Sci & Educ (2017) 26:323–344
DOI 10.1007/s11191-017-9895-1

ARTICLE

Tension Between Visions of Science Education

The Case of Energy Quality in Swedish Secondary Science Curricula

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Published online: 23 May 2017

Abstract The aim of this study is to contribute to an understanding of how curricular change is accomplished in practice, including the positions and conflicts of key stakeholders and participants, and their actions in the process. As a case, we study the treatment of energy in Swedish secondary curricula in the period 1962–2011 and, in particular, how the notion of energy quality was introduced in the curricula in an energy course at upper secondary school in 1983 and in physics at lower secondary school in 1994. In the analysis, we use Roberts' two competing visions of science education, Vision I in which school science subjects largely mirror their corresponding academic disciplines and Vision II that incorporates societal matters of science. In addition, a newly suggested Vision III represents a critical perspective on science education. Our analysis shows how Vision II and III aspects of science education have gained importance in curricula since the 1980s, but in competition with Vision I considerations. Energy quality played a central role in providing Vision II and III arguments in the curricular debate on energy teaching. Subsequent educational research has found that Swedish teachers and students struggle with how to relate to energy quality in physics teaching, which we explain as partly due to the tension between the competing visions.

Keywords Energy quality · Science education · Curriculum · Vision I and Vision II

1 Introduction

Since the nineteenth century and the birth of an awareness of the need for a 'science for the people', it has been debated what to include in primary and secondary science education and why it should be included (Layton 1973; Rudolph 2005; Hultén 2008, Hultén 2016). Science

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education during the twentieth century has seen periods of shifting and overlapping reform movements, reflecting tension between different stakeholders. In Western Europe in the first half of the twentieth century, different school forms had developed different types of science education (Hultén 2008). One type of science was taught in schools for pupils that were not supposed to follow science/academic careers, and another in schools for pupils aimed for academic paths. However, as education became more and more an instrument of societal planning, social engineering and economic development in Western Europe in the post-WWII period, educational systems were democratised in order to even out social differences and educational opportunities. A dual purpose was imparted in the school systems, especially so in secondary education: should science education prepare students for future careers in science or for being the future citizen/worker (Levin 1978)?

Many of the reform efforts during the second half of the twentieth century, in Western Europe as well as in America, can be understood as tensions about this dual purpose of secondary education. The reform efforts in the post-WWII period in America have been described as an elite response to the need for top scientists in the arms race, but it was also a time in which a more inclusive conception of science developed in the liberal arts educational tradition (Rudolph 2002). The reform movements in secondary science education of the 1970s and 1980s can be seen in contrast to the developments of the 1950s and 1960s, as they came to emphasise science in its social context (DeBoer 2000), with an integrated focus on science, technology and society (STS) (Roberts 1998). In the 1990s, the reform efforts turned again in many countries towards science education characterised by standards-based reform and academic rigour (DeBoer 2000).

In parallel with reforms in science curricula, the ideas of what, why and how to teach science have broadened in science education research, often framed using the notion of scientific literacy in the past decades (e.g. Feinstein 2011; Roberts 2007). Different types of scientific literacy have been conceptualised and their respective merits have been explored (e.g. Roberts 2007; Sjöström and Eilks n.d.). However, even though much research has been put into developing new perspectives on scientific literacy, these developments seem to have had little impact on actual curricula (e.g. Feinstein and Kirchgasler 2015; Fensham 2009). Changing the content in education is a lengthy and often conflicted process (Kliebard 2004; Carlgren 1995; Hultén 2013). This points to a need not only to study what science education should contain and why, or critiquing how it is portrayed or has been portrayed in classrooms and in curricula, but also to understand what is at stake and how changes come about and why (e.g. Kliebard 2004; Carlgren 1995; Lövheim 2010; Hultén 2013). By a better understanding of the processes that underlie curriculum change, we can increase our abilities to influence the change in a desired direction.

The aim of this study is to contribute to an understanding of how curricular change is accomplished in practice, including the positions and conflicts of key stakeholders and participants, and their actions in the process (Kliebard 2004; Fensham 2009). As a case, we study the treatment of energy in Swedish secondary curricula in the period 1962–2011 and, in particular, how the notion of energy quality was introduced in the curricula in an energy course at upper secondary school in 1983 and in physics at lower secondary school in 1994.

1.1 Visions and Politics of Curriculum Change in Science Education

Fensham (2009, p. 1076) has argued that: ‘Policy has been a much neglected area for research in science education’, which has resulted in ‘a rather spectacular record of naivete about educational policy and politics' (p. 1078). As a consequence, curriculum development projects have often been conducted in a political vacuum, with too much optimism regarding the adoption of novel perspectives and the resulting curricula in the school practice. Case studies of curriculum development in science education have shown that this is a hotly contested area with different objectives and stakeholders in society, but such studies 'remain too few and far too insufficiently recognized in the communities of science education research' (p. 1079). In conclusion, Fensham calls for further research on the values about science education that underlie different policy statements and from where policies get their authority.

In his review of how the notion of *scientific literacy* has developed and been interpreted in educational research and policy, Roberts (2007) describes two competing *visions of science education*. Vision I gives meaning 'by looking inward at the canon of orthodox natural science, that is, the products and processes of science itself' (p. 730), with a focus on matters "*within science*" (p. 730). In contrast, 'Vision II derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens... …… *about science-related situations* in which considerations other than science have an important place at the table' (p. 730). Roberts argues that both visions have to be taken into account in curriculum development, but his sympathy seems to lie primarily with Vision II, with its explicit ambition to make students grasp science as a human endeavour and able to make informed decisions on societal matters.

Roberts' (2007) proposal of two visions of science education has led to a debate in science education research of how to interpret the visions (e.g. Feinstein 2011), and whether important additional aspects of scientific literacy are missing. In particular, it has been argued that where Vision I emphasises the products and processes of science and Vision II relates science to relevant contexts in society and matters of students' everyday life, none of them assumes a sufficiently *critical perspective* on science and its role in society (Sjöström et al. 2016). Hodson (2003) has argued that in order for science literacy not to be reduced to a mere slogan, science curricula should be oriented towards socio-political action: 'Politicization of science education can be achieved by giving students the opportunity to confront real world issues that have a scientific, technological or environmental dimension' (p. 654). A first stage is to raise students' awareness of such issues, but the ultimate goal would be for them to turn knowledge into political action; going beyond being 'armchair critics'. Although Zeidler (2007) has pointed to how a focus on socio-scientific issues may contribute to a more inclusive Vision II, a more radical suggestion has been to offer an additional, more critical Vision III of science education. Aikenhead (2007) has identified Vision III with a less Eurocentric, more pluralistic perspective on science education, with insight into other indigenous or non-indigenous science traditions, while Yore (2012) has emphasised the *literacy* aspect of science literacy, including 'the essential constructive, persuasive, and communicative functions of languages in science' (p. 7). Sjöström and Eilks (n.d.) argue for Vision III in terms of *science for transformation*, a critical scientific literacy justified by the Central/Northern European *Bildung* tradition. Resonating with the ideas of Hodson (2003), this is 'a politicised vision of science education aiming at dialogical emancipation, critical global citizenship, and socio-ecojustice', in which '[c]ontroversial, relevant and authentic socio-scientific issues, e.g. from the sustainability debate, shall become the drivers for the curriculum' (Sjöström and Eilks, n.d.).

