Does Research on Nature of Science and Social Justice Intersect? Exploring Theoretical and Practical Convergence for Science Education

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Chapter 6
Does Research on Nature of Science and Social Justice Intersect? Exploring Theoretical and Practical Convergence for Science Education

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6.1 Introduction

The rise in inequality in the distribution of income among people is well-documented and displays the characteristics of a trend, having affected large numbers of countries, from the poorest to the most affluent (United Nations 2006). The inequality gap between the richest and poorest countries, measured in terms of national per capita income, is growing as well. Concurrently, new socio-political realities caused by the massive migration of refugees to Europe and the urgency for including refugee children into society. In 2017 UNHCR registered 172,301 sea arrivals of refugees and migrants, mainly from Nigeria and the Syrian Arab Republic, to Europe. In the first 6 months of 2017, 16% of all arrivals were children, 72% of which were unaccompanied and separated children (UNHCR et al. 2017). UNICEF reports show that children are increasingly showing signs of deep psychological trauma as a result of their suffering and displacement and are excluded from the communities they now live. These new sociopolitical realities and the rise in poverty in all its manifestations, along with the increase in the numbers of refugees, displaced persons and other victims of circumstance and abuse, represent sufficient evidence for a judgment of persistent, if not growing, injustice in the world. Addressing such

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injustice at different levels and areas creates new challenges for education in general and science education in particular, that centre around goals related to social justice. The theme of social justice as an intellectual theme is relatively new:

> None of history's great philosophers—not Plato or Aristotle, or Confucius or Averroes, or even Rousseau or Kant—saw the need to consider justice or the redress of injustices from a social perspective. The concept first surfaced in Western thought and political language in the wake of the industrial revolution and the parallel development of the socialist doctrine. It emerged as an expression of protest against what was perceived as the capitalist exploitation of labour and as a focal point for the development of measures to improve the human condition. It was born as a revolutionary slogan embodying the ideals of progress and fraternity. Following the revolutions that shook Europe in the mid-1800s, social justice became a rallying cry for progressive thinkers and political activists. Proudhon, notably, identified justice with social justice, and social justice with respect for human dignity. (United Nations 2006, pp. 11–12)

From 2006 until today, quite a few researchers in various disciplines such as education, sociology, social psychology and gender studies have engaged with research that aims to promote goals related to social justice. Situated within socio-cultural research traditions, social justice has been a concern for science educators for more than a decade now (e.g. Calabrese-Barton and Upadhyay 2010; Reeve and Sharkawy 2014). Researchers interested in promoting social justice in the context of science education have suggested various programs, frameworks and interventions that aim to provide equal opportunities for science learning to all students regardless of their gender, race, culture, ability, language, and religion. This broad conceptualization of social justice is consistent with the accounts presented in this chapter.

A review of literature indicates there can be at least two senses of inclusion of social justice in science education. First, social justice can be conceived as an overarching goal and a vision for schooling and curriculum. In this case, education can serve the function of promoting and maintaining social justice. A second sense of inclusion of social justice in science education is more directly related to learning goals and outcomes. Here the emphasis would be on the equipment of students with habits of mind and values that would ensure that they contribute to social justice themselves as active citizens. Enhancement of students' understanding of social justice is thought to contribute to good citizenship. In what follows, we argue that contextualising social justice in science education remains challenging for teachers as social justice is not conventionally a common feature of science teaching and learning. This is partly due to the fact that missing remains a conceptualization of school science that explicilty addresses social justice. As a matter of fact, the way that science is conceptualised in school science does not tend to lend itself to invite discussion of social justice issues.

