevant science education since this would require a joint understanding of what is meant by 'relevance' in science education, and how the term might be operationalised. This paper will give a critical analysis of how the 'abstract and diffuse' term, as stated by Newton, is used and operationalised, where we will find parallels and differences, and finally how different curricula try to approach their understanding of 'relevant' science education. From this analysis, we will attempt to present an advanced organising scheme for the term in order to avoid further ambiguity. This article's main goal is to provide insight into the question: 'What kind of meaning can or should 'relevance' take in science education?' Based on a broad review of the literature, this paper will develop a step-by-step definition of the term 'relevance' with regard to science education by summarising ideas and concepts taken from different sources. This definition will be illustrated by connecting the different dimensions of relevance within science education, combining them into one single model of relevance, which will then be connected to different teaching practices in the science curriculum.

'Relevance' in science education: some historical reflections

This review is focusing on the issue of relevance in the context of teaching and learning science. However, this issue has a quite long tradition already beyond the field of science education. It can be at least tracked back to the reform movements in education in the early twentieth century. By that time, one focus of educational reform was the question: what makes the learning in school relevant to the students' life and future. Among many others, the idea of connecting school learning with the learner's out-of-school experiences was introduced by many scholars who tried to influence the way content in schools should be taught in general and how science education should be operated in particular. One example is the philosophical work by John Dewey (1956) in the USA. In an essay about school and life, he wrote:

> From the standpoint of the child, the great waste in the school comes from his inability to utilize the experiences he gets outside the school in any complete and free way within the school itself; while on the other hand, he is unable to apply in daily life what he is learning in school. That is the isolation of the school–its isolation from life. When the child gets into the schoolroom he has to put out of his mind a large part of the ideas, interests and activities that predominate in his home and neighbourhood. So the school being unable to utilize this everyday experiences, sets painfully to work on another tack and by a variety of [artificial] means, to arouse in the child an interest in school studies … [Thus there remains a] gap existing between the everyday experiences of the child and the isolated material supplied in such large measure in the school. (Dewey, 1956, pp. 75–76)

Coming from the reform movement in the first-half of the twentieth century, after World War II, one can identify four periods how the issue of relevance was taken into focus in science education: the 1950s to early 1960s, the late 1960s and the 1970s, the 1980s and finally, from the 1990s until to today.

The late 1950s and early 1960s

During the late 1950s and early 1960s, during the 'Sputnik Era', science education reforms were initiated in the USA, which were then echoed in many countries (e.g. the UK, Israel, and Germany). This period was fondly called the 'Golden Age' of curriculum reform (see Bybee, 1997b). During this period, many curricular projects were developed and implemented in all the sciences for all age range groups. Examples include the *Biological Sciences Curriculum Study* (1963), the *Physics Science Study Committee* (Finlay, 1962) and *CHEMStudy* (Merril & Ridgeway, 1969) for upper secondary schools. In the primary schools: *Science – A process approach* (American Association for the Advancement of Science [AAAS], 1963), the *Science Curriculum Improvement Study* (Karplus, 1964) and the *Elementary Science Study project* (Morrison & Walcott, 1963).

The main focus of this curriculum movement was to enhance student achievement when learning scientific knowledge with the greater aim of recruiting and training more scientists, medical doctors and engineers (De Boer, 2000). These curricula mirrored (in many cases) the point of view of scientists regarding the learning of science. The curricula mainly followed a model using a 'structure-of-the-discipline' approach in order to promote a more effective learning of science facts, concepts and theories (Eilks, Rauch, Ralle, & Hofstein, 2013). In the context of this approach, basic concepts and the structure of each discipline were chosen as the focal points of the curriculum. The main idea was to prepare more scientists so that a given society could react more competitively in science and technology. On the political level, improving science education was considered to be relevant for the competiveness of Western societies against the Communist threat during the Cold War.

The central arguments of these curricula are seen in the AAAS guidelines and its goals for science curricula published in 1962 which influenced parallel approaches in many other Western countries:

- Science education should present learners with a real picture of science, including theories and models;
- Science education should present an authentic picture of scientists and their method of research;

- Science education should present the nature of science (NOS);
- Science education should be structured and developed using the discipline approach (key concepts in each of the subjects).

Clearly, the target population of the above goals was a group of students which were assumed to represent future scientists, medical doctors and engineers. This is, however, a rather small percentage of the overall learner population in realistic terms. This still remains a large problem in the European Union and other Western countries, since only a minority of the younger generation wants to study science subjects (Jones & Young, 1995; Osborne & Dillon, 2008).

The late 1960s and 1970s

In the late 1960s and 1970s, hundreds of papers were published which discussed the fact that such an approach was only relevant for a small portion of the student population, namely the few students pursuing further education in the sciences and engineering (Osborne et al., 2003). One result was the idea of 'Scientific Literacy for All', which became a leading component in reform debates for science education in general and science curricula in particular (Hofstein & Yager, 1982; Hurd, 1970; Pella, 1967). Pella (1967) claimed that the science curricula developed throughout the Golden Age failed to include ideas and issues related to technology, social applications and interrelations between the sciences and humanities. In the words of Bybee and De Boer (1994), science education had to change so that:

> Science knowledge was to be used to answer important questions that people encountered in their everyday lives, not just to provide answers about theoretical sciences. (p. 378)

This movement emphasised the relevance of learning science for the vast majority of students who would never embark on future careers in either science or engineering. The focus shifted towards helping all pupils cope with their life worlds through an understanding of the role that science and technology plays, both in their personal lives and in society. Hurd (1970) also claimed that science needed to be taught in a context broader than the mere processes of which it is formed. He called for a greater recognition of social and personal goals, which should also be included in science teaching and learning. This interpretation of the relevance of science education for understanding the World (already mentioned in the early twentieth century by John Dewey in the USA) and the applications of science and technology remains a prime element in many curricula, especially within the context-based science curricula movement (Gilbert, 2006; King, 2012). In context-based learning, educational topics adopted from everyday life and society are used not just to provoke the situated learning of science, but also to allow students to recognise the importance of science for understanding scientific phenomena and technological issues (Gilbert, 2006). However, Fensham (1976) wrote that many of these programmes led to insufficient consideration of the societal implications and consequences of science within the resulting curricula. This is still the case today in some context-based science curricula, where the contexts of science teaching sometimes remain largely detached from their societal, ecological, and economic implications (Gilbert, 2006).

The 1980s

The 1980s were declared by many (mainly in the USA) to be 'years of crisis in science education' (Hofstein & Yager, 1982; The National Commission on Excellence in Education, 1983). The nature of the crisis was clearly visible in low levels of student interest in the sciences, which resulted in a decline in student enrolment in optional science courses, reduced the volume of practical work performed and led to vast dissatisfaction with the programmes developed from the 1950s to the 1970s. This was in fact a call for a rethinking of the goals of teaching (and learning) science (National Commission on Excellence in Education, 1983).

In their paper entitled: *Feature of Quality Curriculum for School Science,* Hofstein and Yager (1986) described the goals of school science, based on the publication of Harms and Yager (1981). That science education should:

- Emphasise science as a path to a future career;
- Include major concerns regarding science as a means for resolving current societal problems;
- Provide a means to attend to the personal needs of students; and
- Provide greater awareness of potential careers in science, technology, and related fields, including suggesting goals which are more important than those traditionally used to academically prepare for future science courses.

This set of goals reaches beyond curricula which use contexts only as a vehicle for learning science. Apart from preparing students for potential careers and helping them understand phenomena or use technology in their personal environments, the societal perspective of science education now became a new dimension for creating relevance. The resulting curricula suggested that science needs to be taught not just to prepare students for academic careers in the sciences, pupils also needed to learn how to become effective citizens in a society largely dependent on techno-scientific manifestations and applications.

In his essay, 'What counts as science education?' Roberts (1988) suggested that the objectives of secondary school science are (among others):

- To promote an understanding of the role of science in the development of societies;
- To promote awareness of the humanistic implications of science;
- To develop a critical understanding of current social problems which have a significant scientific component in terms of their cause and/or their solution (e.g. air pollution, overpopulation, improper use of chemicals); and
- To promote understanding of and development of skills in the scientific method.