Then again, this debate on what should be included in Vision II or whether it should be complemented with a Vision III has little to say about how such curricular change should be brought about, or what the results are, in practice. Roberts (2007) emphasised that rolling out a curriculum that is guided by Vision II is a challenging task. First, there is a risk of retreat from

Vision II intentions of curriculum development projects to a reality of Vision I outcomes in curriculum committees that are composed primarily of academic scientists (Roberts 2007). Second, there is an asymmetry in how subject teachers receive Vision I and Vision II curricula, since they are typically more familiar with Vision I from their own university education, with its perspective from within science (Roberts 2011).

In a Swedish context, the visions of science education may be mapped onto Englund's (1994) characterisation of a struggle between *essentialist* and *progressivist viewpoints* in Swedish educational policy. Where essentialism takes a clear standpoint in conveying the ideas of science for their own sake, adopting Vision I, progressivism entails attention to what is relevant to pupils' own life and society, in line with the thoughts of Vision II and reaching towards Vision III.

1.2 Energy in Science Education

Against the background of the energy crisis and the rise of the environmental movement, together with an increased interest in students' understanding of science topics, international research on energy education intensified during the 1970s and early 1980s. The energy crisis and the public debate on the virtues and shortcomings of different energy sources may have motivated a more prominent position for energy in science teaching with Vision II or Vision III considerations, but the educational research at the time typically had a Vision I emphasis on students' conceptual understanding. Central questions posed concerned students' understanding of conservation, transfer, transformation, and dissipation or degradation of energy (Duit 1984), the role and relation of the first and second law of thermodynamics and whether they should be the focus in primary and secondary education. For example, what advantages and disadvantages are there in conceptualising energy—an abstract, mathematical entity that has the property that it remains unchanged throughout physical processes—as if it were a substance-like entity (Warren 1983)?

In empirical studies, Solomon (1982) and Duit (1983) revealed serious problems in students' understanding of the first law of thermodynamics, the conservation of energy, as students tended to wonder: if energy is conserved, how could there be an ongoing energy crisis? As a consequence of these problems, Solomon and Duit proposed that the second law of thermodynamics, with the idea of energy degradation and spontaneous heat transfer from objects of higher temperature to objects of lower temperature, may be easier for students to grasp than the first law of thermodynamics. In spite of the appeal of teaching the second law of thermodynamics before the first law (Duit 1983), Duit and Kesidou (1988; Kesidou and Duit 1993) found that students, who were previously exposed to traditional teaching of thermal science also had considerable conceptual challenges related to the second law of thermodynamics. They concluded that:

> …a mere enlargement of the traditional physics curriculum by the addition of ideas of the second law is not sufficient to familiarize students with these ideas. A totally new teaching approach to heat, temperature, and energy is necessary. In this approach, basic qualitative ideas of the second law should be a central and integral part from the beginning of instruction (Kesidou and Duit 1993, p. 85).

The notions of *exergy* and *energy quality* have been suggested as such qualitative ideas that provide more accessible routes to the teaching of the second law of thermodynamics and connecting it to environmental issues in school science (Ogborn 1986; Schlichting and Backhaus 1983; Rosen 2002; Viglietta 1990a, b; Andersson 2008). Exergy can be interpreted as the part of the total energy of a system that can be transformed into mechanical energy, and energy quality is an efficiency measure of the percentage of a particular energy form that can be transformed into mechanical energy. For example, the energy quality of electrical energy is close to 100%, whereas the energy quality of thermal energy is considerably lower and depending on the temperature of a system and its surroundings (about 20% of thermal energy at the temperature of 70 °C is the maximum that can be transformed into mechanical work, when the surrounding has temperature 0 °C).

The introduction of energy quality is worth considering in energy teaching, whether adopting Vision I, Vision II or Vision III of science education. Its potential for contributing to qualitative understanding of the second law of thermodynamics and for providing insight into the degradation of energy has a science-insider Vision I appeal, even though it comes from the engineering sciences rather than chemistry or physics. The use of energy quality as a quantity, the value of which can be compared and assessed across different energy forms, provides a Vision II context that is connected to societal, environmental issues. Finally, energy quality can be incorporated in a critical Vision III discussion of sustainability, influencing choices we are confronted with and that require action at personal and societal levels. For instance, students can come to realise that direct electrical heating of their homes is a bad idea, and make choices in their life accordingly. Furthermore, the notion can be used to connect societal matters to science content: 'Pupils that by themselves pose the question of how there can be an energy crisis if the energy is indestructible are maybe motivated to entertain lines of reasoning involving energy quality' (Andersson 2008, p. 14). In this way, energy quality may be considered as a boundary object, which is shared across and used in different traditions, but with different interpretations (Star and Griesemer 1989; Hultén 2013), in this case within all three visions of science education.

Although appealing in many ways, there may be conceptual challenges in grasping what exergy and energy quality mean. For example, exergy is treated in engineering thermodynamics as a substance-like entity that can be stored and flow, a kind of treatment that has been found problematic in the teaching of energy (Warren 1983). In turn, energy quality as a notion has emotional, anthropocentric connotations. Somewhat counterintuitively, the message is typically that we should use as low energy quality as possible for a particular application.

In practice, the notions of exergy and energy quality are used primarily within engineering thermodynamics (Sciubba and Wall 2007), or in applied areas such as the study of ecological systems (Odum 1973), but rarely in physics or chemistry, or in the teaching of the corresponding school subjects. Science education in Sweden is an exception to this pattern; as we will see, energy quality has been part of the content taught in the physics syllabuses for the lower and upper secondary school since 1994.[1] The experience from Sweden during the past two decades, however, shows that the introduction of energy quality in the educational system has not been unproblematic. As an example, Engström (2008) studied Swedish upper secondary students as they engaged with small-group exercises involving sustainable energy systems in a physics laboratory setting. Her analysis focused on how students selected and connected explanations from the contexts of physics and environmental issues. She found that students expressed ideas from both contexts in small-group discussions, but not without difficulty and with a feeling of uncertainty whether environmental considerations really are physics. They moved between these two contexts, but did not manage to connect them.

[1] Lower secondary education (grades 7–9) in Sweden has from 1962 to the present day been integrated with primary education in a national curriculum for compulsory school, covering grades 1–9 (ages 7–15).

