Ingrid Sánchez Tapia *Editor*

International Perspectives on the Contextualization of Science Education

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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)

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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

Chapter 2
What to Eat Here and Now: Contextualization of Scientific Argumentation from a Place-Based Perspective

Pablo Brocos and María Pilar Jiménez-Aleixandre

1 Introduction: Contextualization in Science Teacher Education

Contextualization and place-based science learning offer a promising framework for the creation of meaningful environments by using local issues for connecting the curriculum to students' lives (Demarest 2014). These environments hold the potential to integrate scientific practices – as argumentation – with the understanding of place and culture as part of a social-ecological system while empowering students to participate in democratic processes. Chinn (2012) suggests three reasons for taking an explicitly culture-based and place-based approach in science education: to address scientific literacy, to promote equity and social justice, and to support sustainability. From these, our work focuses on the interactions between scientific literacy, in particular the practice of argumentation, and sustainability. A place-based approach is particularly suited to address sustainability, because local places provide the specific contexts from which reliable knowledge of global relationships emerge (Greenwood 2013), thus enabling the identification of ways in which local populations can contribute toward a sustainable Earth.

While there has been substantial theoretical development of the conceptualization of place-based design, more classroom-based studies are needed to generate evidence on how to best support novice teachers to engage in contextualized education. Accordingly, this chapter seeks to address this gap by studying the enactment of an argumentation sequence by preservice teachers about the socio-scientific issue of diet election framed in the local context of Galicia. The analysis focuses on the argumentative and decision-making processes in relationship with the place-based features of the task. Specifically, we analyzed the written arguments of 20 small

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groups and the oral debates of four small groups. The objective of our study is to examine how the dimensions of the task were framed in preservice teachers' argumentation, in terms of place-based versus global approach.

2 Theoretical Framework: Argumentation and Place-Based Approach

In the first part of this section, we discuss the socio-scientific issue (SSI) approach in connection with the practices of argumentation and decision-making. Then we outline the foundations of place-based education (PBE) emphasizing its links with sustainability and democratic education. We argue that instructional environments designed with a place-based approach provide appropriate contexts for the practice of argumentation and decision-making about SSI and that a place-based perspective in science teacher education can be helpful to better contextualize teaching in students' communities, practices, and cultural knowledge.

2.1 Argumentation About Socio-scientific Issues

In our global, constantly evolving society, scientific development has shown a great potential to shape the world. The impact of technology on habits and cultures around the globe has become noticeable over the last decades (e.g., use of cell phones). The advancements in fields of knowledge such as genetic engineering or computational science brought the introduction of technologies that have a great impact in lifestyles and the environment. Hence, a range of highly controversial issues such as human cloning or nuclear energy has captured the public's and media attention. These issues, which are far from being purely scientific matters and have strong ties with societal factors, interests, and values, are termed socio-scientific issues. These include large-scale concerns, such as climate change or the use of stem cells, but they can also be local issues, such as beach restoration, the election of a heating system, or the construction of a new road. It should be noted that the efforts to explicitly include science-society interactions in science classrooms are not new (Driver et al. 2000; Kolstø 2001). The SSI framework builds upon the science, technology, and society (STS) movement developed since the early 1980s, which aims to instruct students about the interdependence of these three domains (Yager 1996).

One reason frequently held to support the inclusion of SSI in science classrooms is their role in the development of a responsible citizenry capable of applying scientific knowledge and of taking part in collective decision-making (Kolstø 2001). This aligns with what has been termed Vision II of scientific literacy (Roberts 2007), which highlights the role of science in connection with problems of people's life, such as how to feed the world population or how to guarantee water supply, in other words, issues related to social, political, economic, or ethical perspectives (Sadler and Zeidler 2009). This standpoint has been recognized in curricular frameworks as the Next Generation Science Standards (Achieve 2013) or in international assessments. For instance, the Program for International Students Assessment (PISA) characterization of scientific literacy includes the "awareness of how science and technology shape our material, intellectual and cultural environments" and "willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen" (OECD 2013, p. 100).