The above arguments were formulated from a school policy disseminated in Alberta, Canada in the late 1970s. In addition, Kempa (1983) outlined modern chemistry education goals, which included many more facets than a simple learning of Chemistry facts and principles. He suggested that future approaches of teaching and learning the subject (as well as the development of learning materials) should include six interrelated dimensions, including a societal and technological perspective.

It has been suggested (Byrne & Johnstone, 1988; Hofstein & Walberg, 1995) that achieving scientific literacy through science curricula needs to focus on the direct relevance of science for students' personal lives and the societies in which they live. This was the first approach which understood the word 'relevance' in the sense of real-life consequences resulting for the learner. One of the manifestations of such consequences is the acceptance or refusal of science and engineering as a career choice. Another is giving individual learners the chance to contribute responsibly to societal decision-making processes. In 1982, the National Science Teachers' Association (NSTA) in the USA adopted the following new position statement for the 1980s. They declared (based on Bybee & De Boer, 1994) that:

> Many of the problems we face today can be solved only by persons educated in the ideas and processes of science and technology. A scientific literacy is basic for living, working, and decision-making in the 1980s and beyond. (p. 377)

This statement became an essential component of the modern understanding of the objectives of science education and scientific literacy in many position papers (see for example: AAAS, 1993; Fensham, 2004; Osborne & Dillon, 2008; Ware, 2001). It has been implemented in several new syllabi, e.g. Project 2061 (Rutherford & Ahlgren, 1991), and the US Science Education Standards (National Research Council, 1996).

Many science curricula based on societal backgrounds and issues have been developed in the 1980s under the following keywords and acronyms: STS (Solomon & Aikenhead, 1994; Yager, 1993), Science and Technology in Society (Holman, 1986) and Scientific and Technological Literacy for All (Holbrook, 1998). The major goal of the STS curricular movement is that science education becomes relevant for developing students' scientific and conceptual understanding, critical thinking and problem-solving skills. In the Netherlands, for example, the PLON project (Eijkelhof & Kortland, 1988) shift the emphasis of the content from a conceptual-oriented to a more STS-oriented approach. The aim was to find a balance between:

- Preparing students for coping with their future life roles as consumers and future citizens in a technologically developing, democratic society and
- Preparing students for future careers

Such skills are important for learner's individual lives and represent essential prerequisites for societal participation when it comes to decisions about science- and technology-related world issues and problems (Ben-Chaim & Zoller, 1991; Dori & Herscoviz, 2005; Hofstein & Yager, 1982). In addition, Keeves and Aikenhead (1995) stated in their review titled *Science curricula in a changing world* that:

> The relevance of science should be emphasised through greater consideration of the application of scientific principles to everyday life, technology, the production of food, and the conservation of the environment. (p. 43)

From the 1990s to date

During the 1990s, the curricular approach continued the movements of the 1980s but added a more radical focus on development and implementation. Large projects were established to connect curriculum development with bottom-up (as opposed to top-down) strategies in which high school teachers were intensively involved in the design of curriculum and its implementation (for example in Germany, The Netherlands and the UK).

Two central approaches can be identified. One is implementing context-based science education in several countries in the western world at the end of the 1990s and the beginning of 2000 'in an attempt to make the learning of science more meaningful for students' (King & Ritchie, 2012):

> These curricular developments generally strive to achieve an in-depth understanding of few key ideas instead of conventional coverage of scientific content, and attempt to enhance learning, improve the relevance of the science being taught and the engagement of students, as-well-as increase personal satisfaction for participating students. (pp. 69–70)

The second movement is a more radical development and implementation of a societal-oriented approach to science education that emerged in parallel. This approach intends to foster the relevance of science education by curricula which use socio-scientific issues in the classroom to teach about the current and future implications of science and technology on society (Marks & Eilks, 2009; Sadler, 2011). This approach is strongly connected with an opinion that achieving general skills for societal participation through science is one of the most relevant components of science education and that students should develop skills promoted by science education in order to achieve the goals of Education for Sustainable Development (ESD) (De Haan, 2006). The philosophical framework of ESD seeks to promote learning which includes reflections on the interaction of the societal, economic and ecological implications of science (Burmeister et al., 2012; De Haan, 2006; Wheeler, 2000). The common goal of both curriculum approaches is education through science for societal participation (Holbrook & Rannikmäe, 2007; Roth & Lee, 2004), instead of the rote learning of scientific facts and principles as it occurred in the 1950s and 1960s – a method which is, coincidentally, still commonly used in many countries of the World today (Hofstein et al., 2011).

Based on this historical perspective, we see that the question of relevance in science education – and the use of the term – has different dimensions and that its emphasis can change over time. There are at least three clear dimensions suggested for making science education 'relevant', which can also be combined in many various ways:

(1) Relevance for preparing students for potential careers in science and engineering;
(2) Relevance for understanding scientific phenomena and coping with the challenges in a learner's life; and
(3) Relevance for students becoming effective future citizens in the society in which they live.

'Relevance' and its alignment with interest, meaningfulness and worth

As mentioned above, for over 40 years, the term 'relevance' often used within the scope of science education and curriculum reform is still popular in debates about science education (Fensham, 2004). If one searches the Internet for a combination of the terms 'relevance' and 'science education', several of the foremost hits refer to the Relevance of Science Education survey (ROSE) by Schreiner and Sjøberg (2004). Although called a relevance survey, the ROSE study essentially focused on student interests. The authors of the ROSE study themselves admit that they used the term 'relevance' in the sense of contextual relevance when choosing potential topics to be covered by pupils. In ROSE, the authors state that they gave no clear definition and used the word interchangeably with other terms:

> The term relevance was chosen … We could have chosen other words, like meaningful, motivating, interesting, engaging, important, etc. Relevance should therefore not be interpreted in a narrow or precise sense, and we will not try to provide any operational definition of the term. It should rather be understood as an indication of an important dimension that underlies the project. Besides, we found that ROSE was nice and suitable acronym and that it calls up metaphors, analogies and mental images. (Schreiner & Sjøberg, 2004, p. 21)

Other authors also tend to interpret 'relevance' as more or less a synonym for interest (e.g. Childs, 2006; Levitt, 2001; Ramsden, 1998). As in ROSE, these authors provide examples of other synonyms which might be used. This is also mirrored by our Internet search. For the first ten hits, the search engine also provides links for 'science education' and 'importance' even though the search term was relevance. According to the results, 'importance' and 'relevance' seem to have the same meaning whenever they are associated with science teaching and learning.

Several contributions from the relevant literature take the view that relevance in science education is mainly related to the question of whether science education content accurately matches the students' real or perceived interests (e.g. Schreiner & Sjøberg, 2004). But there are also good reasons to consider 'relevance' and 'interest' as consisting of overlapping but non-identical ideas. Krapp and Prenzel (2011) describe the meaning of 'interest' and research on 'interest in science'. They separate interest from other terms like enjoyment. This is comparable to the differentiation between interest and relevance:

> […] it is important to note that interest cannot be equated with 'enjoyment while learning'. Enjoyment can occur for many reasons, and interest is only one of these. (Krapp & Prenzel, 2011, p. 30)

Indeed, some aspects of science education can be relevant without the students being interested in them (and vice versa). This claim can be seen for example in mathematics. Much of the mathematics teaching is highly relevant for the learner's future, e.g. for a later understanding of Physics and/or Chemistry or for coping with issues related to many business areas. However, many topics in the mathematics curriculum will not fall into most students' real and perceived interest categories at the time they are being taught and learned. The same might be true for science, e.g. lessons dealing with atomic structure or bonding theory. On the other hand, magic shows in which someone demonstrates experiments generally prove to be interesting, even though most pupils will never repeat the scientific experiments themselves or obtain the necessary chemicals to do so. Such magic shows can hardly be considered to be relevant simply for their entertainment value, unless raising curiosity and motivational levels among learners is considered a part of relevance. To sum up, many scientific phenomena can be enjoyable to the learner but not necessary relevant.