Engström suggested energy quality as a missing link between natural sciences and students' everyday life:

> What is 'missing', among other things, in their lines of reasoning is discussion about the energy quality of different energy forms, as a concept, but also as a phenomenon in a discussion about sustainable energy. … An implication of this may be that the notion of effectiveness and reasoning involving the concept of energy quality can serve as a bridging concept between a natural science perspective and a perspective from everyday life (Engström 2008, pp. 252–253).

From the point of view of the visions of science education, the students were unable to connect physics content to environmental contexts, and thereby go beyond Vision I. In fact, energy quality as a concept was not readily available to them even for Vision I considerations. As we will see, an environmental perspective is stated in the curriculum of the time as one of four overarching perspectives that should permeate all education at upper secondary school. One may wonder why the students at this stage are not able to engage in physics-informed dialogue on societal contexts of a Vision II or Vision III character. We believe that insight into the process of how energy quality was introduced in the curricula sheds light on this matter.

1.3 Method

The starting point for the current study is an analysis of the expression of scientific literacy in the Swedish national curricula for the lower secondary school during the period 1962–2011, using Roberts' (2007) Vision I and Vision II of science education, later expanded with more critical Vision III considerations (Sjöström et al. 2016), as an analytical framework. In particular, we have focused on what kinds of scientific literacy have been emphasised in the curricula in relation to energy as a content area. This content area was chosen because energy has been a central concept in lower secondary science education since the early 1960s, it developed into an even more significant content area in the 1970s along with the energy crisis and the environmental movement, and has continued to evolve in close relation to rising environmental and energy concerns in the 1980s and onwards. While the 1962 national curriculum has a clear Vision I emphasis in relation to energy, which is treated as a purely scientific and technical concept (Skolöverstyrelsen 1962), the present national curriculum for compulsory school clearly frames energy in relation to Vision II and Vision III considerations. For example, in the physics syllabus it is stated that:

> …pupils should be given the preconditions to manage practical, ethical and aesthetic situations involving choices that concern energy, technology, the environment and society (Skolverket 2011, p. 120).

In the light of such changes in visions linked to energy, we asked if there were any content changes that could help us understand the change in visions in the framing of energy. In order to answer this question, we mapped content changes in national curricula in Sweden during the period 1962–2011 and identified the concept of energy quality as breaking with the Vision I emphasis in the energy vocabulary. Broadening the scope to include both lower and upper secondary education, we conducted a systematic study of the introduction of energy quality in curriculum texts, through which we identified that energy quality was introduced in the revised syllabus of the energy course at the upper secondary technology programme in 1983 and in the physics syllabus in the lower secondary curriculum in 1994. The development of these syllabus texts became the main focus of our study.

In addition to analysis of the final curriculum texts, in order to gain more insight into the processes and key stakeholders of the curricular change of 1983 and 1994, we studied the archived working material from the curriculum groups from the perspective of energy teaching, with a particular focus on energy quality. This has been complemented with selected texts from the public debate on energy as an environmental issue, the educational debate during the curriculum reform of 1994 and subsequent academic studies of the process of curriculum change and how the curriculum was received at school. All these texts have been selected and analysed from the point of view of how energy and energy quality relates to Visions I, II and III of science education.

2 The Case of Energy Quality in Swedish Debate and Curricula

In presenting the case of how different science visions have influenced the treatment of energy in Swedish curricula with a focus on the notion of energy quality, we account for changes in curricula in a chronological fashion. We start by giving a brief context to how energy quality was introduced in the Swedish public debate on the energy issue in the 1970s.

2.1 Energy Quality as a Central Concept in Public Debate over Atomic Power and Energy Supply

The post-WWII period was, despite full of fear of nuclear war, a period of technological optimism and rationality, driven by keywords like ‘atomic power’ and ‘automation’ (Judt 2005). In Sweden, the promises of using the newly discovered nuclear fission for generation of electrical power were particularly great. Against the predictions of a constantly increasing demand for electricity and decreasing supply of fossil fuels, nuclear power appeared as an attractive solution to prominent scientists, such as Nobel laureates Theodor Svedberg (chemistry, 1926) and Manne Siegbahn (physics, 1924). The environmental movement of the early 1950s also saw nuclear power as a possible alternative in order to save the last rivers from hydropower exploitation (Lindström 1991). Combined with factors such as the neutrality of Sweden and an already developed industry in electrical power generation (ASEA, later ABB, among other companies), Sweden initiated a nuclear programme early on (Anshelm 2006), and developed into a country with a central role on the international scene of nuclear power.[2]

With the development of the environmental movement in the 1970s, however, the issue of nuclear power was openly debated in Swedish media and was at the top of the political agenda. The environmental movement had changed sides, and struggled against the development of the nuclear programme. This debate naturally involved the political parties at the time, but also prominent Swedish scientists. Physics professor Tor Ragnar Gerholm was one of the most outspoken optimistic voices in the public debate regarding the possibilities and safety of nuclear power (Gerholm 1973):

> Nuclear energy is a well-nigh ideal energy source. It is well suited for electric power production, and can be located almost anywhere. Fuel transports and storage pose no problems. (p. 65) … One has to realise that never ever has a new technology been introduced where safety issues have been attended to so intensely as those of nuclear power (p. 66). … As regards the current type of nuclear power plants, it can

[2] The International Atomic Energy Agency (IAEA), was headed by a succession of two Swedes, Sigvard Eklund and Hans Blix, in the period 1961–1997. With comparatively high electrical energy consumption, 90% of the supply of which from equal parts of nuclear energy and hydropower, Sweden has produced the highest per capita nuclear power output in the world (Moberg 2014).

> be said without doubt that they are idiot proof. These reactors are constructed so that they are only just operating. Whatever happens to them, the nuclear reactions will stop almost automatically (p. 67).

Nobel laureate professor Hannes Alfvén (physics, 1970) stood on the opposing barricade. Alfvén had a central role in the development of the Swedish nuclear programme already from 1945, but in the 1970s he became a central figure in the political fight against nuclear power in Sweden. Two main arguments are found in Alfvén's texts: the waste problem and the need to recognise the difference between the relative values of different energy forms. These are illustrated with striking rhetoric[3]:

> If our food is cooked with electricity from an atomic reactor, there is radioactive waste that has to be taken care of at the reactor station. This waste is indestructible for hundreds of years. The result is that for every meal we cook, we leave what is probably a lethal dose of radioactivity as a heritage for our coming generations (Alfvén 1973).
> To simply add up energy of different values is as wrong as to indicate the cash balance in a number of coins without specifying whether they are one crown coins or five-öre pieces (Alfvén 1975).

Noticeable in this publicly debated issue are the concerns raised regarding the use of high quality energy such as electric energy for low quality purposes such as heating. In conjunction with the quote on energy forms of different values, Alfvén (1975) proposed an 'accounting of energy' that was based on the notion of *exergy*, in reference to research in engineering thermodynamics at Gothenburg University (later collated in Eriksson et al. 1976).

