Ingrid Sánchez Tapia *Editor*

International Perspectives on the Contextualization of Science Education

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Ingrid Sánchez Tapia
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Contents

Chapter 1
Introduction: A Broad Look at Contextualization of Science Education Across National Contexts

Ingrid Sánchez Tapia

In a world shaped by science-based technology, scientific literacy is essential for full citizen participation (OECD 2016). Citizens who are scientifically literate are better able to participate in conversations and debates about issues that affect them and their communities, such as public health and social and environmental problems. Therefore, developing scientific literacy provides agentic room to maneuver in decision-making at the community and national levels, a primary goal of citizens in democratic societies (Roth and Désautels 2009; Roth 2009). Yet, in many countries, students show limited interest in learning science, perceiving it as disconnected from their lives. The lack of opportunities for learning contextualized science leads to a lack of motivation and cognitive engagement. This is particularly true for girls, children, and adolescents living in poverty or living in communities that consider their system of beliefs at odds with school science, such as religious communities or indigenous cultures.

In this book, contributors propose that science learning can be more relevant and interesting for students and teachers by using a contextualized approach to science education. The contributors explore the contextualization of science education from multiple angles, such as teacher education, curriculum design, and assessment, and from multiple national perspectives. The aim of this exploration is to provide and inspire new practical approaches to bring science education closer to the lives of students to accelerate progress toward global scientific literacy.

The views expressed in this chapter are solely those of the authors and do not necessarily represent those of the United Nations Children's Fund (UNICEF)

I. Sánchez Tapia (✉)
UNICEF, New York, NY, USA
e-mail: isancheztapia@unicef.org

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1 Contextualizing Science Education Is Deeply Constructivist in Nature

Learning science with understanding can be considered a generative process of constructing meaning from (1) our own knowledge and experiences in the world, (2) new incoming sensory information, and (3) shared cultural narratives. In this view, learning science is a highly contextual process (Osborne and Wittrock 1983), where understandings of the natural world are used as substrates to develop understandings of scientific concepts. Student prior knowledge and experience is taken into account during the teaching and learning process (NRC 2007) to allow students to construct meaning by linking new information to relevant aspects of their lives.

Accounting for student prior knowledge and experience must necessarily go beyond testing students to find out what they may have learned in previous grades or using examples from pop culture. In the studies included here, "prior knowledge and experience" is understood as the ways that we make sense of the world around us, which is a function of the cultural and historical context. Prior knowledge and experience comes precisely from the interaction between the psychological (individual level) and the sociological (community and institution level) and can only exist through language (Roth 2010). We create and experience thought and culture only through language, and in turn, language-mediated interactions shape our thinking and worldviews (Vygotsky 1978). In a truly constructivist perspective, where knowledge is constructed by the learner based on prior cognitive structures and experiences, it follows that the dimension of context must be included.

In sum, contextualization of science education can be broadly understood as leveraging students' prior knowledge and experience to foster their understanding of challenging science concepts (Rivet and Krajcik 2008). Therefore, throughout this book, different aspects of science education are explored from the point of view of achieving greater relevance for students and teachers through contextualization. In this sense, different chapters explore students' and teachers' cultural-based practices, views, expectations, and norms so that those aspects of their lived experience become social and cultural resources that support their science learning (Lee 2003).

2 Multiple Ideas About Contextualization of Science Education

Contextualization of science education has been defined in different manners depending on the subfield of science education (teacher education, learning, curriculum design, assessment) and the situation or setting where contextualization has been operationalized (higher education, secondary education). Instead of advocating for a single idea of contextualization, this book takes a broad look at contextualization of science education, including making science relevant to students' lives, making science culturally relevant, examining learning science as border crossing, exploring learning science combining local and global perspectives, and constructing contextualized assessments.

Contextualization of teaching and learning is not unique to STEM education. Educational research at large has recognized the power of contextualized learning to foster student intrinsic motivation (Becker et al. 2010; Cordova and Lepper 1996) and the transfer of learned concepts to new situations (Barnett and Ceci 2002) and to make teaching and learning more culturally relevant and therefore more meaningful to students (Herrera et al. 2012).

The definitions of contextualization of teaching and learning and the process by which they are enacted vary across settings. For example, Perin (2011) defines contextualization for higher education settings as an instructional approach connecting foundational skills and academic or occupational content by focusing on concrete applications in a specific context that is of interest to students to improve learning outcomes. Perin identifies two forms of contextualization:

- *Contextualized basic skills instruction* aims to teach basic skills for meaningful application in the context of specific subject matter that students need to master. The emphasis is on teaching the basic academic skills in a meaningful and motivating way rather than on teaching subject content.
- *Integrated basic skills instruction* aims to teach the subject content by embedding the teaching of basic skills needed by students to better comprehend the disciplinary content. For example, reading comprehension tasks can be embedded in a science class to support students' reading skills.

