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SCIENCE TEACHING - SCIENTIFIC LITERACY IN A SCHOOL PERSPECTIVE

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Abstract: -
The article highlights professional teachers' understandings of what they see as the most important content in science education. The study is based on conversations with professional teachers and explore how they understand what is the most central content in science education. Their understandings are related to the importance of science in the society and to the language's importance to students' learning opportunities. The results of the study's interviews are analyzed using Basil Bernstein's concept of the horizontal and vertical discourse as a framework, which demonstrates the opportunities for pupils to approach scientific content based on a contextual understanding. How science is taught is an important question in the aspect of students coming from different socioeconomic conditions and with different conceptions of the outside world and the science school discourse. In the present study professional teachers stress the importance of a holistic understanding of the content in science, the methodical aspects in science education and the consequences of science and technology development in particular. To be science literate in a classroom context means that the students will get 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.

Keywords: *science education, content, technology, society, literacy, language*

INTRODUCTION

In different countries education in the disciplines of natural science, is often on the agenda when there seems to be a risk of decreasing national technical and scientific development. There is also a desire among these nations to be the leading countries with regard to both prosperity and technology. Looking back in history we can find signs of panic initiatives in education with investments and suggestions of new school curricula, especially highlighting subjects as science, technology, engineering and mathematics (STEM). In the United States, for example, it became a major issue in the education system in the late 1950 triggered by the so called "sputnik effect" when the former Soviet Union had taken over the leading role from the United States in space technology. This was the case again during the 1980s in the movement known as "Science for all Americans" (Rutherford, 1990). Presently these movements seem to be repeating again, when a number of international surveys are done which provide opportunities to make comparisons between countries in terms of the students' achievement (OECD-PISA, 2003, 2009; TIMSS, 2016). Objectives in these comparisons can be discussed in terms of political, industrial and economic influence and power for instance between the EU, United States, India and China. They can also be discussed in relation to a person's individual development in a general educational perspective (Andresen & Dimenäs, 2006). In Sweden there are political signals which indicate a receding interest from students to study STEM subjects. This is thought to lead to consequences for the country which are visible in a lack of innovation and technological development. It will likely lead to declining prosperity and lower ranking among the countries in the world. Sweden has declining results in school subjects of natural sciences during the 1990s and early 2000s. However there are trends of improvement and Sweden now is ranked around the OECD average in science subjects in the last measurements (Skolverket, 2016).

The starting point of this article is that education and teaching sciences can be developed regardless of the objectives of international measurements or other motives. Novak (2005) demonstrates that it is of great importance that preschool and primary school children in particular are offered opportunities for developing their scientific knowledge. If the potential of children to develop scientific knowledge is overlooked, it is likely to have an impact on the success of these children in later studies. The issue of how children and students may be offered additional development opportunities to develop science knowledge can then be justified. The present article also takes into account the hypothesis that language is a key factor in childrens development and expertise in science. Both every day and scientific language must be central for the development of such expertise. Research shows that children in preschool and in primary school have few opportunities to practice and develop their language in a scientific context (Appleton, 2006; Danielsson, Andersson, Gullberg & Hussénius, 2018, Nilsson, 2008). We have good reasons to draw attention to language as a fundamental part of students' development and understanding of the world around them. In this study language refers to all the words, feelings, attitudes and experiences, which could be expressed by an individual in relation to a scientific context. Snow, Griffin and Burns (2005) describe this relationship to language that every school subject has its "survival words" or "qualification words". This study is based on conversations with professional teachers and how they understand the most central contents in science education, related to scientific language and importance for society.

LINGUISTIC ABILITY IN SCIENCE EDUCATION

Linguistic activities linked to everyday teaching are reading and writing activities of various kinds. Linguistic activities can be seen as a natural part of science teaching that Norris and Philips (2003) argue as necessary to develop knowledge. Science also has a historical tradition of producing texts from experimental results with a structure of background, methods, results and conclusions. This is a standard way to structure scientific reports and articles considered as a way of communicating scientific results even in the social sciences. It is important to know how texts are used to communicate (Knain, 2005; Varela, Pappas & Rife, 2006) and it is commonly seen in, for example, school laboratory reports. Other researchers express a critical view of how school today often presents fragmented scientific teaching goals. They believe that the teaching of natural sciences instead should support children, use more of contextualization and scientific distinctions in relation to the traditional school scientific discourse (Säljö & Wyndhamn, 2002). Bliss (2008) believes that it is important in education to pay attention to the problem of children common surface understanding of scientific phenomena. He considers that it is important to help students find a scientific discourse of deeper understanding through science language.