Meaningfulness as aligned to relevance was discussed by leading scholars from the field of general education, e.g. by Dewey, Freire, Schwab, Novak and Bruner. According to Dewey (1973), the school in the past was often unable to utilise meaningfulness in the sense of an understandable connection of the science learning with students' everyday life. He suggested that teaching should begin more thoroughly from the everyday experience of the child. Dewey claimed that unless the initial connection is made between school activities and the life experiences of the child, genuine learning and growth would be impossible. Bruner (1996) stressed the impact of culture on meaningful learning. He placed his work within a thorough appreciation of culture, which provides the children with a toolkit by which they construct not only their worlds but also the perceptions and understanding of themselves and of what they learn. Similarly, for Freire (1998), education should raise the awareness of the students so that they become subjects, rather than objects, of the world and the society they live in. This should be done by teaching the students to think democratically and continually make meaning from everything they learn, based on their culture:

> … our relationship with the learners demands that we respect them and demands equally that we be aware of the concrete conditions of their world, the conditions that shape them. To try to know the reality that our students live is a task that the educational practice imposes on us: Without this, we have no access to the way they think, so only with great difficulty can we perceive what and how they know. (p. 58)

We can find the question of meaningful learning with reference to society and culture also in the work of Schwab (1973), who suggested that any educational event involves the learner, the teacher, the subject matter and the context or the social environment. Only by taking into account these components can we develop well-organised and relevant knowledge structures with the potential for applicable knowledge in the sense of everyday coping and critical behaviour in society (Novak & Gowin, 1984).

Westbroek, Klaassen, Bulte and Pilot (2005, 2010) discussed the issue of 'meaningfulness' when trying to justify context-based Chemistry education. They suggest that making science education more meaningful has three characteristics: contextualised learning, a need-to-know approach and attention to student input. They argue that science education will become relevant to pupils, and thus motivating, if the content is embedded in a meaningful context as seen from the students' point of view. The learners must feel a need to know and have a chance to actively participate in the issue at stake.

Gilbert (2006) links the issue of relevance to the question of context-based learning and meaningfulness. He claims that the main problem with science education is that the vast majority of students do not want to study science subjects after leaving school. He suggests that this is partially based on their gloomy experiences with scientific content and contexts in their school science curricula. He also states that the perceived 'lack of relevance' among students is mainly caused by inappropriate contexts and structures chosen by most curricula. Gilbert does not differentiate between relevance in the sense of the context not fitting pupils' interests and the inability of science education to present material as worthy of being learned. He does, however, clearly refer to students' interests, thus suggesting that higher levels of the perception of relevance among students need to be better aligned with contexts and topics fitting the learners' needs. He also makes it clear that both present and future interests must be taken into account. Regarding Chemistry education, he wrote that:

> For all students, the collection of contexts used must make chemistry more relevant and enable the development of a sense of ownership of that which is to be learnt. The structure of the curriculum must be such that it, at best, resonates with students' present and anticipated interests, and, at worst, is capable of engendering interest and commitment. (Gilbert, 2006, p. 959)

The connection between relevance and interest is obviously tied to various motivational models based on learning environments. Motivational theory differentiates not only between interest and relevance but adds further components as well. For example, Keller (1983) outlined four components of successful motivation with respect to learning environments: interest, relevance, expectancy and satisfaction. Based on these four components, Keller (1987) and Keller and Kopp (1987) suggested a model of motivational design. In their model, it is important to raise the levels of attention, relevance, confidence and satisfaction (ARCS) among the learners to promote motivation.

The ARCS model sums up potential instructional techniques in the four domains that can be mixed and matched to promote and sustain motivational levels in teaching and learning (Feng & Tuan, 2005). Within this model, the perception of relevance should be promoted through strategies which include informing the learners exactly how new material will be of use in developing already-existing skills. It should be made clear why a given topic matters for current learning and how it will eventually match the learners' future needs. The learner should also understand what can be accomplished with the new knowledge, e.g. allowing 'learning by teaching'. Pupils should also be given the option of organising their work load based on their personal interests and prior skills. Relevance in Keller's model means much more than just satisfying students' present interests and curiosity or explaining the meaningfulness of specific knowledge. Keller (1983) defined six components of relevance with regard to learning environments: experience, present worth, future usefulness, and needs matching, modelling and choice. The points of future usefulness and matching learner needs shows that there can be future relevance which may (or may not) be in the pupils' present and perceived interest.

Other models based on motivation express the same thoughts but use different terminology. In their Six C's Model of Motivation, Turner and Paris (1995) described the components that can motivate students: choice, challenge, control, collaboration, construction of meaning and consequences. In this model, the last C (Consequences) leads our discussion one step further because consequences can be interpreted beyond the influence of learning as a change in cognitive abilities.

Turner and Paris suggested that connecting learning to positive consequences can motivate the learner even more, e.g. rewards, praise, successfully completed experiments or highly-desired end products. Such consequences suggest that there might be more than an intrinsic component in the term relevance, as suggested for example by Holbrook (2008), and that this intrinsic component can be understood as more than an interest in a subject area or context. Rewards and praise form an extrinsic part of motivation in the sense of positive reinforcement. It has been suggested that extrinsically motivated components existing beyond students' immediate range of perception can also play an important role. For example, parents and educators purposely try to keep pupils' career chances open by fostering them to complete all necessary courses or achieving high enough grades to later be allowed entering specific academic programmes.

The idea of connecting worth (or positive consequences) to the idea of relevance beyond the basic idea of meaningfulness is also presented, among other places, in the outline of the PARSEL project (EU, FP7 programmes) by Holbrook (2008). This project also makes it clear that the term relevance can have different meanings, both intrinsic (felt by the student) and extrinsic (provided by the curriculum, parents, teachers and examinations).

So far, relevance in the sense of consequences has been mainly aligned with affecting student cognition. Such a definition was given in the relevance theory of Sperber and Wilson (2004):

> […] any external stimulus or internal representation which provides an input to cognitive processes may be relevant to an individual at some time. […] According to relevance theory, an input is relevant to an individual when it's processing in a context of available assumptions yields a positive cognitive effect. A positive cognitive effect is a worthwhile difference to the individual's representation of the world: a true conclusion, for example. False conclusions are not worth having […] (p. 608)

However, beyond Sperber and Wilson (2004), 'consequences' can also be interpreted as real effects on the conditions of students' life and beyond.

With respect to developing countries, Knamiller (1984) discussed the relevance of science education for economic development of a society. His interpretation of the idea of the relevance of science education is directly connected to real-life effects, e.g. increases in economic growth and societal wealth. This is an idea which – under the inclusion of an ecological component – is central to the current ESD movement (Burmeister et al., 2012; De Haan, 2006).

Thus far, it appears that any definition or meaning applied to the term relevance remains quite diffuse when used in the rhetoric of science education and curriculum reform. Twenty-five years ago, Newton (1988a) described England's school curriculum suggesting that teachers are required to teach 'relevant' science. His concern was that the curriculum descriptors did not really define what this meant. According to Newton (1988b), relevance means reflecting upon the trio of concerns related to products, processes and people. Knamiller (1984) connected his perceptions regarding relevance to the question of consequences and fulfilling of personal needs. Together with the more recent literature discussed so far, the use of the term relevance and its connection to other socio-psychological terms in the science education literature can be grouped in five main categories, even though distinctions between them is not always clear and very often different papers overlap the different meanings of the term:

(1) Relevance used as a synonym for student interest (Childs, 2006; Ramsden, 1998; ROSE, 2004)
(2) Relevance used as students' perception of meaningfulness for understanding contexts connected to their lives (Gilbert, 2006; King, 2012; Lyons, 2006; Mandler, Mamlok-Naaman, Blonder, Yayon, & Hofstein, 2012).

(3) Relevance connected to student needs, which is used as a synonym for importance, usefulness or needs-matching (Keller, 1983; Simon & Amos, 2011).
(4) Relevance viewed in the sense of real-life effects for individuals and society, e.g. in terms of growing prosperity and sustainable development by the application of science and technology to societal, economic, environmental, and political issues (De Haan, 2006; Hofstein & Kesner, 2006; Knamiller, 1984).
(5) Relevance viewed multi-dimensionanally and applied as a combination of selected elements borrowed from categories I–IV (Aikenhead, 2003; Kahl & Harms, 1981; Newton, 1988a, 1988b; Rannikmäe, Teppo, & Holbrook, 2010).

