Science education as public and social wealth: The notion of citizenship from a European perspective

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ABSTRACT

In this paper, (a) we present a framework for developing a science content (i.e., science concepts, scientific methods, scientific mindset, and problem-solving strategies for socio-scientific issues) used to design the new Cypriot science curriculum aiming at ensuring a democratic and human society, (b) we use the previous framework to explore the citizenship notion which is cultivated by the science curriculum content of the primary education (grades 5 and 6) of two European countries: Cyprus and Greece. The analysis focuses on two science topics: (a) Health and human body, and (b) Natural environment. The results of this analysis highlight features that outline two different kinds of citizenship. On one hand, the cultivation of the citizenship in the Greek science curriculum is based on the knowledge acquisition by students, mainly related to science concepts. The Greek science curriculum promotes the idea that citizenship education is strengthened when science education focuses on the acquisition of knowledge concerning the "academic world" of science in order for the students to be able to decide on various socio-scientific issues. On the other hand, the Cypriot science curriculum promotes the notion of citizenship based on the cultivation of knowledge, competencies, and mindset that can contribute to the improvement of children's everyday lives. In this direction, students are strengthened socio-politically to reshape our society towards social justice and equity. We support the latter notion of citizenship and argue that the "scientific literacy for all" movement can radically overthrow the social obstacles that prevent us from moving towards a democratic and human society.

KEYWORDS: *Science education, citizenship, curriculum, framework, analysis*

1 INTRODUCTION

The Cypriot science curriculum, which is presented elsewhere (see Siatras, Pramas, Stampouli, & Koumaras, 2013), was based on the principles established by the Commission of the Curriculum Reform of the Cypriot Public Schools. These principles are: 1) acquisition by all students of an adequate and coherent body of knowledge, 2) development of key-competencies, and 3) the cultivation of citizenship (i.e., knowledge, competencies, mindset, and engagement in socio-political action that constitute a democratic citizen) to all students through all school subjects. Following the above principles, we support the idea that it is important for the Cypriot science curriculum to ensure that all children are able to contribute to a knowledge society, participate in all aspects of social life such as labour, politics, economy, and culture, as well as live in conditions of freedom, democracy, prosperity, and social justice (Curriculum for Public Schools of Cyprus, 2008).

A number of researchers support the idea that in order for the *scientific literacy for all* movement to be strengthened, it is important that science education be based on three different domains: 1) a body of knowledge including facts, definitions, concepts, theories, laws, etc, 2) scientific methods, which are referred to procedures used by scientists to generate new knowledge, and 3) Nature of Science (NoS), that describes the characteristics of the nature of knowledge (ex. scientific knowledge relies on empirical evidence and it is a subject to be changed in the light of new evidence) (Bell, 2009).

Many science curricula have been developed using the above domains, often including a limited amount of content related to environmental and socio-scientific issues to teach the three science domains described earlier. However, without including a fourth domain concerning socio-scientific activism, science curricula cannot ensure that students *actively* participate in the sociopolitical and cultural contexts that emerge through direct problem-solving situated within socio-scientific issues. Without a domain of sociopolitical activism, students are mainly prepared to deal with a minor set of abstract(ed) environmental and socio-scientific issues in a world of many different relations (Bazzul, 2013; Hodson, 2011). Roth & Calabrese-Barton (2004) state that *"if we wish science education to be relevant to people's citizenship or everyday lives, we do well to allow the learners to participate in a diversity of these relations"* (p. 159).

We support the idea that science education can empower students to acquire knowledge, competencies, and mindset in order to be prepared not only to recognize the tentative characteristics of science or to acknowledge its impact on society and culture, but to use science in making informed decisions in their everyday lives, as well as struggle for values such as social justice and equity which are important aspects of a democratic and human society (Bencze & Carter, 2011; Freire, 2005; Hodson, 2011; Τσιάκαλος, 2003). Following this path, we have designed a framework for content development which is being used with the new Cypriot science curriculum. This framework aims at ensuring the relevance of science content with different aspects of children's everyday life by intertwining four different levels: a) science concepts, b) scientific methods, c) scientific mindset (cultivated by teaching and implementing NoS and scientific methods), and d) problem-solving strategies in everyday life (see **Figure 1**).