Svensson (2009) draws attention to the problems of the scientific discourse and argues that a linguistic variation in a scientific discourse is not primarily a deficiency by the teacher or the teaching material. He argues that students express themselves with the living language and need a greater degree of theoretical knowledge and its expression. This is not problematized by teachers when teaching in a traditional scientific discourse. When students do not understand the expected scientific discourse it can be seen as a knowledge problem rather than as a language problem. Svensson's findings demonstrates the importance of focusing on linguistic meanings, instead of focusing on socio-cultural, communicative and cognitive theory. Furthermore he posits that language is dependent on context, which sometimes can be difficult to achieve in a classroom. Svensson believes that it is of crucial importance for an individual's knowledge that she can perceive the different meanings of given phenomenon, and that these meanings are related to linguistic expressions. These various contexts related to the different meanings and linguistic expression should be considered as central aspects when we discuss building scientific knowledge (Åkerblom, 2009). Englund (2010) discusses this in relation to the phenomenographic research tradition, which in the early stages focused on learning of scientific concepts, and argues that this constituted a limitation of the learning perspective. He argues that the phenomenographic perspective in later stages was to understand learning as a personal knowledge process framed in a linguistic communicative context. It highlights that both the context and communication are of crucial importance for the development of understanding. Englund also critizises the socio-cultural learning perspective. He believes that this perspective is characterized by a limited explanation of learning and argues that the contextual conditions for meaning-making have been set aside. Anderberg (2009) pointing to several empirical studies which show that the most essential is the meaning of the phenomenon itself, not only the linguistic expressions themselves. In a study of physics education in high school, Alvegård (2009) showed that students have difficulties in understanding and using different meanings of different phenomena and this appears to be limited in the traditional science discourse previously mentioned. Liberg, af Geijerstam and Folkeryd (2007) stress the importance of paying attention to language in order to make the content and context visible. They also claim that certain words in a discourse are more powerful than others. Another way to broaden the understanding of how children develop science knowledge is to identify and support the child in relation to all the science around them. Teachers should have the insight that children can learn from everything around them, both institutionally and in the living environment (Siraj-Blatchford & MacLeodBrudenell, 1999). The discussion of language and a scientific discourse is relevant in relation to understanding science literacy as an important field of research.

SCIENTIFIC LITERACY AND SCIENCE IN SOCIETY

An alternative starting point for this study where the scientific content in education is in focus, is found in the term "scientific literacy". An attempt to define the term is made by Knain & Prestvik (2006) whom believe that scientific literacy includes languages, culture, actions, and also reflection of experiences. The term has been used in relation to science education since the 1960s, but has been used in such a broad way that accuracy is partly lost. Roberts (2007) tried to give the concept an alternative definition and argued that scientific literacy originally had two different directions On one hand it had an internal meaning to science itself, in the form of laws and theories. On the other hand, science is perceived more as a societal civic competence.

Roberts suggests that the term should stand for both directions. Sjöberg (2000) also discusses the concept of scientific literacy. He poses the question that asks if scientific laws and theories are something that everyone should acquire. In the larger international study (OECD-PISA, 2003, p. 133) scientific literacy is defined as follows:

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.

The definition above should be understood as viewing scientific education in a social and more general perspective.