There is a vast body of work on nature of science (NOS) (Erduran and Dagher 2014a; Erduran and Kaya 2019; Lederman et al. 2002) which concerns understanding of and about science. Understanding NOS is thought to contribute to scientific literacy as well as citizenship. Providing equal access to opportunities for scientific literacy and the development of skills needed for active citizenship is at the heart of such account of social justice. Although social justice and NOS literatures might

share similar themes such as citizenship goals, the precise intersection of these literatures has not been investigated. There are other accounts in science education such as argumentation and deliberative democracy which raise similar issues in relation to synthesis of conventionally disparate areas of research (Erduran and Kaya 2016). In this chapter, we review some selected perspectives on social justice and NOS literatures leading to a synthesis of common themes that can potentially serve both the purposes of learning about NOS while at the same time advance goals related to social justice through science instruction. We focus on definitions of social justice offered by Rawls (1985) and Miller (2001), and map some of their characterisations to the framework on social aspects of NOS defined by Erduran and Dagher (2014). We thus contribute to NOS literature by drawing on theories from political philosophy, an area that has not been previously explored explicitly in the NOS literature. Our goal is to explore how social justice might be fostered through NOS instruction. In so doing, we trace the potential overlap of social justice and NOS concepts, and draw out example recommendations for curriculum policy as well as teaching and learning.

6.2 Theoretical Framework

In this section we describe how we conceptualize social justice by discussing some influential theories and offering definitions of key constructs that have been used in contemporary research in science education. Subsequently, we discuss how a particular approach to characterising NOS (i.e. the Family Resemblance Approach) can be used in science education to promote goals related to social justice. Recommendations are provided for curriculum policy as well as teaching and learning.

6.2.1 Theories of Social Justice

Social justice is generally equated with the notion of equality or equal opportunity in society. Although equality is undeniably part of social justice, the meaning of social justice is actually much broader (Scherlen and Robinson 2008). Further, "equal opportunity" and similar phrases such as "personal responsibility" have been used to diminish the prospective for realizing social justice by justifying enormous inequalities in modern society (Berry 2005). The most recent theories of and scholarly statements about "social justice" illustrate the complex nature of this theoretical construct. Two prominent accounts of social justice are based on Rawls (1985) and Miller (2001). While neither of these theories can be considered an exhaustive treatment of the subject matter, each offers a complex theory of social justice that illustrates its broad meaning. Both conceptions of social justice are similar, so there is significant overlap between the main ideas.

We chose to focus on Rawls' (1985) and Miller's (2001) accounts of social justice because they offer broad conceptualizations of social justice that provide the basis of articulating goals related to social justice in education, especially in identifying how education can tackle equal access to learning opportunities. According to Rawls, social justice is about assuring the protection of equal access to liberties, rights, and opportunities, as well as taking care of the least advantaged members of society. Rawls posits that rational, free people will agree to play by the rules under fair conditions and that this agreement is necessary to assure social justice because public support is critical to the acceptance of the rules of the game (Rawls 1985, pp. 27–28). These rules or principles *"specify the basic rights and duties to be assigned by the main political and social institutions, and they regulate the division of benefits arising from social cooperation and allot the burdens necessary to sustain it"* (Rawls 1985, p. 7). It is important to note that Rawls' theory is one of domestic justice (principles that apply to the basic structures of society) and not of local justice (principles that apply to institutions and associations in society) or global justice (principles applying to international law) (Rawls 1985, pp. 11–12).

Miller's (2001) account of social justice, on the other hand, deals with the distribution of good (advantages) and bad (disadvantages) in society, and more specifically with how the 'good' should be distributed within society. Further, social justice is concerned with the ways that resources are allocated to people by social institutions (Miller 2001, p. 11). Need is a claim that one is lacking the basic necessities and is being harmed or is in danger of being harmed and/or that one's capacity to function is being impeded (Miller 2001, p. 207–210). Desert is a claim that one has earned reward based on performance, that superior performance should attract superior recognition (Miller 2001, p. 134–141). Equality refers to the social ideal that society regards and treats its citizens as equals, and that benefits such as certain rights should be distributed equally (Miller 2001, p. 232). Furthermore, Miller explains three basic modes of human relationships which are solidaristic community, instrumental associations, and citizenship. The solidaristic community exists when people share a common identity as members of a relatively stable group with a common ethos. Instrumental associations is about how people relate to one another in a utilitarian manner; each has aims and purposes that can best be realized by collaboration with others. The citizenship is about members of a political society in modern liberal democracies who are related not just through their communities and their instrumental associations but also as fellow citizens. The main concepts in Rawl's and Miller's accounts are summarised in Table 6.1.