2 A FRAMEWORK FOR THE CONTENT DEVELOPMENT OF SCIENCE CURRICULA

The science curriculum content in order to fulfill the basic principles that were set by the Commission for the Curriculum Reform of the Cypriot Public Schools, must ensure that all students have the opportunity to:

- link taught *science concepts* with their lived realities (Brickhouse, 1994),
- acquire key-competencies through *scientific methods* in order to be able to ask questions that can be investigated, design and implement research, evaluate the implemented research processes, communicate results, and value the effectiveness of different considerations of their peers about investigated issues (Michaels, Shouse & Schweingruber, 2008),
- develop a *scientific mindset* that empowers students to critically evaluate evidence before forming an argument based on information they receive through media and social networking, and to acknowledge evidence that is produced through research (Bell, 2009).

We support the idea that the understanding of science concepts, the acquisition of competencies of scientific methods, and the cultivation of scientific mindset are intertwined with the development of problem-solving strategies that enable students to make informed decisions on *socio-scientific issues* and act towards the common good. We argue that this framework is not limited to preparing students for the labor market (i.e., scientists or engineers), but contributes to the empowerment of students to become critical about their lived realities, actively participate in society by making informed decisions on socio-scientific issues, and be able to fight for values such as social justice and equity.

Figure 1 represents our content development framework. The double arrows in the figure show that each part of the framework is used for (and cultivated by) the other parts.

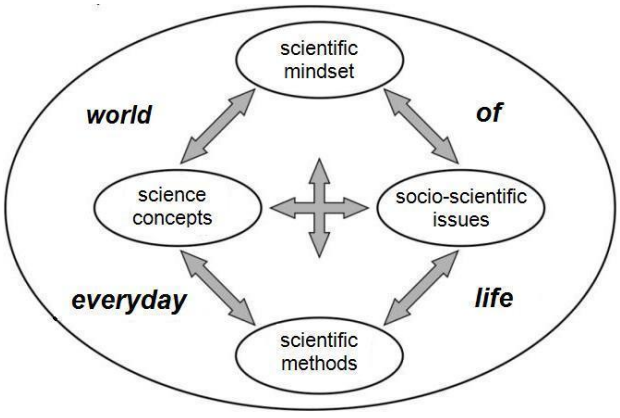

Figure 1: *Framework for the development of the science curriculum content*

2.1 Science concepts

The level of science concepts focuses on providing an adequate and coherent body of concepts that facilitates the forming of explanations about phenomena students observe in their

everyday life. This level highlights the practical and functional features of science optimizing students' everyday life (Aikenhead, 2006; Brickhouse & Kittleson, 2006; DeBoer, 2000).

2.2 Scientific methods

Scientific methods focus on the cultivation of basic and complex competencies that students should acquire in order to deal with socio-scientific issues in their daily life. On a basic level, students are expected to observe, communicate, classify, measure, interpret their observations and make predictions. At a more complex level, students should be able to identify questions that can be investigated, design and implement research that will help them in making a decision on socio-scientific issues, evaluate the implemented processes, as well as assess the arguments and viewpoints of others concerning the socio-scientific issues they deal with. Scientific methods are not necessarily cultivated in children in order to prepare them as future scientists, but to be used by children in their lived realities (Bell, Toti, McNall, & Tall, 2004; Dewey, 1910; Harlen, 2001; OECD, 2007).