Focusing on multicultural secondary education settings, Herrera et al. (2012) propose that practices based on contextualization of instruction are key to support secondary teachers as they work to promote linguistic and academic development among culturally and linguistically diverse learners. The authors find that when teachers contextualize instruction by exploring the sociocultural, linguistic, cognitive, and academic dimensions of students' lives, they can create learning environments that "(a) make optimal use of the physical setting and grouping configurations; (b) are guided by standards, curricula, and objectives that reflect high expectations; and (c) communicate caring through planned instructional accommodations for students' biographies" (Herrera et al. 2012 p. 5).

Contextualization of instruction has also been successfully applied with young learners (Arıkan and Taraf 2010; Ng'Asike 2011). In Turkey, Arıkan and Taraf (2010) examined the effect of contextualizing lessons using cartoons to teach English as a second language to grade 4 Turkish learners. Students exposed to contextualized lessons outperformed students learning with uncontextualized materials in grammar and vocabulary. The authors' approach to contextualization consisted of creating language learning environments in which children get both aural and visual support in meaningful contexts that they enjoy, such as cartoons. The cartoons introduce authentic language, thus contextualizing the grammar and vocabulary. In Kenya, Ng'Asike explored the contextualization of science in early childhood centers and the first years of primary education serving children from a nomadic Turkana community. The author posits that a contextualized education that is culturally relevant empowers young learners by strengthening their cultural ability to contribute effectively to the nomadic lifestyles of their community, which is critical for their socioeconomic survival. In contrast, a decontextualized education creates a gap between school life and community life, leading to poor educational outcomes.

Contextualization of teaching and learning has enormous potential for improving learning outcomes but also poses challenges and risks in curriculum design and its enactment in the classroom. Paliwal and Subramaniam (2006) used a series of case studies to illustrate how using students' local context in India does not necessarily lead to improved learning outcomes, unless the contextualized lessons and their enactment are part of a pedagogical practice based on reflection and continued opportunities for teachers' professional development. The authors observe that quality curricular materials with scaffolding to facilitate contextualization are key to facilitate teacher engagement in contextualized teaching.

Overall, educational researchers and practitioners alike widely accept that learning needs to be sensitive to contextual conditions, student values, and cultural features (OECD 2006, 2012; NRC 2012; King and Ritchie 2012). This idea has also permeated science education, since many studies have emphasized the importance of using real-life situations to contextualize science learning. For example, Aikenhead (1994) proposed that contextualization is at the core of science–technology–society science education, since science content needs to be embedded in a social–technological context. He maintained that the contexts used to teach science content should be meaningful to students and respond to students' need to know about real-life situations. Similarly, Fortus et al. (2005), after implementing a design-based physics curriculum in Israel and the United States, concluded that contextualized science learning can improve the learning of abstract arguments. This is done by using contexts that make tasks meaningful for students and providing entry points for students to investigate real-life phenomena. In Choshi et al. (2005) explored contextualization of biology and physics lessons in secondary education classrooms. They broadly defined contextualization as the reference to everyday episodes and events by teachers or students when discussing biology and physics content. They found that students need to feel empowered to bring events into the discussion that are meaningful to them; otherwise, the process is mostly teacher led.

Building on the importance of leveraging student everyday experiences with real-life phenomena to learn science concepts, Giamellaro (2014, p. 2849) expands the definition of contextualization as "the process of drawing specific connections between content knowledge being taught and an authentic environment in which the content can be relevantly applied or illustrated. This environment includes the cultural backdrop, other actors, the physical environment, and a scenario in which the concept is inherently related and applicable." Giamellaro maintains that using contexts that are unfamiliar to students adds layers of abstraction that may complicate the learning process rather than facilitate it. In other words, without a context that is meaningful to students, any knowledge is of limited use and incomplete. Giamellaro goes on to differentiate between primary and secondary contextualization. He refers to primary contextualization as learning in context through first-hand direct experience with the content, thus deemed authentic learning experience. In contrast, secondary contextualization is described as layering the context onto the content to develop relevance, a process that is heavily teacher and/or curriculum led rather than student led. The two approaches can be complementary, leading to well-contextualized science learning environments. Primary contextualization has been shown to foster student motivation to learn science. In Kenya, Nashon and Anderson (2013) explored high school students' experiences learning with a curriculum that was contextualized to leverage on their real-life experiences with the local informal manufacturing sector. Students reported that this approach was better aligned with their preferred ways of learning and more culturally relevant, encouraging them to learn school science.