It should be noted that some researchers in science education (e.g. Bencze and Alsop 2014) emphasize not only the need for providing all students with equal opportunities to learning science despite their differences but also the need for political activism towards such a goal. As such, social justice has become not only an educational goal but also a political activity. In order to better understand science as a political activity, and to implement teaching practices and curricular that aim to promote social justice, some theoretical constructs can serve as tools to conceptualize social justice through a political stance. For example, Kayumova et al. (2018) summarize through a review of contemporary literature conceptualizations of the

Table 6.1 Key concepts from Rawls and Miller

Rawls (1985)	**Miller** (2001)
Equal liberties	Need
Equal opportunity	Desert
Difference principle	Equality
Fair share of benefits to the least advantaged members of society	Solidaristic community
Opportunities for healthy and fulfilling lives	Instrumental associations
Freedom	Citizenship
Human rights	Formal equality
	Accuracy
	Publicity
	Dignity
	General ethos of the community
	Human rights
	Freedom

constructs related to social justice in light of their criticism of current reform recommendations in Europe and the US as being a-theoretical and a-political. These constructs are not meant to serve as a framework of social justice. Rather, they are meant to serve as operational definitions of constructs that have been used in contemporary research that addresses social justice in the context of science education. These are the following: diversity, equity, identity, and creativity. Diversity is used to hightlight the differences among individuals. Equity is used to refer to addressing barriers to equal access. Identity is used to conceptualize the process of learning and development. Finally, creativity elaborated further below is an alternative construct to innovation. It is socially-just. In particular, the further unpacking of these constructs provides a framework through which to investigate social justice concepts:

Diversity: refers to the inclusion of different types of people, with unique characteristics that might influence science teaching and learning: ethnicity/race, gender and socioeconomic status/social class, dis/ability, linguistic, sexuality, gender identity, political, religious, geographical origins, age etc.

Equity: refers to broadening participation, achievement, and/or access and an examination of issues of power and equity within the structural, cultural, and curricular organization of science education, teaching and learning.

Identity: refers to how one views him/herself and how he/she is viewed by others, and can be better understood as a process of identity construction through social participation and lived experience.

Creativity: an expanded view of innovation that both challenges existing scientific epistemologies and centers addressing global challenges from a critical and socially just perspectives, and which goes beyond a traditional view of innovation and scientific entrepreneurialism that only serves to reproduce inequalities.

These overarching costructs provided by Kayumova et al. (2018) can provide us with the lenses and tools to engage in discussions related to notions of what constitutes truth, knowledge, and power, and to study science learning in the context of bigger questions related to social justice.

6.2.2 Nature of Science in Science Education

Nature of science (NOS) is a significant area of research in science education (e.g. Allchin 2011; Erduran and Dagher 2014; Irzik and Nola 2014; Lederman et al. 2002). Different accounts of NOS have emphasised the social aspects of science in various ways. For example, Erduran and Dagher (2014) provided a comparative overview of NOS from the consensus view (Lederman et al. 2002), Features of Science (FOS) (Matthews 2012) and Family Resemblance Approach (FRA) (Irzik and Nola 2014) perspectives (see Table 6.2). Although all these approaches have reference to the social contexts of science, FOS and FRA make explicit reference to social values where concepts related to social justice are likely to reside. For example, Irzik and Nola (2014) refer to social values in a fairly broad sense. Erduran and Dagher (2014), on the other hand, provide further categories including financial systems, political power structures, and social organisations and interactions. The latter categories provide some nuance through which social justice concepts can be explored. For instance, the category of political power structures inherently addresses power relations that are conventionally at the root of social inequality (United Nations 2006).

Erduran and Dagher (2014) discuss NOS from a "Family Resemblance Approach" (FRA) (see Fig. 6.1) which provides an account of NOS based on epistemic, cognitive and social-institutional aspects of science. The framework is based on Wittgenstein's family resemblance idea which was adapted to NOS by philosophers of science Irzik and Nola. A description of the FRA is available in Irzik and Nola (2014). Essentially, the idea of a family resemblance implies that the various sciences are akin to members of a biological family that share certain characteristics although they also possess some differences. For example, while all sciences might rely on evidence, the precise articulation of what counts as evidence in astronomy versus chemistry can be fairly nuanced. In many instances of astronomical investigations, the evidence is historical in nature, based on the time it takes for celestial bodies to be observed given the distance it takes light to travel to earth. However, in a chemistry investigation for example, it is possible to manipulate materials and collect data that are represented at this point in time.