2.3 Scientific mindset

Scientific mindset includes citizens' understandings and attitudes, citizens' thoughts about their personal or social life, and citizens' decisions about socio-scientific issues. We use the term scientific mindset to highlight the importance of cultivating students' thinking and attitudes through NoS teaching. NoS refers to two interrelated branches: (a) NoS as a content, and (b) NoS as a means for fostering students' scientific mindset not only on science issues, but for their lived realities as well (Yacoubian, 2012). This framework highlights the latter NoS domain mentioned above. We support the idea that blending NoS teaching with teaching scientific methods could empower students' scientific mindset in their everyday life (Bell, 2008). Scientific mindset aims at empowering students to critically review evidence before forming an argument based on information they receive through media and social networking. It is important that the students will be able to form their personal views about issues related to natural and social environments by challenging arguments and strategies that are used by third parties, and if necessary move away from their personal views by acknowledging arguments that are based on evidence produced through research. Aspects of scientific mindset include the willingness of children to use or collect evidence in order to form an argument and to be skeptical, open-minded, as well as critical while reviewing arguments of other people (Harlen & Elstgeest, 1992; Kozlow & Nay, 1976).

2.4 Socio-scientific issues

Students become empowered when they are engaged in problem-solving strategies to deal with socio-scientific issues. Science content must provide opportunities for all students to actively engage with complex socio-scientific issues. In this level, students are expected not only to plan the necessary actions in order to deal with socio-scientific issues, but also act towards improving the conditions of their lived realities, by taking advantage of all the scientific and technological aspects of society, in terms of protecting fundamental human rights (i.e., access to

health services, drinking water, and electricity) (Bencze & Carter, 2011; Freire & Macedo, 1987; Hodson, 2003; Roth & Calarbrese-Barton, 2004).

2.5 A framework for the science curriculum content: "World of everyday life"

The context of everyday life is a key factor in designing a science curriculum. We support the idea that it is important that the science content is relevant to children's lives so as the 'world of everyday life' will be able to effectively inform the *scientific literacy for all* movement. It is crucial that the teaching of science concepts, cultivation of competencies of scientific methods, development of scientific mindset, as well as fostering student engagement in problem-solving strategies to deal with socio-scientific issues, are contextualized in the framework of the "world of everyday life". In this direction, Bell (2009) argues that students should be able "to understand media accounts of science, recognize and appreciate the contributions of science, and be able to use science in decision-making on both everyday and socio-scientific issues." (p. 1) In other words, any content of a science curriculum that is not relevant to children's everyday life (Millar, 1981) or popularizes science without acknowledging any conceptual knowledge within science education (Jenkins, 1999), leads to a "manipulated education", and accordingly prepares "manipulated citizens" (Hodson & Prophet, 1994).

3 A COMPARATIVE CONTENT ANALYSIS OF SCIENCE CURRICULA IN GREECE AND CYPRUS

In the last fifteen years the Greek education system has undergone a number of curriculum reforms which highlight a tentative educational policy in Greece concerning the curriculum. During this time, PISA surveys highlighted the failure of Greek students to apply the knowledge and competencies they had acquired in school to everyday issues (OECD, 2001; OECD, 2004; OECD, 2007; OECD, 2010). Meanwhile, the second author (Panagiotis Koumaras) was the head of a committee responsible for designing and developing the compulsory Cypriot science curriculum as part of a larger project of the education reform (Cypriot science curriculum, 2011). This reform focuses on developing an education in which all students acquire the needed knowledge and competencies to contribute to a democratic and humanistic society, based on values such as social justice and equity. In this way, the Greek and Cypriot science curricula highlight two different views of citizenship, despite the fact that the two countries share a common language and sociocultural values. In the section that follows, we explore the view of citizenship that cultivated by the primary science curriculum content (grades 5 and 6) of both Cyprus and Greece. The content is analyzed in four levels based on the framework presented earlier: (1) science concepts, (2) scientific methods, (3) scientific mindset, and (4) problem-solving strategies for socio-scientific issues. The analysis focuses on two topics related to citizenship: (a) Health and human body, and (b) Natural environment.

3.1 The Cypriot science curriculum

3.1.1 Science topic: "Health and human body"

The Cypriot science curriculum content of primary school (grades 5 and 6) in the topic "Health and human body" focuses on understanding healthy and unhealthy habits, the motion of the human body (skeletal system, joint and muscle function), nutrition (digestion, respiration and blood circulation), as well as human sexuality and reproduction.