LIMITATIONS IN CONTENT

Based on the above discussion, we must also ask ourselves the question when students should confront more tangible and planned scientific content. Furthermore, how can students' daily meetings with science be related to school and schools opportunities to keep and use students' and children's everyday interest, experience and expertise? We can with certainty say that a person's everyday life is full of experiences and thoughts that can be traced back to a scientific realm. For example we see, hear, feel, smell, taste, runs, cycle, stand, fly, construct, think, live and eat. We experience how it feels to increase speed, going up a hill, slip on the snow, to feel an ice cube and to burn our self on a match. We observe how water flows, freezes and evaporates and we observe the light and sound in various forms. It is hard to imagine human life without phenomena that can be traced back to a scientific understanding of the world. It is therefore appropriate to see science as a way of understanding the world and this is important for a child already in preschool and for students in primary school. Thus relevant for the present study is the question of what is a relevant content and should be in state and local government documents and curriculum. Further, what issues must be discussed by curriculum writers and politicians? In this discussion Helldén (2002) suggests that in successful science teaching for younger children, it is important that the teacher focuses on central or core concepts. Helldén continues that the teacher should have the ability and the knowledge to assess children's different understanding of scientific phenomena and provides opportunities for children in different educational contexts to reflect upon these. Additionally there are movements which can be interpreted as a reorientation of teaching science content. Based on their study Schreiner & Sjöberg (2005) argue that a change of direction in curricula towards contents and values that young people today see as relevant is important. It questions where science and technology are part of, and included in societal issues, and example being discussions regarding climate change. This is also visible in other studies where scientists report an increasing interest from students when the content is about the environment, stem cell research or genetic manipulation etc. (Harris & Ratcliffe, 2005; Klafki, 2004; Koutroulis, Papadimitriou, Grillakis, Tsanis, Wyser, Klaus. Betts, 2018; Kärna, 2009; Lewis & Leach, 2006; Lindemann-Matthies, Constantinou, Junge, Köhler, Mayer, Nail, Raper, Schüle & Kadji-Beltran, 2009). This focus on every day questions is of great importance for planning and implementation which Jidesjö, Oscarsson, Karlsson & Srömdahl (2009) highlight, and is based on students' answers to the question of what they are interested in. The students' answers showed they seemed to be interested in science areas such as health, life on earth and the universe. Millar (2006) proposes, instead of a traditional starting point in science teaching, that the teacher should build on the students' everyday experiences which is reflected in the media. Osborne, Simons & Collins (2003) draw attention to more of a societal perspective on science content and are critical to traditional science teaching often being more backward looking rather than forward looking.

In relation to future curricula, there are several reasons to keep the debate alive on what content is relevant to science education and how it is justified and organized. One problem in the Swedish science curriculum is that content is strictly structured into subjects while the content can often be seen as inter disciplinary (Skolverket, 2016). An example of this is that in the science curriculum, the concept of matter is central to both in chemistry and physics, but in real teaching it is often treated in a more contextual aspect. This opens for discussion and research on what teachers actually experience as the central core, and how science teaching can be conducted. It will then be crucial how the teacher understands the relationship between structurally fragmented defined objectives in relation to a contextually defined content in relation to students' learning and teaching.

THEORETICAL AND METHODICAL FRAMES

This study has a primary focus on concepts in a science school discourse related to questions about students' socialization into active members of society. Based on the background and data, Bernstein's concept of framing and classification is used as an analytic tool of contextual understanding (1996/2000). The concept of framing can be related to the teacher who can be seen as the person who reproduces and teaches what society expects as a scientific content. With regards to Bernstein's concept of vertical and horizontal discourse, the teacher could give the students the opportunity to use scientific knowledge that makes it possible for students to develop thoughts about the more complex and sometimes abstract concepts (vertical horizon) in science. The empirical data in this study is based on conversations with teachers and how they give priority to what they believe qualifies preschool- and primary school student abilities to develop the necessary understanding of science. Data collection was carried out in three different focus groups where the discussion could be described as open, yet containing a visible and clarified aim (Davidsson, 2007). Two of the groups consisted of a total of 16 teachers who teach science and technology in primary school. The teachers in each group derived from four different schools. Corresponding talks and discussions were also held with 6 teacher from three different universities teaching science. The data consisted of written protocols which have undergone qualitative text analysis (Esaiasson, Gilljam, Oscarsson and Wägnerud, 2004). In the present study, the approach has been an inductive analysis of text where founded categories were related to the informants' statements. The study's qualitative approach is based on the premise that parts are related to each other and to the whole.

SCIENCE TEACHING – A RESULT

The different themes identified in the focus groups discussions were directed toward *content aspects*, *methodological aspects* and *aspects of consequence*.

Content aspects

The content aspects, which are presented below, are descriptions that can be understood as related to

- a specific science content,
- general abilities to communicate a scientific content, and a
- integration of technology and science content in a social perspective.