Sánchez Tapia et al. (2018) also expand on the idea of contextualization of science learning environments by emphasizing the importance of cultural relevance in science curricula. They propose that contextualization can be culturally relevant by accounting not only for the ideas and experiences that students bring to the classroom but for the culturally based psychological patterns of reasoning that underlie those ideas and for the cultural practices, traditions, and societal structures that render those ideas meaningful to students. They worked with indigenous adolescents in a Mexican indigenous community (Nahuas) to adapt a biology curricular unit on natural selection to be culturally relevant. The biology unit accounted for student cultural cognition (teleological reasoning, essentialism), socialization, cultural narratives, and traditional indigenous knowledge (TIK). By enacting a curricular unit contextualized in such manner, the authors derived seven contextualization principles for designing or adapting science curricula to be culturally relevant (Table 1.1). This approach led to student engagement in learning complex science ideas such as natural selection with significant learning gains and facilitated learning science as "border crossing," proven to be an effective learning strategy

Table 1.1 Sánchez Tapia et al. (2018) empirically developed principles for curricular contextualization

1. Using students' culturally based preference for engaging in certain types of reasoning (e.g., teleological reasoning) to support them in developing understanding of complex science concepts
2. Scaffolding students' reflection on their culturally based types of reasoning through the evaluation of inaccurate evidence-based explanations
3. Using traditional knowledge as a context to explore Western science concepts and to engage adult members of the community in the classroom
4. Contrasting Traditional Indigenous Knowledge (TIK) and Western Science Knowledge (WSK) to debunk the idea that student TIK is inferior to WSK, thus facilitating border crossing while learning science
5. Foregrounding TIK as a legitimate source of knowledge that can enrich WSK
6. Challenging the status quo and developing critical consciousness
7. Using technology to incorporate the ways of learning that are privileged in students' communities into the curriculum

(Aikenhead 2001; Costa 1995; Polman and Hope 2014). Sánchez et al. define border crossing in curricular contextualization as the movement from a worldview rooted in one culture, such as a religious community or an indigenous culture, to a worldview rooted in another culture, such as Western Science Knowledge (WSK). Border crossing occurs when students who have not been enculturated into Western science are exposed to science education (Aikenhead 2001; Hong et al. 2000). The border crossing approach to the contextualization of science learning encourages students to use their Traditional Indigenous Knowledge (TIK) and lived experiences within the science classroom as valuable tools for learning, exercising their agency and feeling empowered to use TIK or WSK in a context-dependent manner.

Tolbert and Knox (2016) take the idea of culturally relevant contextualization of science education and apply it to science teacher education. The authors describe contextualization of science lessons in a culturally and socially relevant way as challenging for both preservice and in-service teachers due to the limited opportunities to learn and practice such approaches during initial teacher education. The authors define contextualization of science instruction as "the ways in which students draw from multiple perspectives to understand and critically evaluate current and historical socioscientific issues." By applying this approach to preservice teacher education in the United States, Tolbert (2011) developed a framework for contextualization to better understand different ways that teachers can contextualize science instruction in multilingual classrooms. The framework includes nine categories of contextualization of science education: multicultural, local–ecological, linguistic, community engagement, critical–feminist, physical–kinesthetic, universal–everyday, hypothetical–simulative, and historical. The authors warn against an overly explicit or prescriptive emphasis on students' cultural backgrounds when contextualizing science lessons, as that could reinforce fixed notions of culture and stereotypes. Instead, they suggest that preservice teachers should be supported to build on their students' knowledge of local places, community funds of knowledge, and the diverse language practices of students as they learn to contextualize science lessons.

Other authors have also embedded critical perspectives in their approach to contextualization of science teaching. For example, Sjöström and Talanquer (2014) propose "humanistic chemistry teaching" as an approach for contextualizing chemistry education in a critical and reflexive manner. In this approach, students become engaged in reflective analyses of historical, philosophical, sociological, and cultural perspectives, as well as critical–democratic action for socioecojustice. This approach requires chemistry teachers to "reflect on the nature of chemistry knowledge and practices from sociocritical and critical-philosophical perspectives, looking to build meaningful inferences for pedagogical practice. Such reflection requires knowledge about the history and philosophy of chemistry, as well as critical understanding of the political, ethical, and environmental contexts in which chemistry knowledge is developed and applied" (Sjöström and Talanquer 2014 p. 1130). However, there is little in the literature about the effects on students' achievement of critical approaches like the ones proposed by Tolbert and Knox (2016) and Sjöström and Talanquer (2014).