Alfvén's reference to the discipline of engineering thermodynamics in relation to exergy is not a coincidence. Rant (1956) coined exergy within engineering sciences as a notion for the maximum amount of useful work that a system can perform, a quantity with the unit joule. By relating the exergy of a system to its total energy, or input and output exergies, efficiency measures can be derived in assessing the energy quality of different energy forms. In the 1970s, exergy and energy quality considerations entered the international discussion of environmental concerns:

> Plainly we are using premium fuels and electricity for many tasks for which their high energy quality is superfluous, wasteful and expensive… Where we only want to create temperature differences of tens of degrees, we should meet the need with sources whose potential is tens or hundreds of degrees, not with a flame temperature of thousands or a nuclear temperature of millions – like cutting butter with a chainsaw (Lovins 1976, pp. 78-79).

In a Swedish context, through collaboration at the Centre for Interdisciplinary Studies of the Human Condition at Gothenburg University, the notions of exergy and energy quality from engineering thermodynamics were brought into interdisciplinary research on energy policy and human ecology with the project 'Sweden's future energy supply in a historical and global perspective' (Eriksson and Eriksson 1980).

All in all, the energy crisis – alongside the rapid expansion of both hydropower and nuclear power in Sweden in the 1970s and 1980s and the Harrisburg nuclear meltdown in 1979—led to a renewed discussion on energy supply in Sweden, in which the quality of different energy forms became one of the central points. As a consequence of the Harrisburg accident, there was a referendum in Sweden on the issue of nuclear power in 1980. The result of the referendum was that there should be no more expansion of nuclear power capabilities, and that the existing nuclear power should be phased out at a pace made possible with the gradual development of alternative renewable resources.[4] This background on the use and meaning of

[3] All quotes from Swedish references in the text have been translated into English by the authors.
[4] At the time of writing, in 2016, some reactors in Sweden have been shut down, and there are no plans to build new ones.

energy quality indicates a concept that is closely linked to political considerations regarding the use of energy, thus helping framing energy from Vision II and III perspectives.

2.2 Energy Quality Is Introduced in a Renewed Energy Course in Upper Secondary School

Apart from being characterised by technological optimism, as already mentioned, the post-WWII period was also a time of large-scale comprehensive reform of secondary education in Western Europe. Technological development, stronger economies, the absence of war, rising populations, and democratic and egalitarian movements drove the educational reform movements of the time (Levin 1978). In Sweden, with the national curriculum of 1962 a unified state-controlled 9-year compulsory school was established, and in 1970, a new common national curriculum was introduced for the upper secondary school. One of the programmes in the reformed upper secondary school was the 4-year technology programme, where students were engaged in theoretically-grounded engineering studies, with specialisation in areas such as mechanical, electrical, or chemical engineering. By the end of the 1970s, there was a perceived need to adjust the curriculum of the technology programme, not least against the background of the energy and oil crises of the decade. The energy course, which was given within the specialisation in mechanical engineering, was one aspect of the technology programme that underwent revision, and a new syllabus was introduced in 1983 (Skolöverstyrelsen 1983). The changes of the energy course were substantive, turning from a technical emphasis of the 1970 syllabus (Skolöverstyrelsen 1970) with a focus on components, such as pumps, fans, compressors, power plants, heat exchangers, and piping, to a more theoretical and comprehensive syllabus arranged around two general themes, energy resources and energy technology. The energy resources theme provided a systemic perspective on energy supply and demand in society, and its environmental impact.

Already in the first proposal for a new syllabus for the energy course, the notion ‘*energikvalitet*’ (‘energy quality’) was used. In the proposal, energy quality was introduced in the section on energy resources, in conjunction with discussion of the world’s energy supply and use, and distinctions between renewable and non-renewable energy sources. The concept of energy quality was explained in the following way:

> An issue that should be treated is the so called quality of the energy. This concept is receiving increasing attention and the reason for this is primarily the striving for utilisation of energy resources in an optimal way. This ought to be achieved if the energy were valued and used first and foremost within areas where the quality demand is matched by the quality supply. An example of this is that low-grade heat preferably should be used for heating of buildings (Skolöverstyrelsen 1979, p. 6).

However, in this same proposal, the first and second law of thermodynamics, including the notion of entropy, were mentioned as part of the other general theme, energy technology, involving the functionality of, e.g. heat engines and heat pumps (Skolöverstyrelsen 1979). In this way, there was no clear link between environmental considerations of energy sources on one hand, and the theory of thermodynamics with technical applications on the other. In this way, energy quality was part of the environmental debate, but not necessarily related to a scientific stance on energy.

The proposal for a new curriculum was sent out to selected referral bodies in April 1979, ranging from engineering and industrial employee organisations to university agencies, municipal bodies, trade unions, and head teachers in the field (Skolöverstyrelsen 1979). In compiling the referral, Per-Olof Lööw (1979), officer at the National Board of Education, noted that the more comprehensive take on the energy course, with a clear systems perspective, was acknowledged and further emphasised by three of the referral bodies. The notion 'energikvalitet' ('energy quality') was mentioned in one of the referrals, as Bengt Hennel, a vice-chancellor at an upper secondary school, expressed a need to clarify and concretise the concept of energy quality. He suggested that energy quality should be defined in relation to energy, exergy, or the Carnot cycle, and discussed in relation to the efficiency and coefficient of performance of heat pumps.

In parallel with the development of a new syllabus, the possibilities of a new energy branch of the technology programme were discussed based on trials in an upper secondary school in Eskilstuna. Lecturer Lennart Wall ran the trial of extended teaching of energy in Eskilstuna and was part of the working group that developed the national energy syllabus. Thore Berntsson (1980), a professor in engineering thermodynamics, was engaged in reviewing the trial and found that the content taught aligned well with university teaching of the subject. All in all, he approved the direction taken, and further stressed the need to take a comprehensive approach to the field of energy at the upper secondary level, thus focusing more on characteristics of energy systems than the components of which they are built. Berntsson also welcomed the theoretical grounding in the first and second law of thermodynamics while at the same time acknowledging that even university engineering students found these laws difficult. In addition, he suggested that energy quality of different energy forms at different temperatures could be introduced in the syllabus by reference to exergy.

Even though the suggested new energy branch was not implemented on a national scale, the changes in the syllabus of the energy course meant a clear step in a new direction towards increased energy education at the upper secondary level. Overall, the referral bodies were satisfied with the new curriculum and one of them even suggested that the section on energy resources should be part of the teaching at all upper secondary programmes (Lööw 1979). Regarding energy quality, the text from the proposal did not change much in the implemented syllabus, and kept its environmental focus, without connections to the laws of thermodynamics, exergy, or efficiency measures:

> An issue that is important to bring up at an early stage is the so called quality of the energy. This concept is receiving increasing attention and the reason for this is primarily the striving for utilisation of the energy resources in an optimal way. This ought to be achieved if the energy were valued and used first and foremost within areas where the quality demand is matched by the quality supply. An example of this is that heat with low quality preferably should be used for heating of buildings where the requirement on the energy level is not particularly high. … The development since the Second World War has led to increasing demand of high quality energy (Skolöverstyrelsen 1983, pp. 11-12).

