CHAPTER 6

Socio-scientific Issues in Education for Sustainable Development

Aslı Koçulu
Yildiz Technical University

Mustafa Sami Topçu
Yildiz Technical University

Socio-Scientific Issues

In today's world, rapid developments in science and technology continuously create new complex and controversial issues in society because science and society mutually affect each other. In other words, dilemmas in society could arise from scientific developments (Sadler & Zeidler, 2005a; Topçu, Muğaloğlu & Güven, 2014). Today's societies often try to cope with political, social and moral dilemmas caused by socio-scientific issues (SSIs). SSIs are defined as complex social issues including conceptual, procedural, and technological associations related to science (Sadler, Romine & Topçu, 2016). SSIs are generally controversial issues and needs the assessments of ethical or moral concerns for multiple possible solutions of these issues (Zeidler & Nichols, 2009). Sadler (2011) emphasized that these solutions cannot be specified by only scientific considerations because SSIs are affected by social factors like economic, politics and ethics. According to Eastwood et al. (2012), there are two important characteristics of socio-scientific issues: the connection with science content and social importance. SSIs require considering both the science dimension and the social ramifications of the issue for developing solutions (Sadler et al., 2019; Zeidler et al., 2005). Therefore, SSIs can help students learn science contents by gaining awareness about the relations among social, political and scientific perspectives. Alternative medicine, climate change, global warming, nuclear energy, genetically modified organisms (GMOs), cloning, gene therapy and stem cells are some examples of SSIs. These issues show the characteristics of SSIs that is complex, debatable, open-ended and ambiguous issues involving both science and society (Eastwood et al., 2012; Sadler, 2004; Sadler & Zeidler, 2005b; Topçu, Yılmaz-Tuzun, & Sadler, 2011).

SSIs are widely used to develop different skills like critical thinking, problem solving, communication etc. (Chung, Yoo, Won Kim, Lee, & Zeidler, 2016; Hestiana & Rosana, 2020; Solbes, Torres, & Traver, 2018). In general, SSIs is basically crucial and effective in terms of fostering students' scientific literacy (Ke, Sadler, Zangori, & Friedrichsen, 2021; Kolstø, 2001; Sadler, 2004; Sadler & Zeidler, 2005a, 2005b). That is, the practices of SSIs in science classroom enable students to become scientifically literate. Scientific literacy provides students to understand connections inherent among SSIs as well as

the ability to analyze, synthesize, and assess information, informed decision making, and moral reasoning (Zeidler, 2001). In other words, scientific literacy help students to become responsible citizens and have sensitivities to the issues around their lives.

Education for Sustainable Development

In our age, sustainable development is one of the most crucial issues to achieve because as humanity, we have been facing to various environmental, economic and social problems and their harmful effects day by day. Sustainable development means "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). Sustainable development involves three dimensions: environment, economics and society and interactions between each other (McKeown, 2002). Therefore, understanding the principles of sustainable development, their implementation, the ramifications of their implementation and the values involved can be realized with the knowledge base from natural sciences, social-sciences and humanities (Hopkins & Mckeown, 2002). In order to achieve sustainable development, education is a main tool undoubtedly. This type of education that is, "Education for Sustainable Development (ESD)" requires a holistic and transformational approach that integrates different fields with the aim of building sustainable life for humanity.

Education for Sustainable Development (ESD) aims to promote learners' knowledge, skills, attitudes and values about the interrelated global issues that people are facing such as environmental degradation, climate change, loss of biodiversity etc. (UNESCO, 2021). ESD aims to prepare young people to become responsible future citizens and participate in social decision making (Burmeister, Rauch & Eilks, 2012; Hofstein, Eilks & Bybee, 2011; Stuckey, Hofstein, Mamlok-Naaman & Eilks, 2013). Gough (2006) stated that ESD comprises environmental education in the broader context of the socio-cultural and socio-political issues of poverty, equity, quality of life and democracy, besides an improvement perspective on social change and evolving circumstances. ESD guide and motivate individuals to make an effort for sustainable livings, participating in a democratic society, and living in a sustainable manner (McKeown, 2002).

Socio-scientific Issues in Education for Sustainable Development

At the 21st century, socio-scientific issues and sustainable development are involved in much of the socio-political rhetoric (Dani, 2011). One of the reasons of that SSIs and sustainable development are closely related and both of them include similar important issues and aims for the society. Most of the issues in education for sustainable development links to SSIs. Tytler (2012) stated that the research, which all relate centrally to SSIs as an approach to teaching and learning, focus to a varying degree on sustainability at the same time. This is why, as Herman, Sadler, Zeidler, and Newton (2017) emphasized, SSIs cover a large amount of real-world issues involving disputative