Besides this aim of developing a responsible citizenship, SSI have been proposed as suitable contexts for learning science, including goals as promoting students' understanding about science concepts and the nature of science, engaging in argumentation practices, and fostering students' interest and motivation (Sadler and Dawson 2012). The ill-structured and open-ended nature of SSI, which entails the consideration of several competing options, makes them useful contexts for engaging students in argumentation and decision-making (Acar et al. 2010; Sadler and Dawson 2012). Both practices are the focus of our chapter.

In science education, argumentation is considered as a scientific practice consisting in the evaluation of knowledge in the light of evidence. There is agreement that the study of argumentation should combine attention to justification and to persuasion (Berland and Reiser 2011). The relevance of different discursive contexts in the practice of argumentation remains an understudied issue. Jiménez-Aleixandre et al. (2014) argue that some argumentative operations and products may differ in contexts specific to classroom discursive practices. They identify four discursive contexts for argumentation: (1) construction and evaluation of causal explanations, (2) decision-making on the basis of evidence, (3) primary data interpretation and drawing of claims in laboratory experiences, and (4) critical evaluation of claims made by others. This study corresponds to the second, decision-making.

The existence of a diversity of proposals, options, or solutions is a condition for argumentation (Jiménez-Aleixandre 2008). In strictly scientific issues (e.g., causal explanations), there is generally one accepted solution, although there could be potential alternatives. In contrast, argumentation about SSI offers the possibility of a range of acceptable options. A sophisticated argumentation about SSI requires the consideration of different dimensions and arguing for or against different positions. This is aligned with the objectives of current decision-making research (Acar et al. 2010). Argumentation has been deemed as an essential ability for civic engagement. In Driver and Newton's (1997) words, "a strong case can be made that, to enable young people to exercise their choices in informed ways and to prepare them as future members of a democratic society, they need support in developing the necessary skills of argument" (p. 15).

The construction of students' criteria for decision-making about SSI has been examined in several studies (Hogan 2002; Jiménez-Aleixandre and Pereiro-Muñoz 2002; Uskola et al. 2010). Science educators acknowledge the need for developing decision-making skills in students who will participate in complex decisions in the future (Acar et al. 2010). The role of values in decision-making becomes apparent in SSI with relevant societal implications. Kolstø (2005) argued that decisions are never based on knowledge alone, since they result from the interaction between knowledge and values, being the latter necessary for judging the desirability of different consequences of alternative decisions.

Students address controversial issues in different ways, which are dependent on their cultural backgrounds and experiences. SSI contexts may provide opportunities for students to engage with complex contexts including a variety of interests and belief systems (Zeidler et al. 2005). When addressing SSI, the cultural differences among the learners may imply ethical discrepancies. Resolving these disagreements through discussion and negotiation is a valuable practice for civic engagement. Since students forge their identity through perspectives and experiences shaped by culturally diverse societies, it has been proposed that science education should be grounded in local community issues and contexts (Aikenhead 1997).

2.2 Place-Based Education and Sustainability

Place-based education (PBE) can be defined as "the study of local places – their cultural and ecological systems – that provide the primary context for learning experiences and curricular activities" (Mathews 2013). Although this label is relatively recent, it has its roots in educational approaches such as service learning, progressive, experiential, and environmental education (Chinn 2012), and its origins can be traced to the work of John Dewey (1938) and his emphasis on connecting school-based learning with students' everyday life. The goal of PBE is to encourage students to understand "the world as intradependent, filled with a variety of locally intradependent places" (Brooke 2003, p. 6). Grasping the complexity and dynamic interconnectedness of local systems requires an integrated and multidisciplinary approach, which PBE is due to provide in the form of authentic, open-ended problems. This expresses the connection between PBE and the SSI framework, which helps students "grapple with the messy cross-disciplinary nature of humankind's current dilemmas" (Smith and Sobel 2010, pp. 21–22). In a survey of the literature, Woodhouse and Knapp (2000) identify essential characteristics of PBE: (1) it emerges from the particular attributes of a place – specific geography, ecology, sociology, and politics; (2) it is inherently multidisciplinary; (3) it includes a component of experience and action; (4) it goes beyond the philosophy of "learn to earn" (i.e., preparing students for the job market); and (5) it connects place with self and community.