Specific science content

All three focus groups returned several times in the conversation to the content priority of *"energy, matter, and life"*, which can be understood as three core concept topics which science teaching should be directed towards. It means that the students' abilities to develop scientific knowledge can be contained to these three areas. It also indicates that both preschool and primary school science teaching can be based on the three areas. The focus groups also referred to content such as *"cycles, photosynthesis and combustion"* which are related to the concept energy. Similarly the prioritizing of *"building blocks and the structure of matter"* could be related to the content matter. The third unifying content area "life" is identified in the conversations related to, *"biodiversity, evolution",* and *"the human body and health"*.

General abilities to communicate a scientific content

During focus group discussions there are examples of students' ability to *"communicate"* the above mentioned content. To communicate something means for example, the ability to *"analyze"* and *"structure", i.e.* the student's ability to problematize different aspects of science content. The term *"creativity"* can be interpreted as a problem-oriented expression which can be understood as needed for the students to develop their own understanding.

Integration of technology and science content in a social perspective

The teachers in primary school exemplify and prioritize *"technology development"* as part of students' learning and see it as a way to give students the opportunity to understand the role of technology in society. In other way technology can be understood as a way for mankind to use tools in various ways to go beyond the human body's limitations whether it be by supporting the senses or using technological tools. Technology then becomes a part of the natural sciences. Examples that were given included *"it is important that students have knowledge about tools because they help us having another image of ourselves"*. This expression shows that special tools or technology made it possible for humans to strengthen the senses.

Methodological aspects

The question of how students can approach scientific content, leads to the identification of methodological aspects which in the focus group conversations leads to two key issues, namely, the ***"How?"*** and ***"How do we know?"*** The question of how to approach scientific content in teaching involves suggestions of teaching strategies, where the teacher uses *"stories"* and *"texts"* for example. One of the teachers said *"kids think everything is already done! They need to be challenged and when it comes to textbooks there is less and less text and more and more graphics and pictures, you should do the opposite"*. Another teacher believes that science education and teaching should aim to *"reclaim the stories"*. In the conversations about the choice of content one of teachers mentioned that *"nothing would be focused without a context"*. Furthermore, one of central strategies in science education, is to be open to discussions about students own genuine questions and to trust on student's ability to communicate. The second question ***"How do we know?"***, could be understood as a different way to approach central science questions. This question can implicitly be seen as a step towards deepening science content that traditionally is referred to as scientific facts. In science teaching it is not enough for students to only replicate facts without being challenged by tasks where they are required to derive, show and prove. Informants give the following examples of questions of this type: *"How do we know that the earth rotates around its axis?"* or;*"How do we know that there will be day and night?"*; *"How can we know that a neutron charge is zero?".* Two of the teachers in the group believed that such examples of issues should follow the students through the whole education system where natural science is taught consistently. Approaching science by asking the question "How do we know?" also leads to follow-up questions such as *"How can we know this*?" or *"Can you find out what is known?"* and *"What is science and what is pseudoscience?"*

Aspects of consequence

In the focus group discussions about science teaching in primary school, the conversation was especially directed toward the *"historical development"* and *"sustainable development"*. The informants understood that students should be given the opportunity to experience science as a consequence of human impact on nature. One of the teachers expressed that science education should start from *"an overview perspective"* of different scientific topics. Examples of such overviews are *"science in a historical perspective"* or science content which focus on *"sustainable development"*. One of the focus groups also expressed this clearly when stressing *"it is important for children to meet science when they begin preschool, it is not reasonable that they first will meet science in secondary school".* When teachers discuss sustainable development, it includes content such as: *"food, construction materials, clothing, air purification using organisms, energy metabolism, radiation, heat and the human body"*, i.e. what it is to feel good or to have good health. The discussions also included *"radiation equilibrium, finite resources, universe, meteorology" and "what technology and tools gives us different views on ourselves".* They understand that technology has a clear impact seen in a holistic perspective if you believe that *"technology is linked to the man, extends our body, strengthens our minds and both protects and threatens our existence".*