3.1.1.1 Science concepts

This science concept level provides the opportunity to talk about hygiene issues and understand the basic functions of the human body systems (i.e., musculoskeletal, nervous, digestive, respiratory, circulatory and reproductive). Teaching objectives provide students the opportunity to negotiate issues related to nutrition and habits that harm the human body (i.e., smoking, alcohol drinking) as well as to understand the impact of illnesses on human body (i.e., appendicitis affects the digestive system, asthma affects the lungs -respiratory system, etc). Moreover, students are urged to organize classroom meetings with doctors, nurses, and psychologists in order to discuss issues and exchange ideas about issues that are related to sexuality, sexual health and precautions against sexually transmitted diseases.

3.1.1.2 Scientific methods

Scientific methods engage students in argumentation about issues concerning human health, the motion of human body (skeletal system, joint and muscle function), the nutrition function (i.e., digestion, respiration and blood circulation), and human sexuality and reproduction. Students are encouraged to observe, collect, evaluate and communicate information and evidence. At a more complex level, students are expected to ask questions that can also be investigated (i.e., "what causes a heart attack?"), and remodel them, if necessary, in order to make them more handy (i.e., remodel the question "how the heart works?" into a question of everyday life that is: "what factors affect the ability of a pump to circulate the water?"), select and use tools for modeling (i.e., using different materials and tools to build a model of a heart), conduct research, arrive at conclusions, and communicate their research work to their peers.

3.1.1.3 Scientific mindset

The Cypriot science curriculum cultivates a scientific mindset that leads the students to evaluate the scientific and technological aspects of society related to human health (i.e., medications, medical equipment, genetic modified foods, chemical products, etc). It promotes teaching objectives that provide students with the opportunity to critically review the different information sources during an investigation (i.e., evaluate and critically review TV advertisements as information sources for healthy food consumption), as well as to reshape their attitudes towards TV messages that promote information related to human health. Students are also expected to be able to assess the impact of technology development related to the human body (i.e., sneakers protect better the musculoskeletal system) by taking into account various

social and environmental issues (i.e., unsafe working conditions, child labour, marketing, plastic usage that are related to shoes manufacturing).

3.1.1.4 Socio-scientific issues

This level refers to teaching objectives that provide students with the opportunity to negotiate issues related to maintaining good health and protect themselves from various infectious diseases. Students are engaged in argumentation processes in order to make informed decisions on socio-scientific issues related to personal as well as public health (i.e., does the increase of commercial air transportation affects public health and how?). Moreover, the science curriculum includes teaching objectives that give students the opportunity to develop their personal views about the way in which emotional expression helps them cultivate feelings of respect about issues of gender identity.

3.1.2 Science topic: "Natural environment"

The Cypriot science curriculum content of primary school (grades 5 and 6) in the topic "Natural environment" focuses on issues of biodiversity, interaction of social and natural environment, recycling, and how the natural environment can be protected.

3.1.2.1 Science concepts

The science concept level includes teaching objectives related to various local and regional habitats associated with plant and animal populations. Students have the opportunity to negotiate issues of biodiversity.

3.1.2.2 Scientific methods

The Cypriot science curriculum engages students in investigating the immediate and broader environment through fieldwork activities. Students are encouraged to identify animals and plants that live in their environment and draw conclusions about food chains and nexuses. Furthermore, teaching objectives focus on other features of scientific methods such as identifying questions that can be investigated in order to deal with everyday problems (i.e., plant or animal extinctions), making hypotheses about different environmental impacts on local communities, researching those hypotheses, and classifying materials from their everyday life in recyclable or non-recyclable.

3.1.2.3 Scientific mindset

The science curriculum includes teaching objectives that ensure to students the opportunity to evaluate the benefits of biodiversity, as well as engage in dealing with disadvantages that are raised by its reduction (i.e., the expansion of single species growing in rural areas reduces the biodiversity and maximizes the usage of chemical fertilizers and pesticides). In the same direction, students have the opportunity to assess the environmental and social impacts of a product changing into other products (i.e., conversion of a tree into paper products, conversion of

oil into plastic items used in everyday life) some of which end up in landfills while others are recycled.