Based on this analytical approach, we suggest applying the idea of relevance to science education with more thorough attention to the idea of consequences. These consequences of 'relevance' can be much broader than simply meeting the perceived interests or desires of the learner or to influence the learners' cognitive development. Consequences also encompass real impacts in a socio-economic means, on the students' physical and material life (today and in the future). Also, these consequences need to be taken into account when the question of relevance of science education is raised. This more open view, coming from the idea of considering consequences, suggests potential dimensions that the question of relevance of science education might encompass. Based on the historical reflections discussed above, we have already seen that there can be different fields of consequences where science education or a lack thereof will be of relevance, e.g. skills for acting in society or abilities to get a well-paid job in the workplace. However, it is not clear at this point whether this list is comprehensible or what a coherent model including the different dimensions might look alike. Therefore, the question of the dimensions of relevance of science education will be discussed in the next section.

Dimensions of 'relevance' in science education

Based on a comprehensive review of the literature, we can identify various dimensions and interpretations for the use of the term relevance in science education. Different organising factors are also suggested, e.g. what is considered to be relevant, to whom, at what time and/or who decides this. Theoretical answers can be obtained from two areas: the area defining the general aims and orientation of education and the area of science education itself.

Two theories seem specifically important for clarifying the dimensions of the term 'relevance' when it comes to a general justification of education. One is the central European tradition of *Allgemeinbildung* (Klafki, 2000a) which has achieved increased levels of recognition in the international educational literature in recent years (Elmose & Roth, 2005; Fensham, 2004; Hofstein et al., 2011; Sjöström, 2011). The second is Activity Theory and its reflections on the definition of general objectives for education (Holbrook & Rannikmäe, 2007; Roth & Lee, 2004; Van Aalsvoort, 2004).

The idea of *Bildung* and *Allgemeinbildung* is a unique, 200-year-old, Central European tradition of defining the overall aims of education. The basic idea is achieving an understanding of the overarching aims of education, thereby making education personally valuable to the learner and dovetailing with the learner's needs for today and the future. Within Allgemeinbildung, the word 'Allgemein' (which can be translated as 'general') has two dimensions. The first means achieving *Bildung* for everyone. The second dimension aims at *Bildung* in all areas of human endeavour (Klafki, 2000a). A more difficult term to explain is the concept of *Bildung*. Our contemporary understanding stems from the 1950s to the 1970s where Allgemeinbildung was described as an ability to recognise and follow one's own needs in society and to be able to behave as a responsible citizen within society. Klafki (2000a) operationalised the latter into an understanding of students' capacity for self-determination, participation and solidarity within the society. From the idea of Allgemeinbildung, Klafki and others developed a tool called Didactical Analysis to decide whether a topic or issue should be taught in compulsory formal education (Klafki, 2000b). Didactical Analysis consists of a set of questions. According to Klafki, the most important questions reflect on whether learning a topic actually has meaning for the learner at present or in the future. This includes possessing the potential for raising learners' capacity for self-determination, participation in society and solidarity with others.

By using the Allgemeinbildung approach, we can see that relevance of (science) education can be defined as a matrix split into the dimensions of time and goal. Education can be relevant if it is meaningful and has positive consequences for the learner – be it today or in the future. Meaningfulness and consequences can arise from individual interests and needs, but they can also be created at the societal level. Education should prepare the young generation to become critical and responsible citizens being able to behave well in society and contribute to society's development. That also means that justifications for relevant education can be given which do not lie in the actual and perceived interest of the students but might be defined by educational theory or a consensus within society about what a student should know and which skills and abilities are expected from him or her when graduating from formal school education.

Part of the latter justification from Allgemeinbildung, the preparation of students to find their place in society and develop the necessary skills to act responsibly in society (today and in future), is also at the heart of applying Activity Theory to reflect on the relevance of science education (Holbrook & Rannikmäe, 2007; Roth & Lee, 2004; Van Aalsvoort, 2004). *Activity Theory* tries to operate in the area between knowledge and social practices. This is done by:

> […] interlinking of knowledge and social practice through establishing a need (relevant in the eyes of students), identifying the motives (wanting to solve scientific problems and make socio-scientific decisions) leading to activity constituted by actions (learning in school towards becoming a scientifically literate, responsible citizen). (Holbrook & Rannikmäe, 2007, p. 1353)

Based on the philosophical work of Leont'ev (1978) regarding *Activity Theory*, van Aalsvoort (2004) derived her understanding of relevance of science education from societal and thus cultural historical perspectives. This means that learners should be able to apply relevant practices in society in order to behave as educated citizens. The learners, from a personal perspective, need to understand the behaviour of expert persons in society that the students can identify themselves with actors in society and thus become able to develop own motives for action. Similar ideas can also be found in the works of Roth and Lee (2004). They added the idea of autonomy: a critical and responsible citizen can only contribute to society if he or she develops the necessary skills to act autonomously and self-directed. This has not only consequences for the science curriculum but also for the related pedagogies.

Conceptualising the two dimensions of individual learning and preparation for societal participation in science education can also be derived from the idea of Scientific Literacy (Bybee, 1997a). This notion is currently more than 40 years old (De Boer, 2000; Holbrook & Rannikmäe, 2009). Although the idea of scientific literacy is not unanimously agreed upon (Shamos, 1995), the concept has become a leading goal of science education policies worldwide. The Organisation for Economic Co-operation and Development (OECD, 1998) has defined scientific literacy as the common basis for the Programme for International Student Assessment (PISA; Bybee, Fensham, & Laurie, 2009). The OECD (1998) provided the following definition:

> Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (p. 5)

Roberts (2007) and Holbrook and Rannikmäe (2009) made clear that scientific literacy in the terms of PISA goes beyond the original concept of 'science literacy'. According to Roberts (2007), science literacy means having sufficient scientific knowledge to be able to understand scientific texts and/or literature. Holbrook (2005) made an even more radical claim when he wrote that the understanding of 'science literacy' as knowledge base in science might not be the most important component within scientific literacy:

> The stress on conceptual understanding and the appreciation of the NOS tends not to be relevant for functionality in our lives, i.e. relevant to the home, the environment, future employment and most definitely for future changes and developments within the society. (p. 1)

Holbrook (2005) suggested that scientific literacy needs to be built upon more aspects than merely scientific knowledge. Extensive literature exists on the broader meaning of scientific literacy (Eilks, Nielsen, & Hofstein, in press; Holbrook & Rannikmäe, 2009). The NSTA (1991) in the USA defined four dimensions of scientific literacy: an intellectual, attitudinal, societal and interdisciplinary dimension. Nearly every contribution to the debate on the meaning of scientific literacy – and thus relevant science education – emphasises the need for a societal component in addition to the personal domain of knowledge and skills development (Hofstein et al., 2011). This societal component encompasses all of those skills necessary for dealing with both science- and technology-related interests and societal debates (Holbrook & Rannikmäe, 2009).

A more concrete example was presented by Shwartz, Ben-Zvi, and Hofstein (2006), who attempted to define 'chemical literacy'. They identified four areas related to this concept. Chemistry education can be considered relevant if it promotes a balanced contribution of individual skills development. It must also aid learners in coping with their individual life. Education must also foster the individual's skills in dealing with any aspects related to the appearance and use of science, including related applications in society as a whole.

Thus, altogether, individual interests, needs, and worth can generate relevance for an individual to participate in any learning activity. However, there is also a range of external justifications (or factors) which demand that pupils learn specific subject matter content or enrol in specific coursework.