Because learning is both content and context dependent, and students may have different ideas about the same phenomenon depending on the context (Disessa and Sherin 1998; Klassen 2006), it is essential to take context into account when designing learning assessments. When students learn science in a contextualized manner but are assessed with items that are decontextualized or present scenarios unfamiliar to them or foreign to their culture, they may fail to demonstrate their knowledge, leading to underestimation of students' learning. Solano-Flores and Nelson-Barber (2001) maintain that valid science assessments need to also be culturally valid, since the student sociocultural context (values, beliefs, experiences, communication patterns, teaching and learning styles, and epistemologies) influences the way students understand science concepts. However, introducing real-world contexts and a sociocultural dimension in large-scale assessment items can be challenging for standardization and overall validity. To overcome this challenge, cultural differences should be considered when designing assessments, and pilot samples should be culturally and linguistically diverse (Solano-Flores and Nelson-Barber 2001).

Multiple approaches and models exist for the contextualization of science education teaching, learning, and assessment. As research in science education becomes increasingly international, studying various national and cultural settings beyond industrialized high-income countries will likely broaden our concept of contextualization of science education. The following section summarizes the perspectives on contextualization presented in this volume from an international perspective.

3 Perspectives on Contextualization of Science Education Presented in This Volume

Contextualization of science education is more effective at engaging students and effecting learning gains when three elements are present: (1) subject matter knowledge is linked to a context that is familiar to students (Lederman 1999; Rivet and Krajcik 2008), (2) students have opportunities for first-hand experiences with phenomena (Delen and Krajcik 2015; Hug and McNeill 2008; Semken and Freeman 2008), and (3) science learning is culturally relevant (Sánchez Tapia et al. 2018). These three elements are presented across different dimensions of science education throughout this book. Chapters 2, 3, 4, 5, and 6 present empirical studies exploring contextualization of science education in different contexts and from different perspectives, while Chaps. 7 and 8 present practitioners' reflections on the feasibility of applying the approaches proposed in the empirical chapters to their contexts, preservice teacher education and educational policy, respectively. Chapter 9 presents an analysis of the different perspectives presented in this volume from the point of view of future avenues for researching contextualization of science education.

In the first empirical chapter, Brocos and Jiménez-Aleixandre offer a practical framework to make contextualization more accessible for preservice teachers. The authors discuss the enactment of an argumentation sequence about diets in the local context of Galicia, Northwest Spain. Their perspective on contextualization is rooted in place-based science learning, offering a framework for the creation of meaningful learning environments for preservice teachers. Chapter 1 offers an exploration of contextualization of science education by acknowledging the tensions and conflicts between global, local, and personal interests, recognizing that solutions to socio-scientific issues may not satisfy every interest. By engaging in the argumentative process, preservice teachers are supported to design lesson plans that are more relevant to their students' lives.

Similarly focusing on the tension between local and larger contexts, in Chap. 3, Román, del Rosal, Rahim, Rossi, and Gates explore the tensions between the Ecuadorian national science curriculum and in-service teacher efforts to contextualize science education in the context of the Galapagos Islands. The authors conceptualize contextualization as a lens that "nurtures the cultural integrity of students and develops their critical consciousness to exercise responsible citizenship" (Gay 2010; Ladson-Billings 1995, 2014). The findings in Chap. 3 emphasize that "science instruction must connect the knowledge that is valued in schools to the one valued by the local communities served by those schools and offer students safe spaces to identify sources of inequity as well as feasible ways to address them."

The idea of understanding critical consciousness and the importance of student culture is also presented in Chap. 4, which focuses on science learning as border crossing using a contextualized biology unit that facilitates the navigation between Western Science Knowledge (WSK) and Traditional Indigenous Knowledge (TIK). Sánchez Tapia et al. show how contextualized science education can not only support Mexican indigenous adolescents in learning science at school but also can nurture their critical voices and foster the development of healthy ethnic identities. Chapter 3 proposes that contextualization can be culturally relevant by accounting not only for the ideas and experiences that students bring to the classroom but also for the culturally based patterns of reasoning that underlie those ideas and for the cultural practices, traditions, and societal structures that render those ideas meaningful for students. Moreover, from a socio-constructivist perspective, if science curricula is to be culturally relevant for students, it must bridge the culture of the student and the culture of Western science to respect and value student culture as a resource for learning.