The debate on scientific literacy and different visions of science education has primarily focused on aspects of science that are important for everybody in their everyday life. The energy course described in this section went beyond this scope as it prepared for technological specialisation and application of science, but Roberts' (2007) descriptions of Vision I and Vision II may still contribute to discerning some tension in the curriculum development. The energy technology theme was grounded in academic thermodynamics as part of Vision I, but its application in engineering could be regarded as an expansion into relevant Vision II contexts. Energy quality was proposed within the energy resources theme as a way to give insight into societal and environmental consequences of energy use, with a clear Vision II focus on science-related situations. However, with the suggestions of a more quantitative treatment of energy quality from the referral bodies and as part of the trial of an energy branch, there was a risk of a retreat from original Vision II intentions to Vision I outcomes, where insight into environmental issues would be replaced by instrumental calculations. In line with Roberts (2007, 2011), these suggestions were driven by representatives from the academic disciplines and teachers who were trained in that tradition.

2.3 Competing Visions of Science Education in Compulsory School

We have described how the notion of energy quality was introduced for the specialisation in mechanical engineering at the 4-year technology programme in 1983. However, only a small fraction of upper secondary students chose this option and thereby got acquainted with the notion. This situation was to change radically with the Swedish national curriculum reform of 1994. We will now follow the path of how energy quality came to be included in the new physics curriculum for the compulsory lower secondary school.

Already the 1969 national grade 7–9 physics syllabus for the compulsory school states 'the central position of the energy concept in science education' (Skolöverstyrelsen 1969, p. 197). However, with a closer look at how energy has been treated in Swedish education, it is fair to say that the birth of modern energy education came in the 1970s, much as a response to growing environmental and energy supply concerns (Hultén 2008). After an initial instrumental focus where energy teaching tended to be reduced to finding technological solutions to environmental energy issues, the treatment of energy saw a theoretical turn in the 1990s, primarily through the introduction of the first and second law of thermodynamics (Hultén 2008). With the 1994 national curriculum for the compulsory school (Utbildningsdepartementet 1994b), the first and second laws of thermodynamics became part of the content to be taught at the lower secondary level (grades 7–9), and the notion of energy quality was introduced.

The 1980 national curriculum for the compulsory school was developed in the late 1970s and saw supplementary curriculum material being issued by the National Board of Education throughout the 1980s. Work with a new common supplement for social studies and science education commenced in the mid-1980s and was published in 1991 (Thorsén 1991). Björn Andersson was involved as a subject expert in the development of the supplement. In 1976, Andersson was the first academic in Sweden to receive a Ph.D. in science education, and in 1997, he became Sweden's first professor of science education, at the time heading the leading and only major research group in science education in the country at the University of Gothenburg.

The supplement for social studies and science education included commentaries and suggestions on how the teaching could be conducted in a more thematic, subject-integrated manner. Energy was put forward as a suitable topic overarching the natural sciences across grade 1–9 teaching, but also touching upon social sciences and technology, not least taking into account environmental issues. The supplement was clearly influenced by 'Our common future' (often referred to as the Brundtland report) (WCED 1987). The role of the social studies and science education was, according to the supplement, to 'articulate values and valuations for a sustainable world' against the backdrop of common problems facing society (Thorsén 1991, p. 15).

In the supplement for social studies and science education (Thorsén 1991), a quite extensive account of the teaching on energy at Årstaskolan in Uppsala was provided. It was a case of thematic subject integration across natural and social sciences, spanning grades 7–9 at the compulsory lower secondary school, where natural science teacher Birgitta Johansson shared her experiences of incorporating environmental issues in the energy teaching. In grade 7, they studied different energy forms in nature that can be transformed, from one form to the other, and used in society by means of technology. In grade 8, the pupils were introduced to the concept of energy quality in relation to different energy forms and encouraged to use energy of low quality wherever possible, such as heating their homes. Johansson's teaching was grounded in the environmental debate at the time, and she explained energy quality with examples such as Alfvén's (1975) critique of adding coins of different types without considering their values and Lovins' (1976) comparison of wasteful use of high-quality energy with cutting butter with a chainsaw. Finally, in grade 9, the teaching focused on the issue of the atom bomb and nuclear power. The natural sciences were clearly submerged deeply in social study and the societal debate and challenges of the period.

From the point of view of the different visions of science education, the promotion of thematic subject integration across social and natural sciences in the supplement for social studies and science education (Thorsén 1991) was a genuine effort towards Vision II with incorporation of STS aspects in science teaching (Roberts 1998). The case of thematic teaching of energy at Årstaskolan took one step further. Birgitta Johansson encouraged the gradual development of a critical attitude among her pupils in her teaching: 'In grade 8, it aimed towards pupils taking a stance on the energy issue. *The elements of energy politics increased*' (Thorsén 1991, p. 132, italics in the original). They questioned the thesis that we need more energy in order to produce more and instead promoted more efficient energy use. Being engaged in the campaign against nuclear power, Johansson suggested incorporating information material from the campaign on how to rely on other sources of energy than nuclear power and coal in the future. The case clearly represents the critical stance of Vision III, a politicised science education.

In 1991, a National Curriculum Committee was formed with the main purpose of changing the form of the curriculum of the Swedish compulsory school into one of 'steering by objectives and results'. Detailed guidelines for teachers as to how these objectives could be met should not be included; it should be up to individual teachers as professionals to make such decisions in their teaching. The work with the curriculum reform was conducted in three tiers. First, there were four members of the committee. Ulf P. Lundgren, a scholar in curriculum theory and Director-General of the newly formed National Agency for Education, chaired the committee. Two of the members were civil servants at the Ministry of Education. The fourth member was Tor Ragnar Gerholm, who—as we have seen—had played a prominent role in the public debate on nuclear power in the 1970s, now professor emeritus of physics. At the next tier, there was a secretariat of four secretaries. Educational researcher Ingrid Carlgren served as one of the secretaries and has described the organisational structure 'as a division of labour where the secretariat was to produce drafts and proposals which the committee members were to decide on' (Carlgren 1995, p. 419). The third tier consisted of subject groups, which were assigned with writing syllabus texts for the different subjects.

Björn Andersson coordinated the effort of the syllabus groups with a focus on natural science subjects. In a series of memoranda submitted to the secretariat, Andersson explained his view on science and science education and how to structure science in a curriculum:

> It is urgent that the wider public has functional *scientific 'Bildung'*, which can be seen as part of *environmental 'Bildung'* or *'Bildung' in relation to the surrounding world*. It is therefore a matter for the school to help the pupil build structures of foundational concepts, which enable for him/her – throughout the entire life – to interpret information, understand, pose questions, learn anew, etc. This can, in turn, lead to suitable decisions and suitable actions (Andersson 1992a, p. 4, italics in the original).