There is now a growing body of research focusing on FRA in science education (e.g. Cheung 2020; Couso and Simarro 2020; Erduran et al. 2019; Park et al. 2020). FRA-based NOS covers a range of aspects of science including aims and values, methods, practices, knowledge as well as social-institutional dimensions of science. As such, FRA is consistent with other frameworks arguing for an inclusive and holistic characterisation of nature of science (e.g. Allchin 2011). Furthermore,

Table 6.2 Comparative overview of Nature of Science (NOS) perspectives (From Erduran and Dagher 2014, p. 26)

NOS Consensus View	Features of Science Approach	Family Resemblance Approach
?	Lists:	Includes scientific aims and values that subsume rationality and theory choice as an aim and value
	Theory choice and rationality which involve a set of aims and values	
?	Lists practices that include:	Includes nature of scientific practices pertaining to observation, experimentation, classification and so on.
	Experimentation	
	Idealization	
	Technology	
	Explanation	
	Mathematization	
Focuses on the idea that scientists use many methods: No one scientific method	?	Methodologies and methodological rules
Distinguishes between	Includes	Scientific knowledge: Epistemic-cognitive aspects of models, theories, laws and explanations and aspects pertaining to them such as knowledge revision
Scientific theories and laws	Models	
Observations from inferences		
Focuses on tentativeness		
Highlights cultural embeddedness	Includes	The expanded social context recognizes cultural embeddedness and societal and religious values.
	Values and socio-scientific issues	
	Worldviews and religion	
Includes	?	Creativity is a psychological component that characterizes aims and methods, practices, and scientific knowledge. It in implicit in the FRA.
Creativity		
?	Includes the following philosophical positions:	The FRA does not make a commitment to any of these positions. In this sense, it is philosophically neutral.
	Realism	
	Constructivism	
	Feminism	

FRA is a framework that accommodates for domain-general as well as domain-characteristics of science highlighting both what is universal across science disciplines and what is particular. The key components of the FRA include cognitive and epistemic dimensions of science including the aims and values of science as well as the social-institutional dimensions of science which are the social certification and dissemination, social ethos, social values, professional activities, social organisations and interactions, financial systems and political power structures. However, research evidence points to the fact that these social-institutional dimensions of science are absent from the curriculum. As shown by studies in numerous

Fig. 6.1 FRA wheel: Science as a cognitive-epistemic and social-institutional system. (Erduran and Dagher 2014, p. 28)

national contexts including Taiwan (Yeh et al. 2019) and Turkey (Kaya and Erduran 2016), curriculum documents tend to contain statements that identify science as a cognitive-epistemic system and they underemphasize science as a social-institutional system.

In developing the social-institutional component of NOS in their framework, Erduran and Dagher (2014) highlight that science involves individual scientists working in social groups in social institutions, exercising social values and activities. The inclusion of the social dimension of science in science education is warranted for various reasons. First, the ways in which scientists organize science socially might have relevance for how science learning environments can be structured. In other words, students may benefit from acquiring the social aspects of scientific communities, and the inclusion of social features of science in the classroom may facilitate students' learning of science. Second, the particular social values and norms that dominate communities of scientists could be considered as potential learning outcomes for students. What this means essentially is that educating students in science goes beyond merely addressing cognitive and epistemic aspects of science to including the social dimension of science.

Hence, understanding science in its entirety suggests that students learn about the social norms that scientists work by. Without the inclusion of the social context of science in science education, students are bound to have limited understanding of how the scientific enterprise works, and how the social structures, relationships and issues guide the advacement of science. Erduran and Dagher (2014) argue that categories of science as a social-institutional system can be visualized in terms of (a) the core features of professional activities, scientific ethos, social certification and dissemination and social values, and (b) the broader features of political power structures, financial systems and social organizations and interactions. The latter

features are referred as broad because finance, politics and institutions are integral components of the larger society in which science, like other organized human activity, is being practised. In reality, however, all categories of this system are interactive, hence the porous boundaries that are symbolically represented in the Fig. 6.1.