Thus far, the discussion has been based mainly on the assumption that relevance in the context of science education should be approached from the perspective of the learner. The question of relevance might also be approached quite differently. Are learners the only ones who should decide what is relevant in science education? Ratcliffe and Grace (2003) suggested that society should consider science education in terms of both a future skills-based society and effective, responsible citizens. As already discussed in the introduction, there are many stakeholders in the educational arena having interest and influence on the topics and objectives science education should follow. The stakeholders who control the economy, for example, will tend to emphasise the relevance of science education with regard to enhancing young peoples' interest in entering into careers in science and technology. One problem remains, however: young people generally do not see any 'sense' in science subjects and drop science courses as quickly as they can in school. Young and Glanfield (1998) described it like this:

> The most frequently [reasons] referred to are that studying science no longer leads to a clear range of future careers and that the sciences are not sufficiently concerned with human and social issues. However, the natural sciences are no less 'humanities' – they are the product of human actions and purposes – than literature or the social sciences. The problem is that in the subject form in which they make up the existing curriculum, their original sense of human purpose is often lost, at any rate from the point of view of students. (p. 16)

In addition, science should prepare pupils for further training and later employment. The above discussion begun by Knamiller (1984) has already raised this point from the perspective of developing economies. Sustainable development for the future and a prosperous economy are also considered relevant by many parents, since their common priority is in helping their children to achieve successful careers and futures. Newton and Newton (1991) have already suggested that:

> Science teaching needs to include in its domain not just a concern for immediate needs and motivation but also the relevance of science for adult life. (p. 44)

The question of future value is directly connected to a question posed by Aikenhead (2003) based on Fensham (2000) namely: 'Who decides what is relevant?' He gives seven different heuristic categories of experts (that might overlap to varying degrees) for making decisions about what should be considered relevant (Table 1). These categories also show the different intrinsic and extrinsic components of relevance. Intrinsic relevance is represented by personal curiosity (or interest) of students, while extrinsic relevance is defined by all other stakeholders. 'External' experts (such as science educators, policy-makers, etc.) can exert a large amount of influence on an upcoming curriculum. Considering these heuristic categories in connection with the above outlined understanding of relevance of science education might allow us to better reflect upon and plan exactly how curricula are developed. Contemplating curriculum development from this viewpoint might allow us to understand why coursework is often perceived by students as being totally

Table 1. Heuristic categories of different experts who decide what is relevant? (Aikenhead, 2003; based on Fensham, 2000).

Heuristic category	Who decides what is relevant?
Wish-they-knew science	Academic scientists
Need-to-know science	Curriculum policy-makers and researchers
Functional science	Science-based industries and professions
Enticed-to-know science	Mass media and internet
Have-cause-to-know science	Economics, public health experts (those who deal with real life matters)
Science-as-culture	Experts in the area of cultural aspects
Personal curiosity science	Students

irrelevant (Holbrook, 2008). It has been suggested that the current curriculum approach has also contributed to the fact that science teaching is often viewed as inappropriate and lacking in job focus by future employers.

These general thoughts on (science) education fit several concrete organisational schemes for understanding the dimensions of relevance as suggested in the literature which has appeared since the early 1980s. Schollum and Osborne (1985), Newton (1988a, 1988b) and Harms and Yager (1981) all made attempts to characterise the relevance of science education by suggesting different dimensions. Schollum and Osborne (1985), for example, suggested three aspects of relevance: relevance for everyday events, relevance for pupils' existing ideas and relevance for human relationships. These considerations are quite similar to the ideas of scientific literacy discussed above. Newton (1988a) and Kahl and Harms (1981) presented a new aspect of the term relevance, which is not always present (or even very explicit) in common, definitions of scientific literacy: A vocational dimension (see also Hurd, 1998). Kahl and Harms (1981) suggested four clusters of goals for justifying the relevance of science education. These include relevance not only for personal needs and societal issues, but also for career education/awareness and academic preparation. This broad field covers both intrinsic and extrinsic components. The intrinsic dimensions encompass students' interest in specific topics and also their interest in being rewarded and praised as successful learners by their teachers or parents. The latter aspect can also belong to extrinsically motivated relevance. The extrinsic dimension includes outside expectations regarding the personal environment of the learner, e.g. by parents, future employers or social institutions which might have influence on the student's career.

As mentioned earlier in this paper, relevance can also mean the importance of scientific learning for economic growth as a prerequisite for societal wealth. Regarding this point of view, Knamiller (1984) made it clear that justifying education using 'relevance' as an argument will remain difficult as long as no universal definition is available. He suggested that developing countries should differentiate between 'outside observers' and 'inside consumers'. This is an important contribution, since it makes it clear that the relevance of science education is always connected to the socio-economic circumstances in which the learner lives. Knamiller wrote:

> For the 'outside observer', those who do not have children in the common Third World community school, educational relevance is a direct assault on the basic needs issue and even unemployment. […] To the 'inside consumer', the children, parents and teachers who inhabit local community school, however, educational relevance is viewed as an indirect path to improving life. Success in the traditional academic curriculum leads to a modern sector wage-paying job with money flowing back to enable the family to improve its lot. (p. 61)

Eilks et al. (in press) integrated all these approaches by suggesting the following three dimensions for relevance in science education: An individual, a societal and a vocational. These same three dimensions were found in the analysis of the history of curriculum reform in science education as described above. Van Aalsvoort (2004) has similar views on relevance. He summarised these in three dimensions: personal relevance, professional relevance and societal relevance. Additionally, as we have already seen in the previous section, many interpretations of relevance cover both intrinsic and extrinsic components, as well as the aspects of present and future meaning. Bringing all these arguments together, we suggest three basic dimensions of relevance of science education, with each having a spectrum from present to future worth, and from intrinsic to extrinsic points of view:

- The individual dimension: the relevance of science education for the individual encompasses matching the learners' curiosity and interests, providing students with necessary and useful skills for coping with their everyday lives today and in the future, and contributing to the development of intellectual skills.
- The societal dimension: the relevance of science education from the societal viewpoint focuses on preparation of pupils for self-determination and a responsibly led life in society by understanding the interdependence and interaction of science and society, developing skills for societal participation and competencies for contributing to society's sustainable development.
- The vocational dimension: the relevance of science education in the vocational dimension is composed of offering orientation for future professions and careers, preparation for further academic or vocational training and opening up formal career chances (e.g. by having sufficient coursework and achievements to enter into any given higher education programme of study).

These dimensions are not necessarily independent; they are interrelated and partially overlap each other. For example, career orientation can either match personal curiosity or it can provide an answer for a demand for more scientists and engineers in the future. The latter is directly linked to the idea of the prosperous, sustainable development of society. Additionally, it is also clear that the different dimension have a different emphasis at varying school levels. Where the individual dimension might be the most important on primary level, the societal dimension may be very important at lower secondary level before compulsory school education ends. But even within the dimensions there might be a shift in emphasis (Newton, 1988b). Wherein the vocational dimension the preparation for further learning might be important at every level, career orientation might have the biggest emphasis in the age of 12–16 years where students really have to decide which career pathway they intend to enter. This aspect will be discussed in further details below.

Suggestions for modelling the term 'relevance' in science education

From the analysis of the literature, we tried to make clear the different meanings and also where the meaning in the use of 'relevance' in science education is broader than the meaning of other terms like 'interest' or 'meaningfulness'. We also found different dimensions (individual, societal, vocational) as well as present–future and intrinsic–extrinsic components. Bringing all these issues together, a common model can be derived that covers most of the issues posed in the science education literature. Such a model offers more clarity in the debate on reform in science education since it articulates the parallels and distinctions with other constructs, like interest or meaningfulness. It also provides a basis for modelling the different dimensions of relevance in science education. Such a model would be of benefit for analysing different curricula to whether they support the different dimensions in a balanced way, but also for deciding about new curricular developments concerning their focus or balance between the varying aspects of relevance of science education. From the discussion above, we suggest that relevance with respect to science education should be defined as follows and illustrated in Figure 1:

- Science learning becomes relevant education whenever learning will have (positive) consequences for the student's life.
- Positive consequences can include:
    - ○ Fulfilling actual needs related to a student's personal interest or educational demands (of which learners are aware), as well as