With this declaration, Andersson's intentions with the syllabus development are clearly in line with Sjöström and Eilks (n.d.), with regard to a critical *Bildung*-oriented view on science education. It represents a holistic and agentive perspective on how pupils' scientific literacy serves a larger role in their lives and in society, characteristic of Vision III.

Moving towards the treatment of particular content, energy was put forward as one of the central conceptual areas in physics, and the study of flows of energy on Earth was seen as an overarching 'pattern of orientation' across the science subjects. Andersson was grounded in science education research, and his ideas resonated with Solomon (1982) and Duit (1983) on the challenges of teaching the first law of thermodynamics: '[S]tudents maybe wonder: If energy does not disappear – why are so many people talking about an energy crisis?' (Andersson 1992b, p. 4). The answer is to be found in the intuitive meaning of the second law of thermodynamics: energy tends to spread out, and as it loses its ability to perform work, the exergy is used up, and the entropy increases (Andersson 1992b). In addition, energy quality is listed as one of the central concepts in physics in the first memorandum (Andersson 1992a). The energy quality concept was also present in the first draft of a syllabus that Andersson's work group sent to the committee (Andersson 1992c).

In our interpretation, in this way Andersson managed to connect central concepts in thermal science to matters of technological and economic efficiency and the environmental debate of the time, which we argue was not quite achieved in the energy course syllabus at the upper secondary technology programme (Skolöverstyrelsen 1983). He thereby went beyond the immediate Vision I concern for pupils' conceptual understanding, by grounding it in Vision II societal contexts.

However, Andersson was not the only expert working on a proposal for a new science syllabus. A competing proposal was presented by one of the committee members, professor Tor Ragnar Gerholm. A few important differences appear when comparing the proposals of Andersson and Gerholm. Whereas Andersson had a holistic perspective, Gerholm (1992a, p. 1) treated science hierarchically, with physics as the centrepiece:

> Physics actually means the study of nature, and physics is thereby the origin of other natural sciences. Even though several other subjects have been delimited from physics, such as chemistry, meteorology, geology, biology, and medicine, but to name a few, and have established themselves as independent disciplines with their own identity, methodology and tradition, physics nevertheless appears as the central base of knowledge within the entire field of natural science.

In addition, whereas Andersson anchored the themes and structure of his syllabus proposals in arguments from science education research and the perspective of the pupil, Gerholm (1992a) structured his syllabus proposals based on the corresponding academic subjects of physics, chemistry, and biology, and thereby adhered to Vision I of science education. For example, in his proposal for a grade 6–9 syllabus in physics, although pointing out its relevance for technological applications and environmental issues, the subject was treated as a self-contained area of knowledge. Gerholm recommended a focus on classical physics, where the central topics of mechanics and electrodynamics could be studied without further consideration of how they relate to one another or to other subjects or themes at school or the surrounding society. Energy was introduced in the following way, incorporating the first and second law of thermodynamics, but in a rather traditional academic fashion, without mentioning of energy quality:

> The energy principle is introduced as a unifying concept, which is valid for both mechanics and electrodynamics. … Different energy forms are defined. … Transformations between different energy forms are discussed and demonstrated. The unique position of heat energy is noted. All energy forms can entirely be turned into heat, but heat energy can only partially be turned into other forms of energy. Heat transfers spontaneously always from a warmer location to a colder one (Gerholm 1992a, p. 3).

Against the background of Gerholm's (1973) active engagement for nuclear power in the public debate in the preceding decades, it is further interesting to note his motivation of why natural sciences should be taught in compulsory school:

> In recent years, the connection between scientific knowledge among the broader population and environmental issues has become increasingly evident. Many threats to human health and wellbeing are invisible, such as radiation of different kinds and molecules in the air and water. These threats are difficult to perceive for those who lack scientific concepts. Thereby, a rational and balanced debate on environmental problems is made more difficult, as is rational action (Gerholm 1992b, p. 1).

In our interpretation, he argued that if the broader population develops an understanding of scientific concepts, it is more likely to engage in rational debate and action with regard to environmental issues, implicitly in contrast to the movement against nuclear power, which is seen as driven by irrational emotions. Insight into the products and processes of science, Vision I knowledge, will enable people to make wise choices in society. In this way, Gerholm was part of the international trend in the 1990s of emphasising academic rigour in curricular development (DeBoer 2000).

2.4 Vision I Comes to Dominate the Revised Curriculum

In September 1992, the curriculum committee published their main report with proposed syllabuses for the different subjects in the compulsory school (Utbildningsdepartementet 1992). As for the science subjects, the structure and content largely followed Gerholm's proposal, where energy quality is not mentioned in the physics syllabus, rather than that of Andersson's syllabus groups.

Educational researchers Tomas Englund and Leif Östman were critical of the curriculum proposal (Utbildningsdepartementet 1992), in particular the trend of the science subjects (i.e. physics, chemistry, and biology) coming to mirror the corresponding academic disciplines (Englund and Östman 1992, pp. 32–33):

> The tendency is thus a development towards the school subjects seeking their essence and legitimacy as mini-courses of traditional research disciplines and/or as strictly delimited concept area … What is problematic with this is that legitimising [taught content] with research often gives *an unambiguous* picture and that different points of view (grounded in research) are neglected in the school subject knowledge.

Englund and Östman (1992) argued that apart from providing different points of view within science, other perspectives—from areas outside science—also needed to be taken into account in the selection of content for teaching. In this regard, they saw a lack of attention in the curriculum proposal regarding the science subjects to the everyday perspective of the individual pupils and their development into conscientious citizens, with an ability to form their opinion on societal issues; Vision II and Vision III were missing.

Birgitta Johansson, the teacher who had developed the thematic work on energy at Årstaskolan, also wrote a series of critical articles in response to the curriculum proposal. One of her overall concerns was that environmental issues were demoted to a part of a new subject—technology and environment—rather than being treated as an aspect that should be considered across all subjects (Johansson 1992b). Under the headline 'Setting the fox to mind the geese', Johansson (1992c, pp. 18–19) explicitly questioned Gerholm's role in the committee:

> These questions are all the more pertinent when you know that one of those who signed the curriculum proposal is Tor Ragnar Gerholm. He was recently called 'the nuclear power attorney'… The professor

> understands why the opponents of nuclear power think as they do: they do not understand the technology. … With Gerholm's philosophy, the environment puts no greater demands, neither on us as individuals or on political decisions. We can carry on as we have become used to, use more and more energy and other natural resources.