Social certification and dissemination refer to the social mechanisms through which scientists review, evaluate and validate scientific knowledge for instance through peer review systems of journals. Scientific ethos refers to the norms that scientists employ in their work as well as in interaction with colleagues. Social values refer to specific values such as freedom, respect for the environment, and social utility. Professional activities is about how scientists engage in professional settings such as attending conferences and doing publication reviews. Social organisations and interactions refer to how science is arranged in institutional settings such as universities and research institutes. Financial systems are defined as the underlying financial dimensions of science including the funding mechanisms. Political power structures are the dynamics of power that exist between scientists and within science cultures. Social certification and dissemination, scientific ethos, social values, scientists' professional activities, social interactions, financial systems and political power structures are all key constructs in conceptualizing and implementing curricula that promote goals related to social justice. In what follows, we elaborate on these constructs, through a discussion that cuts across conceptualisation of social justice and NOS.

6.3 Intersection of Social Justice and Nature of Science

In this section we provide educational examples for an inclusive agenda that promotes the teaching and learning of NOS and social justice concurrently and in ways in which goals related to social justice can be achieved through understanding NOS. The first example focuses on the formulation of curriculum standards that serve the purposes of both NOS and social justice. Here we synthesise theoretical perspectives and provide some illustrations of curriculum statements. The second example draws on a project of a pre-service teacher's teaching practice illustrating the instructional resources developed to teach about social-institutional aspects of NOS.

6.3.1 Curriculum Policy Statements

In developing a set of curriculum policy statements, we focus on selected frameworks on social justice and NOS: the social justice frameworks proposed by Rawls (1985) and Miller (2001), and the NOS framework proposed by Erduran and Dagher (2014). In developing this set of curriculum statements, we sought to determine some common themes that provide an overlap of different categories of social

justice and NOS. Essentially, the particular concepts from both social justice and NOS approaches could potentially unite under a broader overarching concept. In the case of "human rights" as a social justice category (i.e. from Rawls 1985) for instance, the relevant NOS concept is "social values" (Erduran and Dagher 2014) that a community of scientists must abide with such as respect for communality. One overarching common theme is "respect" which applies to both categories. In order to address the synthesis of social justice and NOS concepts for science education, we illustrate some applications on the synthesis of the themes for considering some potential curriculum statements (see Table 6.3). With respect to the "human rights" and "social values" categories, we propose the statement "*Students will understand that scientists should have the right to express their research without feeling threatened about potential backlash."* Here the scientists are positioned to have basic human rights in performing their professional tasks and in being part of a respectful community. In a similar vein, we took all of the social context

Table 6.3 Suggested Curriculum Statements on NOS and Social Justice

Overlapping theme	NOS category (Erduran and Dagher 2014)	Social justice category	Potential curriculum statements
Diversity	Social certification and dissemination	Difference principle (Rawls 1985)	*Students will understand that scientists with diverse social positionings and backgrounds may debate and enrich the scientific enterprise collaboratively.*
Respect	Social values	Human rights (Rawls 1985)	*Students will understand that scientists should have the right to express their research without feeling threatened about potential backlash.*
Identity	Professional activities	Solidaristic community (Miller 2003)	*Students will engage in activities such as writing, presenting and communicating results of investigations to other teams and demonstrate social responsibility in contributing to the school community.*
Equity	Political power structures	Equal liberties (Rawls 1985)	*Students will be respectful of people from different backgrounds such as gender, class, national origin and race, and understand the injustices resulting from discrimination and exclusion.*
Ethos	Scientific ethos	Freedom (Miller 2003)	*Students will understand that scientists and citizens should have freedom of expression of ideas.*
Opportunity	Social organisations and interactions	Instrumental associations (Miller 2003)	*Students will understand that scientists have aims and purposes that can best be realized through collaboration with others.*
Economic fairness	Financial systems	Share of benefits (Rawls 1985)	*Students will understand that scientists and societies rely on economics but that there should be justice in how commodities are distributed and traded among communities.*