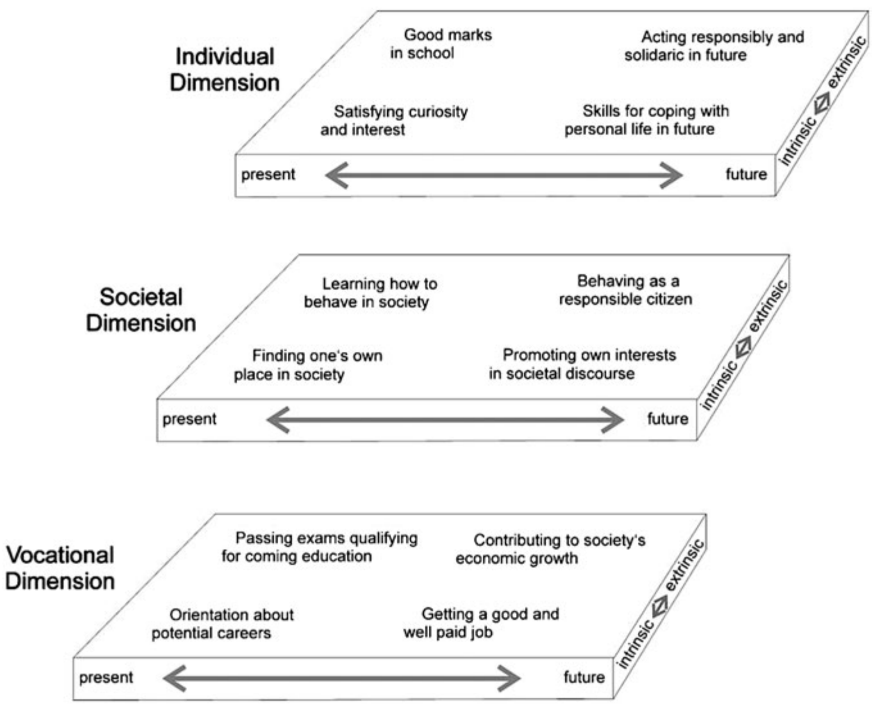

Figure 1. A model of the three dimensions of relevance with examples of aspects allocated in the span of both the present–future and the intrinsic–extrinsic-range.

    ○ The anticipation of future needs (of which students are not necessarily aware).

- Relevance in science education covers both intrinsic and extrinsic components. The intrinsic dimensions encompass student's interests and motives; the extrinsic dimension covers ethically justified expectations of one's personal environment and the by the society in which they operate and live.
- Relevance can be considered to consist of three different dimensions: individual, societal and vocational. For science teaching, this means that relevant education must contribute to pupils' intellectual skill development, promote learner competency for current and future societal participation and address learners' vocational awareness and understanding of career chances. Each of the three dimensions encompasses a spectrum of present and future aspects.

It is suggested that it is vital to make the idea of 'relevance' more manageable for both the science curriculum developers, the science teacher and for classroom teaching practices (Newton, 1988a). It can be helpful for teachers to actively analyse their lesson plans and curricula with respect to the different dimensions of relevance. The model given in Figure 1 can act as tool for science education. Educational research needs to encompass such questions as 'How do teachers personally view relevance?' We also need to reflect upon students' perception regarding the notion of relevance (e.g. learning materials). In addition, it is also possible to focus on other aspects when using this model. For example, it can be used as a tool for analysing the topics and contexts found in science curricula to determine their educational effectiveness.

The authors of this manuscript have used the definition and model in seminars in initial and in-service teacher training. The ideas presented in this section were used for both reflecting on the objectives of relevant science education and also on analysing different curriculum approaches and models such as: conceptual approach (structure-of-the-discipline), history-and-philosophy-of-science lessons, context-based science education and/or socio-scientific issues-based science teaching. Using the model that is presented in Figure 1 for the purpose of analysing different science curricula (and their related textbooks) enables identifying (and highlighting) the strengths and weaknesses of the different curriculum approaches related to various components and levels of relevance.

Different approaches to science curricula and the issue of relevance: applying the model

It is reasonable to assume that every curriculum is based on a specific understanding of what makes science learning relevant. This is close to the idea of the curriculum emphasis explored and described by Roberts (1988). Roberts reviewed North American science curricula covering a time span of almost one hundred years. Apart from the specific content addressed, he found that every curriculum contained a set of hidden messages about science itself – a message the curriculum designers seem to consider being 'relevant' to be transmitted to the students. He (Roberts, 1982) called this the 'curriculum emphasis' and described it as:

> … a coherent set of messages about science (rather than within science). Such messages constitute objectives which go beyond learning the facts, principles, laws and theories of the subject matter itself - objectives which provide answers to the student question: Why am I learning this? (p. 245).

This emphasis points to the type of relevance which the learning of science suggests within a given curriculum. Examples included an emphasis on everyday coping (which focuses on part of the individual dimension of relevance), science and technology decisions (focusing on part of the societal dimension) and providing a solid career foundation (part of vocational relevance).

Roberts (1988) wrote that the different curriculum emphases do not exist in a vacuum. They often change with time and can be combined in new permutations which encompass completely new meanings. Nevertheless, such factors allow us to reflect upon the issue of relevance in differing science curricula. Van Berkel (2005) updated Roberts' study (1982) and examined the idea of curriculum emphases in more recent curricula. Focusing on Chemistry curricula, van Berkel refined the original seven emphases described by Roberts and melded them into three more general ones: fundamental Chemistry, knowledge development in Chemistry and Chemistry–Technology–Society. This distinction has parallels in the teaching domains of Biology and Physics. Van Berkel's study made it clear how curriculum emphasis directly influences science learning with respect to the different dimensions and domains of the relevance presented above.

De Jong (2006) presented a similar approach characterising different domains which offer textual approaches towards science learning in chemistry education:

- The personal domain: connecting chemistry with the student's personal life.
- The professional practice domain: providing information and background for future employment.
- The professional and technological domain: enhancing the learners' understanding of science and technological applications.
- The social and society domain: preparing the pupil to become a responsible citizen in the future.
- Understanding of career opportunities

The approach presented by De Jong solidifies the idea that the starting points selected for teaching science will automatically focus the lesson plan on a specific area (or at least emphasise specific areas) when it comes to relevance.

The ideas based on Roberts, Van Berkel and De Jong can be connected with the above described model on relevance with the goal in mind to reflect on the question of relevance of different basic types of science curricula. Eilks et al. (2013) (based on Van Berkel (2005) and De Jong (2006)) described different basic orientations/ approaches that can be found in science curricula. Several of these were partially discussed in the section related to the historical developments of relevance in science education in this review paper. The paper outlined the following orientations: (I) the structure of the discipline, (II) the history and philosophy of science, (III) context-based science education and STS, (IV) socio-scientific issues-based science education and (V) interdisciplinary and *ESD*-type curricula. All of these basic curriculum approaches encompass an extremely broad range of interpretations in their underlying theories, in the example materials provided and, of course, the translation of topics into concrete teaching practices in the different countries. However, the basic justifications of the various curricula fall closely in line with the different dimensions of relevance suggested by the model presented in Figure 1.

Curricula organised along the ‘structure of the discipline’ approach (e.g. CHEMStudy; Merril & Ridgeway, 1969) focus primarily on learning scientific facts and theories, including how the different academic science domains are structured and presented to learners. Approaches of this type of curricula attempt to achieve relevance by offering learners a promising basis for future learning in the field of science. They also express a desire to prepare the student for further academic studies in the respective scientific discipline. Within the individual dimension, such curricula will fulfil the interests and curiosity of pupils who are intrinsically motivated in the particular science domain. Regarding the vocational dimension, this approach might present the best option for demonstrating to school students what they can expect, if they plan to embark on future academic careers in an area of science. However, this approach largely neglects the societal relevance of science and the broad spectrum of possible science careers beyond academic research. Often, this aspect is relegated to the fringes of the curriculum without directly being related to the assessment of students’ achievement and progress (Eilks et al., 2013).