Johansson (1992a, p. 52) further criticised that physics was treated as the supreme science subject, at the expense of, in particular, biology, and proposed the introduction of energy quality in the curriculum:

> So if physics wants to take on the role as the central subject, the curriculum author should at least have chosen physical concepts with a little bit more concern and thought for the future. He has for example (consciously?) left out the concept energy quality. It is needed to give a perspective on what our energy demands actually look like, how much we need of different energy forms. … Then, why is the concept energy quality not included in the preliminary curriculum proposal? It is hardly because it is too difficult to understand. … Energy quality is an example of a scientific concept that is politically charged, and that therefore does not fit in the comparatively watered-down curriculum proposal.

In particular, Johansson (1992b, p. 51) suggested that energy quality could be introduced in relation to the second law of thermodynamics: 'Everything spreads out. The disorder increases; the quality decreases. This holds true for both matter and energy'. Once again, in reference to Lovins (1976) and Alfvén (1975), she argued that pupils needed to be made aware of the unreasonableness of heating our homes with electricity that has been produced by nuclear power.

Even though the final revisions of the curriculum by the curriculum committee responded to some of the criticism, it largely retained the structure with regard to the science subjects as developed by Gerholm. The final proposal was communicated to the syllabus groups in December 1992 and was met with clear disappointment from Andersson's research group, which had been involved in writing the science syllabus text proposals. For example, in a response to Carlgren at the secretariat of the curriculum committee, Christina Lindblad, from the chemistry syllabus group, wrote:

> The novel thinking that we have tried to achieve, in order to make natural science every man's property in compulsory school, can hardly be discerned. … I refrain from even trying to produce an acceptable version, but refer to [Andersson's collated proposal of science syllabuses]. … With this response, I regard myself as released from my commitment to the curriculum committee, and thereby free to criticise the proposal that will be put forth in the beginning of 1993 (Lindblad 1992).

The revised curriculum was suggested in the final report from the curriculum committee in January 1993 (Utbildningsdepartementet 1993), and later installed by the minister of education (Utbildningsdepartementet 1994a, b). The introductory section of the 1994 curriculum for the Swedish compulsory school states that: 'In partnership with the home the school should promote the development of pupils into responsible persons and members of society', and that 'the school has the task of imparting fundamental values and promoting pupils' learning in order to prepare them to live and work in society' (Utbildningsdepartementet 1994b, p. 5). Furthermore, an environmental perspective was brought forward as one of four overarching perspectives, the others being ethical, historical, and international perspectives, which should permeate the teaching and provide overview and coherence across all subjects:

> An environmental perspective provides [pupils] with opportunities not only to take responsibility for the environment in areas where they themselves can have a direct influence, but also to form a personal position with respect to global environmental issues. Teaching should illuminate how the functions of society and how our ways of living and working can best be adapted to create conditions for sustainable development (Utbildningsdepartementet 1994b, p. 6).

In addition, in the physics syllabus, it was now stated that the school should strive for, among other things, pupils' development of 'knowledge on energy and energy forms, energy transformations and energy quality, and about the society's procurement of energy' (Utbildningsdepartementet 1994a, p. 12). With this statement, every child in Sweden should be introduced to the topic of energy quality in the compulsory school.

In our interpretation, the introductory statements of the 1994 curriculum for the compulsory school on preparation for students' life in society as citizens bore the hallmark of Vision II of science education; we cannot teach science in isolation but have to consider how it influences the society and the everyday life of our pupils. This is reinforced by the statement that an environmental perspective was meant to permeate all education. However, the syllabus texts for the science subjects came to be dominated by Gerholm's essentialist view from within science, i.e. Vision I. In this way, there is a tension between more progressive statements at the general level of the curriculum, and the essentialist subject-specific science syllabuses which detail the content to be taught and goals for students to achieve. In this light, insertion of 'energy quality', a single Vision II notion—from the traditions of engineering thermodynamics and environmental activism—in the syllabus text does not make a big dent in the Vision I identification with the corresponding academic physics discipline.

2.5 The 1994 Reform in Hindsight

As we have seen, educational researchers took an active part in the 1994 curriculum reform process, both in the role of developing curricular material and in engaging in critical, public debate. After its instalment, Englund (1994) was critical of the 1994 curriculum overall, as he saw it as a development away from the Swedish tradition of a unified, common compulsory school for all pupils. The curriculum reform had been initiated by the left-wing Social Democrat government, but was taken over by a right-wing non-socialist alliance in 1991. From his perspective of curriculum development as a matter of social and political struggle, Englund interpreted this as a move in a conservative, essentialist direction, in particular for sciences and social studies. By considering individual school subjects in isolation, the potential for holistic approaches and comparison between different perspectives was missed.

Another interpretation has been offered by Carlgren (1995), who analysed and reflected upon the curriculum development process from the perspective of an insider educational researcher. Rather than being a matter of political struggle and striking compromises, in her view, the process was dominated by practical problem solving in tight time frames:

> Thus, from the inside perspective, national curriculum making is largely a practical, problem-solving enterprise. The curriculum proposals did not come about as compromises in relation to substantive and ideological discussions, but from an interaction between the factors framing the process, incidental events and practical considerations (Carlgren 1995, p. 412).
>
> Almost more important than the directives was, I think, the time frame. We were supposed to solve more questions than any earlier committee – in a shorter time than any other committee. Lack of time means proposals that were not thoroughly thought through. (Carlgren 1995, p. 417).
>
> [T]here was neither consideration of the link between overall curricular aims and the organisation of content in terms of school subjects nor the proportion of time allocated to different subjects (Carlgren 1995, p. 419).

Nevertheless, Carlgren acknowledged that part of the challenges in the curriculum development work was due to the political tension between the secretariat, including herself, and the committee members:

> There were also ideological differences between the secretariat and the committee members. The secretariat was quite strongly identified with earlier school reforms and the idea of 'comprehensiveness'

> while the Ministry committee members in particular embraced the neo-liberal school rhetoric (Carlgren 1995, p. 418).

In addition, in a shared reflection on the curriculum development process of 1991–1994 and how it related to didactics research in Sweden, Carlgren and Englund saw similar tensions between the curriculum committee and some of the syllabus groups:

> One reason for the varying influence from didactical research [on the different syllabuses] (and that some groups were allowed to influence and others not) was antagonism between the direction of the committee and some of the syllabus groups – in particular in the orientation subjects [sciences and social studies] you can say that the committee was oriented in a more essentialist direction than the syllabus groups (Carlgren and Englund 1994, pp. 12-13).

As we have seen, for the science syllabuses, which were coordinated by Björn Andersson, this antagonism was expressed by Tor Ragnar Gerholm writing a competing set of syllabus proposals, which later were largely adopted in the final texts and heavily criticised by the syllabus groups. Carlgren and Englund (1994) argued that part of the problem was that the science syllabus groups were driven by a narrow didactics approach (Englund 1997), which was not flexible enough to address the new structure of steering by objectives:

> The system of steering by objectives implied certain principle changes of the structure of the syllabuses which meant that the syllabus groups were confronted with some problems for which they were not prepared. … The poor preparedness for such issues in the syllabus groups of the science subjects is interesting against the background that a large part of didactics research during the 1980s has been conducted in these subjects. However, it has been of a mainly narrow character, i.e. directed towards pupils' learning of taken-for-granted content, rather than problematising this content in relation to the objectives of the curriculum… (Carlgren and Englund 1994, p. 13).