3.1.2.4 Socio-scientific issues

This level refers to cultivating students' action to protect the local environment. Teaching objectives provide the opportunity to students to develop their personal views about the danger of reducing biodiversity, find images from websites that highlight local environments that have undergone environmental disasters, interview local community members (business owners, local authorities, environmental organizations) in order to examine their views about the local environment, and make decisions on protecting their community environment. In this way, students are encouraged to form community collective initiatives for the protection of the natural environment.

3.2 The Greek science curriculum

3.2.1 Science topic: "Health and human body"

The Greek science curriculum content of primary school (grades 5 and 6) in the topic "Health and human body" focuses solely on the study of the human body.

3.2.1.1 Science concepts

The Greek science curriculum includes teaching objectives that can be grouped into six categories: (1) circulatory system, (2) digestive system, (3) hearing, (4) vision, (5) respiratory system, and (6) reproductive system. In the first category (circulatory system), teaching objectives focus on concepts about the heart and its parts, veins and arteries, large and small circulation, heart rate measurement, as well as other factors that affect the blood and the circulatory system function. In the second category (digestive system), teaching objectives refer to the digestive organs and their function, factors that affect the digestive system, as well as naming details about the different types of teeth and the role of each one of them. In the category of hearing, the included concepts refer to the parts of the ear, the hearing function and the factors that affect the hearing. In the category of vision, teaching objectives are respectively the same to the previous category of hearing where students learn about the eye parts, the vision function and the factors that affect it. In the category of the human respiratory system, teaching objectives focus on the respiratory organs, its function, the way in which the human voice is produced, and the factors that affect the function of respiratory system. Finally, the reproductive system category focuses on the reproductive organs of the human body (male, female), the process of fusion of gametes that create a zygote, embryo fetal development, and the factors that affect the health of newborns.

3.2.1.2 Scientific methods

The Greek science curriculum does not include objectives related to scientific methods in the topic "health and human body". Moreover, the analysis shows that the Greek science curriculum

does not provide opportunities for the students to implement research, but they only learn how to follow given instructions in order to accomplish tasks assigned within science courses.

3.2.1.3 Scientific mindset

The analysis shows that the Greek science curriculum does not include teaching objectives related to scientific mindset cultivation.

3.2.1.4 Socio-scientific issues

The Greek science curriculum does not include teaching objectives about engaging students in protecting their personal hygiene. For example, in the subtopic "transmissible diseases", the Greek science curriculum focuses on concepts that are related to pathogenic microorganisms, content and function of vaccines, how drugs work, differences between drugs and antibiotics, etc. In this level, the science curriculum highlights broader socio-scientific issues by focusing on teaching the hardcore of scientific knowledge.

3.2.2 Science topic: "Natural environment"

The Greek science curriculum content of primary school (grades 5 and 6) does not include a standalone science topic called "Natural environment". For this reason, we focus on analyzing the content of subtopics we consider that fall into the broad topic of "Natural environment" which are: (1) chemical phenomena - interactions, (2) mineral resources, (3) living matter, (4) energy and its conversions, and (6) ecosystems.

3.2.2.1 Science concepts

The Greek science curriculum includes teaching objectives that focus on knowing that atmosphere consists of a mixture of gases and its components. Additionally, students are expected to be able to describe carbon dioxide's composition because it is considered harmful for the environment, and to recognize that many substances react with each other to form new substances and call these conversions "chemical phenomena". Moreover, the science concept level in the Greek science curriculum focuses on concepts about the description of how to export iron ore, understand the existence of microorganisms in the environment, and acknowledge microorganisms' interaction with humans and other organisms. In addition, students are expected to be able to distinguish the different alternative energy sources (solar, geothermal, wind, biomass) and group them into renewable and nonrenewable sources.