Science curricula that use the history and philosophy of science generally focus on learning the most essential theories of science (see Matthews, 1994) (focusing on stories) like the historical development of the model of atomic structure. This approach attempts to contribute to an understanding of how science functions as an intellectual endeavour (the NOS). The approach is relevant for a vocational orientation of the students since it can influence whether or not science might be a potential field for future academic studies. However, using the history of science as an integral part of the science curriculum is often justified as a support for problem-based, meta-cognitive learning (Teixeira, Greca, & Freire, 2012). In other words, it is intended to be relevant for the individual in the development of higher-order learning skills such as problem-solving capabilities. It has been suggested, however, that this approach is insufficient. It often lacks sufficient consideration of the contemporary and future societal relevance of science, contains no broad vocational orientation, and neglects the most important vocational preparation relevant for the majority of the learners.

Context-based (and STS-type) curricula operate in a wide range of contexts in order to provide meaningful situations to support the learning of science, e.g. the SALTERS curricula in the UK or ‘Chemie im Kontext’ in Germany (King, 2012). Such curricula try to contribute to relevant science education by clarifying the role of science and its related applications in the everyday lives of the pupils. With respect to the selected contexts, context-based education has potential for contributing to vocational orientation and promoting learning in the societal dimension of science. It is assumed that this approach provides learners with opportunities to learn structured scientific knowledge, thus giving them a starting platform for more advanced scientific learning. Therefore, context-based curricula contribute to all three relevance dimensions. However, the overall contributions to each dimension and their respective weighting can vary significantly regarding the chosen contexts and their aligned pedagogies (Gilbert, 2006).

Hofstein and Kesner (2006) suggested a specific approach for widening context-based science teaching. They recommend connecting science teaching with businesses and industry applications. This would highlight the interconnectedness of science, the economy and society, thereby offering students valuable insights into possible career chances in science and technology. This extension of context-based science education falls in line with the theoretical foundations of the so-called 'socio-scientific issues-based' science curricula (see Sadler, 2011). This approach to teaching clearly expresses a wish to make the social dimension of science and its applications a central aspect of classroom teaching. Authentic and controversial issues and debates derived directly from current social affairs should be employed to promote interest among pupils. These topics, however, should not only represent starting points for learning, but should also be the focus for the subject-matter content of the lessons. This approach not only broadens the contents and objectives selected, but also widens the spectrum of pedagogies implemented (Eilks et al., in press; Hofstein & Kempa, 1985). It is necessary to discuss and develop skills for handling these debates in society – all within the scope of teaching science (Marks & Eilks, 2009, 2010; Sadler, 2011). This type of curriculum is most effective in achieving the goals of discipline-oriented ESD (Burmeister et al., 2012). ESD curricula consciously aim at providing students with skills necessary for participation in social debates and decision-making for sustainability (De Haan, 2006). In this view, this is the essential component which makes science education or any other domain of education relevant to individuals and the society in which they live. The example from Hofstein and Kesner (2006) quoted above can also be viewed as a socio-scientific issues-based curricular approach, because it connects science related context and societal issues related to technical applications in industry and businesses, while simultaneously allowing a vocational orientation.

Finally, a more radical approach regarding socio-scientific issues-based science education, Marks and Eilks (2009) and Eilks et al. (in press) recently readdressed the question of relevance. They posed the question of what exactly turns such societal contexts into 'relevant' socio-scientific issues in the student's opinion. Following the ideas in Sadler (2004), Marks and Eilks (2009) found that the most fruitful topics for teaching and learning about science in society consist of authentic societal debates having personal relevance to the student and possessing controversial characteristics. Marks and Eilks (2009) suggested a more thorough consideration of the respective contexts as an initial point for relevant science teaching. This can take place by using authentic societal debates which have varied and contradictory standpoints actively reported by the press. Criteria for topic selection and suitability testing include: (1) authenticity, (2) relevance, (3) an outcome yet undetermined by social consensus, (4) topics allowing open discussion, and (5) issues dealing with questions based on science and technology (Eilks et al., in press). Concerning relevance, the authors suggested defining the relevance of socio-scientific issues via the resulting consequences. A topic is therefore relevant if 'any societal decision on it will directly impact the lives of the students, either today or in the future'. They suggested the following for proving potential contexts: 'Scenarios must be outlined where societal decisions on the different alternatives for action will impact students' lives today or in future, e.g. concerning restrictions on personal consumption or options for action'.

The choice of a particular approach or the emphasis placed on a specific part of the science curriculum needs to be carefully reflected upon with a view towards the students, their interests, needs and potential future career opportunities. This should take into account not just the personality of the student, but the students' age group

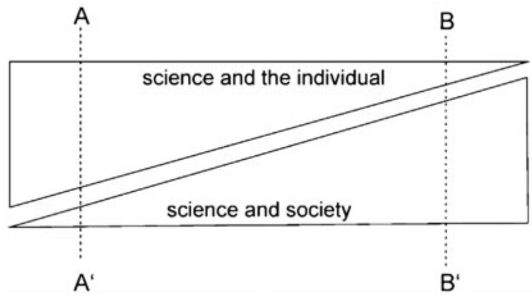

Figure 2. Emphasis on different dimensions of relevance in the science curriculum (based on Newton, 1988b).

as well. Newton (1988b) has already suggested that the relative balance between individual relevance and societal relevance in the curriculum needs to change over time. The individual dimension might be more important for younger children, but this importance will shift towards societal relevance as the child grows and matures (Figure 2). However, exactly how such change needs to happen will differ in the sub-domains which each of the relevant dimensions possesses. Newton argues that science curricula for younger children should be more balanced along the line AA' shown in Figure 2, whereas more mature students might require science curricula located along line BB'.

Additionally, the sub-dimensions for vocational relevance will also undergo change over time. Solid preparation for further learning is equally important over the entire range of schooling. However, its overall meaning and importance will increase, especially at junctions where the learner transitions from one educational level to another. Relevance can also decrease once a student has consciously decided not to choose a career in the sciences. Learning science to keep formal career chances open will grow with time since transition mechanisms and knowledge requirements become more selective with increasing educational levels. Finally, vocational orientation may not play an important part in primary education. It is important in lower secondary school because students have to decide about their job future. At higher levels of education, it will again fade into the background details.

Inhibitors for effective implementation of relevance in teaching science

There are several factors that inhibit the effective implementation of teaching and learning materials which contain a balanced presentation of the different relevance dimensions. The societal dimension is particularly neglected by many curricula in different countries (Hofstein et al., 2011; Hughes, 2000). It is beyond the scope of this manuscript to elaborate on all these factors, but it is worthwhile to briefly mention them in order to obtain an objective and comprehensive picture regarding the issue of relevance.

One of the most central factors inhibiting effective implementation is a teacher's personal beliefs. Teacher beliefs are thought to be the most influential factor regarding why and how educators behave and make decisions in the classroom (Bandura, 1986). However, these beliefs are usually not developed systematically based on empirical evidence. They can, however, become barriers to the effective implementation of different content, instructional techniques and pedagogical interventions. They may also result in the perpetuation of traditional teaching practices (Goodman, 1988; Lumpe, Honey, & Czerniak, 2000; Pederson & Totten, 2001).

A recent survey conducted in the USA (Luft, Ortegaz, & Wong-Kavas, 2009) showed that a high percentage of science teachers strongly support the incorporation of more real-world issues into the classroom in order to increase the relevance of science education. However, this does not automatically lead to the situation where the societal dimension of socio-scientific issues becomes an equally recognised partner in the science curriculum orientation. The teachers' positive response does not receive enough support from their immediate professional community. Approaches like socio-scientific issues-based science education, context-based science education and opening broader, more comprehensive career orientation and preparation aspects remain scarce. Such approaches are unfamiliar to the traditional academically-oriented teacher of physics, chemistry, biology or engineering (Hofstein et al., 2011). Although some teachers already possess positive attitudes towards a stronger inclusion of societal-oriented science education, they often fail to implement such issues in their own teaching due to lack of imagination, support and scaffolding (Pederson & Totten, 2001).