environmental issues like global warming, climate change, greenhouse effect, ozone depletion, environmental pollution, waste disposal, nuclear or hydroelectric power plants, alternative energy fuels. Mamlok-Naaman, Katchevic, Malka, Burmeister, Feierabend and Eilks (2015) stated that many chemistry-related issues of sustainable development like traditional or alternative fuels, bioplastics, climate change etc. meet the criteria of SSIs. These criteria are authencity, relevance, evaluation, allowing for open discussions, dealing with questions based on science and technology (Stolz, Witteck, Marks, & Eilks, 2013). According to Herman et al. (2017), the challenging moral nature of environmental issues, the importance of decisions concerning these issues, and the chance to link learning opportunities with the lived experiences of learners can be promoted with SSIs based education. In terms of environmental issues, SSIs-based education helps train individuals as responsible and conscious citizenry. In other words, it develops individuals' self-regulation, self-awareness, and apparent moral recognition of being very effective component of a larger system. SSIs-based education is one of the ideal ways of teaching controversial environmental issues because these issues are challenging and cannot be solved by understanding the science simply. With the SSIs based education, individuals have chances to discover complicated problems, discuss multi-solutions, and improve and justify their own perspectives about environmental issues. Responsible scientific literacy, citizenship and environmental stewardship can be achieved with the discussion of multiple dimensions of controversial environmental issues such as unequal effects on different groups and the environment, ethical concerns, political and ideological dimensions (Herman et al., 2017).

As Herman et al. (2017) emphasized that SSIs-based education is one the ideal way to contribute individuals to conceptualize and respond to environmental issues in terms of the various aspects (e.g., scientific, social, political, and ethical). SSIs promote students to learn by discussing effectively controversial ethical issues like sustainable development (Gresch, Hasselhorn, & Bögeholz, 2013). In addition, SSIs in education for sustainable development help students consider multiple perspectives from local to global issues. Scientific dimension of SSIs in education for sustainable development could be taught to students like at below:

Global Warming

The gradual heating of Earth's atmosphere, surface and oceans and the effect on the climate caused by human activities that leading to the release of carbon as carbon dioxide into the atmosphere with substantial quantities of greenhouse gases (methane, nitrous oxide and chlorofluorocarbons (CFCs)) because of the combustion of fossil fuels like coal, oil and gas and large-scale deforestation (Houghton, 2005).

Climate Change

A long-term change of weather patterns identifying Earth's local, regional and global climates (NASA, 2021)

Greenhouse Effect

A natural process warming the Earth's surface by the reason of greenhouse gases like carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs), and water vapor which absorb and re-radiate some energy of the sun reaching the Earth's atmosphere while the rest is reflected back to space (Houghton, 2004).

Biotechnology

The technology which uses living organisms and biological systems to develop and produce different products (Bhatia, 2018).

Nuclear Power Plants

A thermal power station that produces electricity by using a nuclear reactor as heat source to provide vapor for a turbine generator (U.S. NRC, 2021).

Environmental pollution

Any unnatural and negative changes in physical, chemical and. biological characteristics of the ecosystem causing harmful effects on various forms of life (Singer, 1970).

Socio-Scientific Issues related to Sustainable Development in Turkish Science Curriculum

One of the goals of Turkish Science Curriculum is to 'improve reasoning skills, scientific thinking habits and decision making skills with socio-scientific issues' (MOE, 2018). In this manner, there are different SSIs relate to sustainable development at different grade level in science curriculum. At 5th grade level, local and global environmental issues are taught as SSIs. Alternative thermal insulation materials, fuels (solid, liquid, gas, fossil) and renewable and nonrenewable energy sources are emphasized as SSIs at 6th grade level. Domestic waste and waste management, recycling (recyclable-non-recyclable wastes) are SSIs of 7th grade level. At 8th grade level, global climate changes, global warming, ozone layer, greenhouse effect, biotechnology are SSIs which are taught. Table 1 shows the SSIs related to sustainable development and the objectives of these issues in Turkish science curriculum.

Table 1. Socio-Scientific Issues Related to Sustainable Development in Turkish Science Curriculum

Grade Level	Socio-scientific Issues	Objectives
5	-Local and Global Environmental Issues	Students; -offer suggestions about the solutions for an environmental issue in immediate environment or our country -infer environmental issues which may occur at future as a result of human activities -discuss the advantages and disadvantages of human-environment interactions on examples
6	-Alternative thermal insulation materials -Fuels (Solid, Liquid, Gas, Fossil) -Renewable and nonrenewable energy sources	Students; -develop alternative thermal insulating products -argue about the significance of thermal insulation of structures in terms of household and national economy, and efficient usage of resources -give examples of commonly used fuels by classifying as solid, liquid and gases -explain that fossil fuels are finite and nonrenewable energy resource, and the significance of renewable energy sources with examples -discuss the effects of usage of different kind of fuels for the purpose of heat on human and environment
7	- Domestic Waste and Waste Management - Recycling (Recyclable-Non-recyclable wastes)	Students; -distinguish renewable and nonrenewable domestic waste products -design the project related to the recycling of domestic solid and liquid waste -inquire the recycling in terms of effective usage of resources and the contribution of recycling plants on economy. -take care of waste management at immediate environment and the workings of public institutions and nongovernmental organizations related to waste management.