Understanding and valuing the cultural backgrounds of students is also emphasized in Chap. 5, where Delen and Inal explore the need for contextualized science learning environments in the context of the Syrian humanitarian crisis that compelled approximately three million people to migrate to Turkey. This migration has understandably challenged the national education system with providing education for the newcomers. The authors frame contextualization as the necessary changes in the classroom setting to respond to the learning needs of refugee students and work closely with in-service Turkish science teachers to offer ways forward to better contextualize science instruction for refugee students.

The last empirical chapter focuses on contextualization of science assessments. In Chap. 5, Härtig and Neumann frame contextualization of science education as the process of supporting students to develop integrated knowledge, relating science ideas to each other, connecting these ideas to observations of the real world, and establishing such connections across multiple contexts (Bransford et al. 2000; Fortus and Krajcik 2012). The authors propose that this perspective should not only inform learning but also assessment. Therefore, they propose that assessments of science learning need to go beyond declarative knowledge and assess integrated knowledge and students' ability to use the knowledge in the context of the actual challenges they may face in their daily lives.

Chapters 7, 8, and 9 explore the empirical studies presented in Chapters 2, 3, 4, 5, and 6 by reflecting on how to apply these perspectives in real-life scenarios: teacher education, policy design and implementation, and research in STEM education. In Chap. 7, a science teacher educator, Nargund-Joshi, reflects on applying various ideas from Chapters 2, 3, 4, 5, and 6 in her own practice. She provides valuable insight into how a science teacher educator in a United States public university serving urban students can apply the perspectives presented throughout the volume to better prepare future science teachers.

Chapter 8 explores policy options to scale up these ideas to affect change at the national level. De Leon and Heller, both working with the government of Panama to strengthen STEM education policies, offer an insightful perspective of the interconnected aspects of a national education system (education laws, teacher education, education budgets, curriculum reform). The authors keep the focus on national-scale equity-based policies that can improve the quality of STEM education for all but especially for marginalized populations served by public schools.

Finally, Krajcik and Fortus present their view on the ideas discussed throughout this volume, highlighting promising practices and ideas as well as the challenges of implementing such ideas in real classrooms and within national education systems. The authors also point out gaps in knowledge and future research suggestions to contribute to contextualizing STEM learning environments to engage students of all backgrounds to develop knowledge to make decisions, solve real-world problems, innovate, and become lifelong learners.

4 Contribution of the Book

Scientific literacy should be accessible to every child and adolescent as part of their right to quality education. Unfortunately, many science learning materials present phenomena and examples that are only familiar to students from mainstream cultural backgrounds in affluent countries. Without examples of how to make science relevant for children and adolescents of all ethnic and language backgrounds and of all socioeconomic status and nationalities, teachers will see themselves ill prepared to educate the next generation of citizens that can effectively respond to challenges such as climate change, public health, and sustainable agriculture, among others. All children and adolescents must become scientifically literate to respond to such challenges, especially the most marginalized, who are often the most affected by these issues. Against this backdrop, this book offers diverse examples of how to make science education significant and useful for learners in diverse scenarios and contexts in different parts of the world. These examples are derived from rigorous studies demonstrating that the contextualization of science learning environments is essential for student engagement in learning science.

Throughout the chapters, the different approaches to contextualizing science education (curriculum, assessment, teacher education) are meant to inspire science teacher educators and researchers to design learning environments that are relevant and meaningful for all students. The authors describe various strategies for teaching science in their specific context, through a framework that places student experiences, language, and culture at the core of the learning process. Through the rich description of the particular contexts and the contextualization strategies, the reader becomes able to extrapolate core principles of contextualized teaching, learning, and assessment for application in their own contexts.

The examples presented in this book illustrate the value and challenges of contextualizing science education in a wide variety of national contexts and educational levels, allowing the reader to gain an international global perspective while exploring different under-studied contexts (e.g., the Galapagos Islands, the Aegean region of Turkey, and the highlands of Eastern Mexico, among others). Moreover, through the reflective chapters, the reader gains insight into how the proposed contextualization approaches are relevant for science teacher education, educational policy, and research in science education.

Finally, an important contribution of this book is the broad approach to contextualization of science education. This allows the readers for an expansion of their theoretical frameworks and for a diversification of the student-centered approaches used when designing science learning environments, thus benefitting children and adolescents from all backgrounds.

The studies in this book come mainly from Latin America and Europe but also include perspectives from Turkish-, Israeli-, and USA-based researchers. We hope this volume motivates researchers in Africa and Asia working on contextualization of science education to assemble a similar volume to highlight experiences from those regions.

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Part I
Empirical Chapters