Another inhibitor is student assessment regarding their achievement and progress in the sciences (Holbrook, 2005; Sadler & Zeidler, 2009). Even if science is taught through context or socio-scientific issues with genuine attempts to cover broad components relevance of science education, students often continue to be assessed by their teachers using traditional, concept-oriented, paper-and-pencil tests. Hughes (2000) wrote (based on the SALTERS curriculum in the UK) that students often marginalise the socio-scientific dimension of learning if the structures and language of texts and classroom practices are not aligned with a context-based approach. This factor is necessarily aligned with traditions and practices concerning external examinations, in which the systems often neglect the societal and vocational dimensions in favour of pure science content. Thus, unique and authentic assessment methods aligned with the goals, pedagogical approaches and contents of respective approaches are also necessary to make such approaches successful (Holbrook, 2005). The literature contains many valuable strategies for effective implementation of socio-scientific issues in the science classroom (e.g. role-playing, drama, business games, debates, or simulating political decision-making (Eilks et al., in press; Feierabend & Eilks, 2011; Marks & Eilks, 2010). However, the picture is rather gloomy with regard to the development of assessment tools aligned with the philosophical features described here (Hofstein, Mamlok-Naaman, & Rosenberg, 2006).

Assessment is also influenced by universities and central examination boards. Both are very influential regarding the issue of how science is taught (regarding content and methods) and how students are assessed (Fensham, 1993). As a result, teachers quite often teach purely scientific concepts using a content-structure-driven, teacher-centred approach while tending to omit or diminish any student-centred strategies for teaching the relevant societal aspects. We need to be aware that teachers themselves are products of the same system. They often never had the opportunity to experience open, social or vocationally-oriented curricula aligned with alternative forms of assessment for themselves, either in school or as university students and as teacher trainees. Their previous experiences with the traditional approach operate as a filter and inhibitor for their present teaching and learning practices (Goodman, 1988).

Summary and conclusions

In this paper, we have shown that the use of the term 'relevance' in science education is widespread and multi-faceted. We can say that it is unclearly defined. In other words, 'relevance' in science education is used in various ways and is often used synonymously with other educational concepts.

We have already made several suggestions for conceptualising and operationalising the term relevance in science education. These suggestions intend to differentiate between a perception of relevance which merely overlaps students' interests and a perspective which contains other areas of relevance, e.g. those justified by economical needs and/or defined by societal interests. We propose that without such distinctions (and definitions) usage of the functions and descriptions associated with the term relevance will remain confusing and subjective. The definition of 'relevance' we have chosen to employ possesses a multi-dimensional character (not just the perspective of learner needs and interests). It was demonstrated and described above why exactly there is a need to differentiate between intrinsically (or internally) motivated perceptions of relevance and extrinsically (or externally) justified perceptions. Clearly, relevance contains different major dimensions, namely those stemming from the individual, societal and vocational realms. All of these dimensions are part of a broader field covering both intrinsic and extrinsic components which have value for both the present and the future.

Reflection upon the issue of relevance and its different implications for various learners needs to have an impact on science curricula and teaching practices. Diverse curriculum-related orientations are available in the literature and can be easily implemented with different objectives in mind. These curriculum-related orientations, however, do have different strengths and weaknesses in terms of the contribution they can make to the dimensions of 'relevance' stipulated above. Structure-of-the-discipline-based curricula are strictly aligned with the guided acquisition of knowledge in order to prepare learners for further science studies. Historically-oriented approaches are possibly more strongly linked to intellectual challenges, whereas everyday life-oriented approaches can perhaps better instil practical appreciation of knowledge for use in pupils' everyday environments.

Context-based curricula attempt to combine these three foci. They evidence particular potential for acquiring applicable, subject-related knowledge in situations encountered in everyday life and in society (Gilbert, 2006). It has been suggested that inclusion of real-world problems emphasises the interdisciplinary nature of the sciences and their relevance to students (Mandler et al., 2012). However, one must be aware that not every context viewed as interesting by the teacher is automatically considered interesting (or learning about it relevant) by students (Hofstein et al. 2011). Comparing a given context to its inherent potential for producing relevant science education can be performed in the foreground of our proposed model of relevance. This idea is in line with Aikenhead's contemplations (2003), which claim that achieving higher levels of attention in science education requires more than simply choosing 'relevant' contexts:

> Relevant contexts alone did not necessarily nurture greater canonical science attainment (although nothing of significance is lost on this count, as well). Values and self-identity necessarily play a large role in focusing students' attention on both humanistic and science content: the more emotional the context of instruction or the more uncertain the relevant scientific information, the more important values become, and thus, the less attention paid to content. (Aikenhead, 2003, p. 75)

Socio-scientific issues-based science education approaches present the most promising approach for addressing value-centred learning and a humanistic perspective in science education (Marks & Eilks, 2009; Sadler, 2011). This form of science education has been suggested as helpful for students to learn about the interrelationship of science and society, while simultaneously developing skills for participating in societal debates and decision-making processes. In other words, socio-scientific issues within science teaching are highly relevant in the sense that the societal dimension broadly influences science education. Nevertheless, learning about socio-scientific issues assumes that students will also learn basic scientific facts and concepts underlying these issues. Many of these issues, including societal discourse itself, are quite intellectually challenging, especially for younger or inexperienced learners. In addition, socio-scientific issues-based science education may contribute to the individual's understanding of the relevant aspects of science education. It can also add to perceived vocational relevance, since the socio-scientific issues selected will often highlight various career paths and possibilities. We can illustrate this with a concrete example. Marks, Otten and Eilks (2010) developed a lesson plan based on the problems of artificial musk fragrances in cosmetics. This case study asked the students to mimic the work of journalists to examine this topic. Learners were supposed to write short news clips for either TV or a newspaper. This pedagogy was chosen to highlight the role of the science-related knowledge necessary for a reporting career in the media. In addition, many general skills were incorporated which developed skills that could serve the learner as a future citizen. An example of this was a teaching unit forcing reflection on the way which science-related information is produced, propagated and selectively used by individuals, interest groups, consumer protection agencies, governments and the press (Eilks et al., in press).

It should be noted that in socio-scientific issues-based science curricula, many of the above-mentioned pedagogical thoughts are closely related to the specific socio-scientific issue (topic) chosen and its related pedagogies. They are also influenced by the teacher's personal beliefs, behaviour and practices. The same is true for interdisciplinary science curricula in general and curricula orienting themselves by ESD pedagogy in particular. For socio-scientific issues-based curricula and interdisciplinary curricula, claims have also been made that the structured acquisition of knowledge, i.e. learning about the structure of a given scientific discipline, is really not the major focus. The same seems to be true for an orientation on traditional careers in science and engineering. This aim is more common to discipline-oriented curricula and some context-based examples which operate using industrial, technological and scientifically-oriented topics (for example, industrial case studies; Hofstein & Kesner, 2006).

We must constantly be aware that not every student has the same interests or pays attention to the same consequences. Many learners are not intrinsically motivated by science. Careers in science and technology might therefore benefit more from science teaching being oriented on the societal dimension. This may even hold true for the majority of students (Hofstein et al., 2011; Ogborn, 2004). On the other hand, students who are interested in and intrinsically motivated by science from the beginning might equally benefit from the individual and vocational dimensions. In addition, the societal dimension is important for them, too.

It should be noted that not only individual skills and interests are important. The weighting of the different dimensions may also include a time- or age-based dimension. The individual domain might be most important for younger students when learning about orientations for their individual lives and personal surroundings. The societal domain can dominate in more mature students (Newton, 1988b). These ideas guided Fensham (2004) as he attempted to develop an overall structure for 12 years of basic schooling. He eventually suggested learning contexts which have different foci for different age groups. In the first years of schooling, the focus should be around wonder and creativity. In the following years, context should increasingly move in the direction of science for responsible citizenship stressing self-awareness and decision-making. In our opinion, the vocational dimension also needs to be integrated into this intellectual framework. Contributions to vocational orientation remain important as long learners still have not fully committed themselves to a career choice and as long as their possible choices remain open, e.g. whether or not to continue enrolling in non-compulsory science courses in school. The emphasis of keeping formal career chances open might be ultimately connected with a final decision for the techno-sciences somewhere down the line, if the learner is given enough time, support and information during the process. Concrete preparation for further, tertiary education at the university level might thus be achieved in upper secondary school science lessons. Such a chronological approach within the science curriculum might possibly connect the needs and interests of all prospective students. In addition, such an approach can potentially contribute to reducing the perception of irrelevance which currently prevails in science education programmes worldwide.

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