CONCLUSION AND DISCUSSION

The conclusions drawn from 22 professional conversations, on what in primary school science teaching assists students to develop necessary scientific understanding, is that the most central content of science education should be understood as general understanding of science. In this context we can identify three main aspects of science education which seem to be central. Aspects of science content in a specific perspective, science methods, and consequences of science and technology development. If we pay attention to science content in a literacy perspective it consists of students understanding and communication of specific science content and integration of technology content in science and society. The methodological aspect describes how students can approach a scientific content through the two central questions *"how?"* and *"how do we know?"* Finally, an approach to science education is that the student develops an ability to understand science and nature based on a holistic approach. This might mean for example, an ability to understand science in a historical perspective and an ability to understand sustainable development in a societal perspective. The above results do not claim to provide a full understanding of what science education stands for, but the results shows that it is possible to identify some key elements in a discussion about science teaching and scientific literacy in relation to a primary school perspective. In this perspective of science education, students are given the opportunity to become scientifically literate i.e. The students can use their scientific knowledge to develop thoughts, challenge attitudes, argue, analyze, etc. which can in turn give them possibilities to influence society. To be scientifically literate means that a person can use scientific language to be able to understand both everyday life and scientific concepts (Anderberg, 2009; Svensson, 2009; Åkerblom 2009. In a science education context language and the scientific discourse therefore is a prerequisite to be able to get this ability (Säljö & Wyndhamn, 2002). In this article, I have asked professionals what they think is the most central content in science education. This should be seen in the light of what in primary school science teaching gives students the ability develop necessary understanding of science. The participating teachers in the study stress three key aspects: the content, methodology and consequences as student's opportunity to develop necessary and qualifying understanding in science (Figure 1).

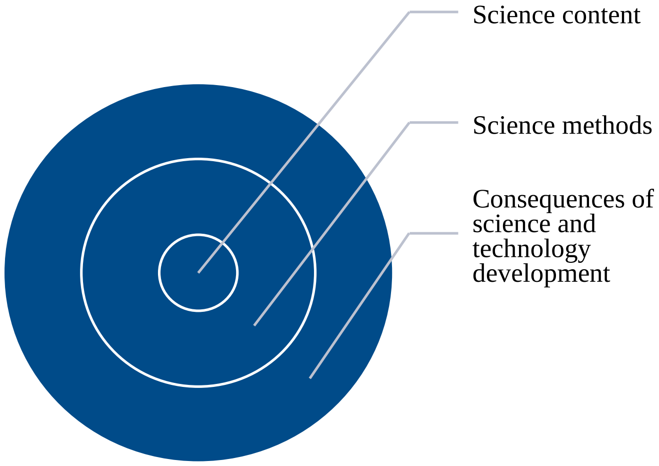

Figure 1. The three central aspects to be science literate; science content, scientific methods and consequences of science and technology development.

To be scientifically (Roberts, 2007; Sjöberg, 2000) is to have the ability to make decisions in relation to the consequences of science related activities in society (OECD-PISA, 2003). The study shows that the scientific content of energy, matter, life and technology are to be some of the most basic elements in a scientific teaching context. It is also possible to understand the importance of methodological understanding. Furthermore, science education can give an ability to understand and act on issues related to decisions in society. Bernstein's (1996/2000) theoretical concepts framing and classification describe the ability of students to alienate or approach science understanding. This is important in the perspective of students coming from different socio-economic conditions and having different experiences of the outside world in relation to scientific content presented in school. It is essential that they feel comfortable with what questions there are to ask in relation to the outside world and in a scientific context. It is therefore essential in science teaching to give students opportunities to look beyond the everyday context (horizontal discourse). It is a context consisting of students everyday beliefs about nature and used in an everyday language. It is of crucial importance that all students in science school discourse are provided an opportunity to use and understand the content through key science concepts, which partly could be seen in the present study (vertical discourse).

To be scientifically literate in a teaching context means that a student show an ability to use scientific information to ask questions and draw conclusions and to prepare her to be able to influence and take decisions concerning human activities in the society and vice versa (Harris & Ratcliffe, 2005; Jidesjö et al., 2009; Klafki, 2004; Kärna, 2009; Lewis & Leach, 2006; Lindemann-Matthies et al., 2009; Millar, 2006). We summarize the results of the study, noting that sciences in school aim to support students ' ability to be scientific literate, which gives the student the opportunity to understand the phenomena of nature and society based on scientific knowledge. A prerequisite for this is to understand that science education is based on the necessity of knowing the science discourse, which include everyday science understanding, concepts in science, feelings, attitudes, experiences, etc. For teachers, it implies knowledge of the specific science school discourse and an ability to support students meeting this discourse.

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