categories from Erduran and Dagher's (2014) NOS framework and mapped the social justice categories from Rawls (1985) and Miller (2001). Another example concerns the overlapping theme of "ethos". In this case, Erduran and Dagher's (2014) category of "scientific ethos" is similar to Miller's (2001) category of "freedom". For example, in scientific communities, ideas and evidence are meant to be exchanged freely without being restricted on ideological grounds. Freedom of expression is an important aspect of scientific ethos as well as a socially just society. A potential curriculum statement to capture the overarching theme is "*Students will understand that scientists and citizens should have freedom of expression of ideas.*" Overall, the intersection of social justice and NOS ideas lead to a set of broad themes such as diversity, respect, community, equity, ethos, opportunity and economic fairness that can provide a comprehensive set of ideas for that might be used as input for setting curricular goals.

The question then becomes: in what ways (if any) have these concepts and goals related to diversity, inclusion and social justice found their place in visions for reform across the world and within science curricula? As Kayumova et al. (2018) argued, an analysis of the various policy documents that have been published in various parts of the world (e.g., *New Generation Science Standards* in the U.S. context, *Responsible Science and Innovation* in Europe) there exists a discrepancy between contemporary global challenges and reform efforts, as reform efforts emphasize goals related to economic competition instead of goals related to students social justice. An example is found in the report by the European Commission called "Science Education for Responsible Citizenship" (EC 2015), which offers a twenty-first century vision for science for society within the broader European agenda. The report places emphasis on the process of aligning research and innovation to the values, needs and expectations of society, referred to as "responsible research and innovation". These reform recommendations, however, do not reflect how global challenges (e.g., migration, refugee crisis) have shaped this vision for science for society and therefore lack attention to the need for more inclusive, equitable, and just societies. As Kayumova et al. (2018) argued, *"goals related to reducing inequality, promoting social change and social justice are completely absent"* (p. X).

Likewise, an analysis of science curricula reveals minimal attention on the social-institutional aspects of NOS. For example, Kaya and Erduran (2016) illustrated that there exists a distinct underemphasis on the social categories of curriculum statements in science curricula in the context of the US, Ireland and Turkey. Consider, for example, the following three example statements from the Turkish curricula, as identified by Kaya and Erduran (2016):

- *"To enable students' appreciation of how science is developed collaboratively among scientists from different cultures"* (Social certification and dissemination)
- *"Scientifically literate person is aware of how social values of the culture and societal structures and beliefs influence how knowledge is cognitively processed"* (Social values)

- *"The students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country"* (Social organisations and interactions)

These examples were fairly rare in a sequence of curriculum documents. The first one relates to diversity, the second one relates to equality and the third one relates to opportunity. A potential contribution of our current analysis is that specific curriculum statements can be generated that would be inclusive of social justice and NOS themes concurrently. For example, for the theme "ethos", a curriculum goal could be "*Students will understand that scientists and citizens should have freedom in expression of their ideas."* Table 6.3 consists of further examples of potential curriculum statements on the various themes.

6.3.2 Teaching and Learning Resources

Alayoglu (2018) developed a series of lesson activities on the inclusion of social-institutional systems of NOS in science education 12 year old students in Istanbul, Turkey. Using a pre-test post-test quasi-experimental research design, the effectiveness of the resources were evaluated following a 4-week intervention. The results showed that there were statistically significant differences between the study groups in favor of students in the experimental group on both study variables. In other words, integration of the social-institutional aspects of science into science lessons enhanced students' understanding of the social dimension of science. In what follows, we describe one of the activities on Moon Mining that incorporated elements of the social-institutional aspects of NOS.