3.2.2.2 Scientific methods

The Greek science curriculum does not include objectives related to scientific methods in the topic "Natural environment".

3.2.2.3 Scientific mindset

The analysis shows that the Greek science curriculum includes teaching objectives that provide to students the opportunity to value the importance of the discovery of iron and

aluminum, and its effects on society, as well as to examine the contribution of iron and aluminum applications to technoscientific aspects of society.

3.2.2.4 Socio-scientific issues

The Greek science curriculum includes teaching objectives related to the cultivation of student understanding about the necessity of saving energy, and the usage of alternative energy sources. Teaching objectives engage students in negotiating environmental problems such as oil reduction or depletion, environmental pollution, as well as human interventions in nature. The analysis shows that teaching objectives mostly refer to abstract socio-scientific issues that are important for the environment, but not so relevant to children's everyday life.

4 DIFFERENT VIEWS OF CITIZENSHIP

The Cypriot science curriculum content analysis shows that the notion of citizenship promoted in the curriculum is based on the cultivation of knowledge, competencies, and mindset that affects children's lived realities. In the context of everyday life, science education is important to empower students in order for the latter to be able to: (1) invoke the scientific knowledge into discussions about the usage of natural resources, the improvement of living conditions, and the protection of the public health, (2) distinguish whether research findings or someone's claims are based on evidence, (3) make informed decisions on issues raised by media or social networking related to health, environment, and natural resources, (4) contribute to the development of scientific and technological aspects of everyday life, (5) evaluate the positive and negative usages of science and technology, and propose concrete actions to reverse the negative ones, (6) understand that the development of scientific knowledge is an ongoing process through assumptions, models, experiments, affirmations or denials, etc., (7) understand the existing limitations of science and the chance to overcome these limitations in the future, and, last but not least, (8) understand that evidence can be interpreted in more than one way. In this direction, the Cypriot science curriculum promotes a notion of citizenship that focuses on strengthening students socio-politically in order for the children to be able to (re)build our society towards social justice and equity.

In the opposite direction, the Greek science curriculum promotes a notion of citizenship that focuses on the acquisition of knowledge concerning the "academic world" of science in order for the students to be engaged with various socio-scientific issues. Within this path, students are expected to be familiarized with specific terminology and laboratory procedures of science. Eleven- and twelve-year-old students in Greece are expected to memorize specific matter-of-fact knowledge focusing on laboratory situations. Furthermore, many teaching objectives are related to specific information, theories, and techniques paying attention solely to science concepts. It is believed that children's critical thinking will be developed by focusing on teaching science concepts and in that way students will be empowered to participate as future citizens by applying the acquired knowledge in socio-scientific issues in order to improve their lived realities.

5 CONCLUSIONS

In this paper we (a) presented a framework for developing science content (i.e., science concepts, scientific methods, scientific mindset, and problem-solving strategies for socio-scientific issues) that was used to design the new science curriculum in the Cypriot education reform aimed at ensuring a democratic and human society, and (b) used that framework to explore the citizenship notion which is cultivated by the primary science curriculum content (grades 5 and 6) of two European countries: Cyprus and Greece. We argued that the cultivation of notion of citizenship in the Greek science curriculum is based on the knowledge acquisition by students, mainly related to science concepts. The Greek science curriculum promotes the idea that citizenship is strengthened when science education focuses on the acquisition of knowledge concerning the "academic world" of science in order for the students to be able to decide on various socio-scientific issues. On the other hand, the Cypriot science curriculum promotes the notion of citizenship based on the cultivation of knowledge, competencies, and mindset that relate children's everyday lives. Students are thereby empowered socio-politically to reshape society towards social justice and equity. In this direction, we support the idea that students become aware of different social, cultural, political, and environmental contexts through science education (Bazzul, 2012; Beck, 1993) in developing collective actions (Hodson, 1999) to build a democratic and human society (Τσιάκαλος, 2003; Yacoubian, 2012; Hodson, 2011).

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