8	-Global Climate Changes -Global Warming -Ozone Layer -Greenhouse Effect -Biotechnology	-Students; -link genetic engineering with biotechnology by giving examples about reclamation, vaccination, gene transfer, cloning, gene therapy. -discuss the dilemmas caused by biotechnological application and advantages and disadvantages of biotechnological applications -predict what genetic engineering and biotechnological applications can be at future. -discuss the causes and possible effects of global climate changes, greenhouse effect, how environmental issues affects the future of world and humans' life. -discuss precautions taken by World countries by calculating their ecological footprint with websites.

As understood from Table 1, Turkish science curriculum covers different SSIs which are open-ended problems and have multiple solutions. These issues serve one of the most important basic aims of science curriculum which is to raise individuals as scientifically literate. With SSIs in science curriculum are not only taught the science content but also help students better to cope with the challenges of science in the real issues of society (Sadler, 2011).

Eco-friendly Person Activities

Nuclear Power Plants

Purpose of the Activity:

- To explain the advantages and disadvantages of nuclear power plants
- To discuss environmental, economic and social effects of nuclear power plants for sustainable development

Time: 30 min.

Activity Procedure:

Students are divided 6 different groups consisting of 5-6 students. The case including the information about what nuclear power plants are and how they work is distributed to students. Teacher states that each group will evaluate the nuclear power plants in different aspects. That is, students in 1st group support the nuclear power plants and discuss the advantages of nuclear power plants in terms of environment between each other. Students in 2nd group support the nuclear power plants and discuss the advantages of nuclear power plants in terms of economics between each other. Students in 3rd group support the nuclear power plants and discuss advantages of nuclear power plants in

terms of society between each other. On the other hand, students in 4th group reject the nuclear power plants and discuss the disadvantages of nuclear power plants in terms of environment between each other. Students in 5th group reject the nuclear power plants and discuss the disadvantages of nuclear power plants in terms of economics between each other. Students in 6th group reject the nuclear power plants and discuss the disadvantages of nuclear power plants in terms of society between each other. After 10 minutes' discussion in groups, all groups explain the determined arguments and discuss their arguments about nuclear power plants as all groups at 20 minutes.

Ecological Footprint

Purpose of the Activity:

- To aware the ecological footprint (the measurement of the demand on and supply of nature)
- To discuss what can be done to reduce ecological footprint locally and globally

Time: 30 min.

Activity Procedure:

Students enter the website Ecological Footprint Calculator (https://www.footprintcalculator.org/) and answer the questions about food, housing, transportation individually in 15 minutes. They calculate ecological footprint and share their results to their teacher and classmates. Under the guidance of teacher, they discuss with each other about their results and suggest what can be done to reduce their ecological footprint in 15 minutes.

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About the Authors

Asli Koculu is a Ph.D candidate and Research Assistant of Science Education in the Department of Mathematics and Science Education at Yıldız Technical University, Istanbul Turkey. She received a B.S. in Science Education from the Middle East Technical University, Ankara, Turkey in 2015, a M.Sc. in Science Education from the Akdeniz University, Antalya, Turkey in 2018. She has been continuing Ph.D. and her research in Science Education at Yıldız Technical University, Istanbul, Turkey since 2018. Her research interests are environmental education, education for sustainable development, and STEM education. akoculu@yildiz.edu.tr

Mustafa Sami Topcu is a Professor of Science Education in the Department of Mathematics and Science Education at Yıldız Technical University, Istanbul Turkey. He received a B.S. in Science Education from the 19 Mayıs University, Turkey, a M.Sc. in Science Education from the 9 Eylul University, Turkey, and a Ph.D. in Science Education from the Middle East Technical University, Turkey in 2008. He also studied as a research scholar at University of Florida in USA, where he completed a significant part of doctoral dissertation about socio-scientific issues and argumentation in 2007. At the ReSTEM Institute of University of Missouri, he studied as a visiting professor in socio-scientific issues (SSI), scientific literacy, and argumentation-based projects during the Fall and Spring semesters of 2015. He has many publications in prominent refereed journals in science education. In addition, he is PI and Co-PI of the many national and international science education projects. He is the Co-PI of the National Science Foundation (NSF)-funded project entitled "Reducing Achievement Gaps in Science, Technology, Engineering and Mathematics (STEM): Promising International Research, Policies and Practices". As a Yıldız Technical University faculty member, Topcu teaches courses for an Undergraduate's level science education program, a Master's level, and a doctorate level science education programs. His research interests are socio-scientific issues, argumentation, epistemological beliefs and practices, and STEM education. mstopcu@yildiz.edu.tr

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