The activity begins with engaging students in a discussion about the moon and asteroids being rich with minerals that are rare on earth. Because of this, some big companies and governments aimed to remove these valuable minerals from space. At the beginning of the lesson, Alayoglu, as a teacher-researcher, offered brief information about the role of politics in science. In the classroom discussion, the point was raised about how science and technology have been historically linked to governments and states. For example, Galileo sharpened his telescope to see distant enemy better. The lesson resources included a range of activities for students. For example, a series of questions were produced to elicit the specific social-institutional category as illustrated in Table 6.4. In our interpretation of the practical questions developed by Alayoglu (2018), there are links to the NOS categories developed by Erduran and Dagher (2014) and the social justice categories discussed by Rawls (1985) and Miller (2003). In other words, these questions which are practically usable at the level of the classroom are also theoretically related to NOS and social justice categories. In this table, the social-justice categories embedded in these activities are presented next to the NOS categories.

What this example illustrates is that even for a topic that is seemingly devoid of social context (i.e. space explorations are not situated in an obvious way to lend

Table 6.4 Example questions for teaching and learning to incorporate NOS and social justice: Synthesis of practical instructional resources and theoretical perspectives

Pedagogical questions (From Alayoglu 2018)	**NOS aspects (From Erduran and Dagher** 2014)	**Social Justice (From Rawls** 1985; **Miller** 2003)
Do astronomers and scientists work alone or within an organization or community? How? Which institutions investigate space and other planets?	Social organizations and interactions	Instrumental associations
Do you know any other scientific institutions like NASA in which many scientists work together?	Social organizations and interactions	Instrumental associations
In February 2012, The Australian Centre for Space Engineering Research (ACSER) in Sydney organized a meeting on "Searching for Mine" and brought together famous companies, scientists, engineers and robotic experts. Why did many people from different disciplines meet? What do you think was discussed at this meeting?	Professional activities & social certification and dissemination	Solidaristic community
Who will benefit from mines being removed from the moon or asteroids?	Financial systems	Share of benefits
Why do China and USA are interested in space mining?	Political power structures	Equal liberties
Could space mining be dangerous? Could it harm the environment?	Scientific ethos & social values	Human rights

themselves to social justice issues), there is potential for their articulation for social justice. For example, the question of *"Who will benefit from mines being removed from the moon or asteroids?"* raises questions about share of benefits. The NOS and social justice categories along with their examples can potentially provide a toolkit for teachers to organise their questioning in lessons to elicit social justice themes through the teaching of NOS. Teacher education at both pre-service and in-service stages needs to support science teachers' learning of strategies that promote students' understanding of NOS and social justice in unison. There is already a book-length account on the design, implementation and evaluation of a teacher education approach that incorporated NOS from an FRA perspective including the social-institutional aspects of science (Erduran and Kaya 2019). Further examples that focus more closely on social justice issues can be designed and tested.

6.4 Discussion and Conclusions

An examination of the research literature of social justice and NOS reveals a set of concepts that cut across the two knowledge bases, such as equality, social responsibility and human rights. By drawing out parallels between social justice and NOS literatures, we forge potential links that can foster both agendas, and provide concrete curriculum statements to correspond to each category of concepts. Given the

scarcity of the social context of NOS in many science curricula from around the world, for instance Turkey (Kaya and Erduran 2016) and Taiwan (Yeh et al. 2019), the paper contributes to the elaboration of potential curriculum statements on the subject while merging NOS goals with social justice goals. The instructional approaches including questions and scoring criteria provide some concrete examples of practical approaches to teaching and learning of NOS and social justice. The curriculum statements can be extended further to a set of practical recommendations that help us to respond to the question: How can science educators provide all learners with equitable opportunities for participating in communities of learners in an increasingly globalized world? As Zembylas and Avraamidou (2008) argued:

> Science education practices and curricula emphasizing professional or Western science alienate underrepresented groups. The premises of these practices are based upon: rigid teaching strategies and uncreative methods; a view of science as a very technical field that is practiced by intelligent individuals who manage to leave their subjectivities outside the field; a context of practicing science that is detached from cultural relevance; and, perspectives in science that lack representation from diverse groups (p. 994)

This is precisely where the role of social justice comes into play in science teaching and learning. Historically, social justice has been conceptualized in various ways and has been used as a theoretical/research constructs in various fields, such as education, philosophy, psychology, and sociology. In this chapter, we asked to what degree is science associated with this goal, how science is connected to greater social issues, and how science falls within political discourses. In doing so, we explored a set of overlapping constructs embedded in conceptualizations of the NOS and social justice. Ultimately, social justice is meant to promote a just and democratic society by valuing diversity, which refers to various aspects of human identity such as race, gender, sexual orientation, nationality, and which have been subjects of discrimination (Harding 1986).