In our interpretation, however, the main challenge of the syllabus groups for the science subjects was not an unwillingness to problematise what content to teach. As we have seen, in his series of memoranda, Andersson expressed the necessity to transform content of academic subjects to something that is accessible and relevant to pupils in their everyday life, and prepares them for taking an active part in society with regard to, for instance, environmental matters. The problem was rather one of trying to bring many diverse perspectives into a coherent whole—combining Vision I, II and III considerations. As a result, it gave the proposed texts from Andersson's syllabus group a messy, incoherent impression.[5]

In her study of upper secondary students' small-group work on sustainable energy systems, Engström (2008) concluded that students were unprepared for engaging in discussions on environmental and societal matters in relation to the energy content, i.e. of a Vision II or Vision III character. Energy quality, which could have served as a bridging concept between science and concerns of everyday life, was missing in their reasoning. The fact that energy quality did not fit well in the 1994 lower and upper secondary physics syllabuses,[6] which were in place at the time of the study, provides part of the explanation for this unpreparedness.

In addition, the reception of a curriculum reform depends on the attitude of the teachers (Roberts 2011). By means of cluster analysis of 268 responses to a survey distributed to Swedish upper secondary physics teachers, Engström and Carlhed (2014) identified three categories of teachers:

- The Manager of the Traditional (corresponding to 46% of the responding teachers)
- The Challenger for Technology (39%)

[5] Personal communication, Ingrid Carlgren, 29 September, 2015.

[6] Energy quality was also introduced in the 1994 physics syllabus for the upper secondary school.

- The Challenger for Citizenship (14%)

The dominating Manager of the Traditional sticks to teaching physics concepts, but shies away from more value-related content, such as matters of sustainable development or encouragement of discussion of societal issues. The Challenger for Technology, in contrast, often with an engineering background, encourages students to come up with designs that will help us come to terms with problems we face in society, with an optimistic view on what can be achieved with technology through industrial solutions. Finally, the Challenger for Citizenship, the least common type of teacher:

> …tends to work as a democratic and intellectual "challenger" of the physics subject, characterized by engagement in society and political issues… This is an "activist" or a "rebel" habitus with an urge and courage to develop the physics subject to be more related to environmental, political, ethic aspects, with an ambition to teach all students physics for their future citizenship (2014, p. 716).

In our interpretation, the Manager of the Traditional aligns with Vision I, with its focus on the products of science and what they have been taught during their physics studies at university (Roberts 2011). The Challenger For Technology seeks for applied solutions in real world contexts in line with Vision II. Only few physics teachers are Challengers for Citizenship with its critical, activist spirit, and thereby embracing Vision III. Whatever curriculum is in place, if most physics teachers are not willing to prioritise such Vision III concerns, it is hardly surprising that their students are unprepared for relating the subject to environmental and political matters.

Roberts (2007, 2011) has identified the risk of retreat from initial Vision II intentions in curricular reform to Vision I statements in the decided curriculum and how it is implemented in schools, due to the influence from academic scientists in the development of the curricular texts and teachers that are most comfortable with an essentialist focus on their subjects. The curricular reform of 1994 in Sweden also reveals other mechanisms of retreat from Vision II, including the change of government and project management in a more conservative direction during the process (Englund 1994) and a drive towards simplification in practical problem solving within tight time constraints (Carlgren 1995). In 1994, this retreat to Vision I occurred in spite of involved science education scholars' fight for Vision II considerations in the syllabus texts.

3 Conclusions

In the present case study, we have investigated how different interpretations of scientific literacy have influenced the treatment of energy in the Swedish secondary curriculum, and have played a role in the introduction of energy quality. We have shown how Vision II and III aspects of scientific literacy came to be linked to the concept of energy quality and how the concept was introduced in the 1994 national curriculum despite its predominantly Vision I character. By taking into account the political debate on the energy issue, archived working material from the curriculum development, and the reception of the curricula in educational debates and the school practice, we have provided a richer account of the process than what would have been possible through the analysis of the final curriculum texts alone. Similar analysis of science curriculum development using a broader range of empirical resources has the potential to bring deeper insight about the process and key stakeholders also in other national contexts than Sweden, although the 1994 Sweden curricular reform may have been better documented than many other reform efforts. In particular, our case study gives an example of how the focus on a certain content area and the treatment of a single notion—in our case, energy and energy quality—can give important insight into the tension and process of competition between different visions of science education. Political and conceptual developments outside academic science—here engineering and the environmental movement—may allow for new ways of framing science education, and can help us understand how new approaches to scientific literacy develop and find their way into the curriculum (Hultén 2013).

We have argued that energy quality has the potential to serve as a boundary object (Star and Griesemer 1989; Hultén 2013) in energy teaching, shared across Visions I, II and III. In the science education of the new millennium we are still seeking for qualitative ways to introduce energy degradation and the second law of thermodynamics with Vision I considerations (Duit 1983; Solomon 1982), but also aim to frame it in Vision II contexts and Vision III societal concerns. As pointed out by Andersson (2008), the tendency towards decreasing energy quality can be used to reconcile the awareness of an energy crisis with the first law of thermodynamics. Then again, Engström (2008) found energy quality to be a missing link between science content and societal matters in the Swedish physics teaching practice, in spite of the introduction of the notion in physics curricula. In this respect, the present study provides another case of the difficulty in formulating and implementing a curriculum that goes beyond Vision I concerns, and the risk of a retreat from Vision II intentions (Roberts 2007; Fensham 2009).

In our view, more general conclusions can be drawn from this case study of Swedish curriculum development. For educational research to have an impact on the process of curricular reform in practice, we have to offer more than theoretical arguments for how to interpret scientific literacy and strengthen students' conceptual understanding of the taught content. Although the particular conditions will vary between countries, time periods, disciplinary areas and reform agendas, we have to consider existing political positions of key stakeholders (Fensham 2009; Englund 1994, 1997), practical constraints of curricular reform (Carlgren 1995), and attitudes among teachers (Roberts 2011; Engström and Carlhed 2014).

Acknowledgements We would like to thank Lars Sjunnesson and Ingrid Carlgren for providing valuable insight into the development of the Energy course of 1983 and the curricular reform of 1994, respectively. Birgitta Johansson has been very helpful in describing how she came to adopt the notion of energy quality from the environmental debate in her science teaching. Finally, we are grateful for comments on the manuscript at different stages from Fredrik Jeppsson and colleagues at the physics education division at Uppsala University, anonymous reviewers, and Kostas Kampourakis in his role as Editor-In-Chief of the journal.

Compliance with Ethical Standards

Conflict of Interest No potential conflict of interest was reported by the authors.

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