John Rawls (1985) and David Miller (2001) are key theorists on social justice. We have used some central concepts from their work in charting out a territory for intersections with NOS literature in science education. Even though these two theories have distinct differences, they share specific commonalities, such as an emphasis on *equality, citizenship,* as well as the *socio-political* forces that shape societies. Equality, citizenship, and socio-political forces are crucial in shaping educational practice as they provide both a goal and a context for conceptualizing scientific literacy, which remains one of the key goals of science education. Scientific literacy is broadly conceptualized as scientific knowledge in order to identify questions, acquire new knowledge, describe scientific phenomena and draw conclusions from evidence, to understand science as a form of human knowledge and research, to understand the role of science to shape our material, intellectual and cultural environment, and to be willing to engage with scientific ideas and topics and to deal with them in a reflective manner (OECD 2006). Taking scientific literature as a point of departure, in what follows we discuss what it would mean for science education to adopt a social-justice lens and we propose a set of key theoretical constructs that are crucial in contemporary conceptualizations of social justice.

Adopting a social-justice lens to framing scientific literacy would mean that all students, regardless of race, sex, class, gender, sexual orientation, or ability, should have equal access to opportunities through school science for becoming scientific literate. In the field of science education, quite a few researchers have raised important questions and engaged in criticism about the role of school science in society through the concepts of equality, equity, power relations and knowledge production in schools, and how Western science has traditionally excluded many groups of students (e.g., Calabrese-Barton et al. 2003; Harding 1986; Rivera-Maulucci and Fann 2016). This is precisely what a social-justice perspective can do for science education.

Essentially, a social justice perspective in NOS instruction provides us with the theoretical constructs to understand social inequalities in school science as well as science more broadly, and to work towards a social or cultural shift where no student or groups of students are excluded. The importance of a social justice perspective in science education is paramount given existing literature that provides evidence that citizens are inadequately prepared to use scientific knowledge to make informed decisions in their everyday lives; the percentages of under-privileged students, such as girls and minorities, following careers in science remain disproportionately low around the world and science is poorly taught in schools (Eisenhart et al. 1996). Echoing Calabrese-Barton's et al. (2003), we argue that re-conceptualizing the NOS and science teaching through a social justice lens requires an understanding of science as a political activity:

> The implications of such a stance are that science (and any education in science) will only be equitable and empowering if students learn—in addition to the standard knowledge base of ideas and skills—to uncloak those assumptions, to draw strength from their exposure, and to expand understandings of the agreed- upon boundaries for where and how scientific ideas are generated. (p. 136)

The contribution of this chapter, then, lies within an argument about conceptualizing NOS being inclusive of a political activity and enacting NOS instruction for the purpose of promoting social justice. In doing so, we offered definitions of a set of contemporary constructs that might be used by researchers interested in social justice. In addition, we offered concrete examples of potential curriculum statements for various themes that relate to social justice issues, and we suggest an example teaching strategy (i.e. questioning) that teachers can potentially use for eliciting social justice themes through teaching NOS. Our argument is consistent with the position presented by Rita Vilanova and Isabel Martins in the next chapter where they explore the relationship between NOS and citizenship education. In Chap. 7, these authors question the limitations of focusing on epistemological perspectives on science for the purposes of citizenship and argue for the broadening of the content of science textbooks. Similarly, we have advocated the broadening of the science curriculum to forge links between the social-institutional aspects of NOS and social justice to serve citizenship goals. In educational systems framed by neoliberal ideologies, surrounded by a rise in inequality in the distribution of income as well as new socio-political realities caused by the massive migration of refugees, there is

already an existing imperative to embrace socially just agendas for science curricula. We do acknowledge that these theoretical conceptualizations and curriculum examples are by no means exhaustive or applicable in all contexts. However, we hope that these serve as a springboard for further explorations of how NOS approaches might serve to promote goals related to social justice in science education.

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