PBE education has been proposed as a potential new paradigm for developing the Education for Sustainable Development (ESD) movement (Skamp 2010), which aims to address the societal and economic implications of human interaction with the environment. Under the ESD label, global, national, and local institutions and groups have gathered their efforts to "initiate authentic action to address eco-social planetary problems" (Somerville and Green 2012, p. 1). However, critical approaches to ESD reveal its association with the maintenance of consumption patterns (Jickling and Wals 2008) and highlight an underlying discourse emphasizing objectivity and faith in technology, "blackboxing" ideologies behind decisions and policies (Ideland and Malmberg 2015). PBE holds the potential to further extend sustainability education to a more thorough social movement aiming to the sustainability of people and places (McInerney et al. 2011; Somerville and Green 2012). To undertake this, people must construct knowledge of ecological patterns, systems of causation, and the long-term effects of human actions on those patterns (Orr 1994). A place-based approach seems particularly suited to address sustainability, since "local places provide the specific contexts from which reliable knowledge of global relationships emerge" (Greenwood 2013, p. 94), thus enabling the consideration of the impact of lifestyles on natural resources (Traina and Darley-Hill 1995) and the identification of ways in which local populations can contribute toward sustainability (Kates and Parris 2003). The practice of environmental education requires the understanding of human beings as part of the natural world and human cultures in terms of interactions between species and specific places (Smith and Williams 1999). Environmental educators have also highlighted the importance of developing a sense of "place" for understanding the relationships between humans and nature (Orr 1994; Smith and Williams 1999; Sobel 1996). As stated by the Board on Sustainable Development of the National Research Council (1999), "Developing an integrated and place-based understanding of such [environmental] threats and the options for dealing with them is a central challenge for promoting a transition toward sustainability" (p. 224).

In order to properly address sustainability in schools, research has shown the relevance of professional development of teachers as sustainable literate agents (Ferreira et al. 2007; Nolet 2009; Tilbury et al. 2005). Chinn's (2012) review of published place-based science programs points out consequences of place-based contextualization of science teacher education for teachers, students, and communities, for instance, that educators trained within a place-based perspective are empowered to contextualize learning in students' communities, practices, and cultural knowledge. Chinn (2012) concludes that envisioning science professional development as participation in place-based and culture-based communities of learners represents a promising path toward educational equity and science literacy for all learners. In Spain, PBE has not received systematic attention in teacher education.

Teachers must be prepared to provide democratic education if we are aiming to build and maintain a democratic society (Goodlad 1996). The potential of PBE for providing experiences and knowledge required to fostering students' active participation in democratic processes has been generally recognized (Woodhouse and Knapp 2000). One of the foundations of PBE is that students should have an active voice within their schools and communities (Mathews 2013). According to Beane (2005), schools should promote students' engagement in democratic practices by providing opportunities to deliberate, solve problems, and produce change. In this regard, the ability to acknowledge other people's standpoints, particularly when they differ from ours, is an essential component of the decision-making and consensus-building process within pluralist and democratic societies (Hess 2009; Johnson and Johnson 2009). The importance of place is that "it provides the context in which the problems can be recognized and articulated, and within which different values can be understood, conflicts resolved and choices made" (Potschin and Haines-Young 2013, p. 1054). Schools are privileged settings for engaging students in practices that involve decision-making and conflict resolution, since in them students are exposed to people who are different from them and because classrooms environments can be designed for scaffolding students' ability to engage in deliberation around controversial issues and decisions (Hess 2009).

Aligned with the democratic education approach, Lay and Biesta's (2006) model of *citizenship-as-practice* highlights that citizenship is situated in day-to-day interactions, choices, and dispositions, rather than a set of knowledge to be transmitted. This perspective entails the development of a sense of agency, which is one of the goals of PBE, understood as the capacity to act upon and improve a place (Sobel 1996). In Demarest's (2014) words, "There is a dance between experience, content, places, and personal agency that takes place when students learn deeply in the context of their communities" (p. 101).

These approaches frame the design of a contextualized argumentation task that includes place-based features, which is the focus of this chapter.

3 Methodology

The methodological approach is qualitative, a case study, appropriated to study processes (Creswell 2009) and knowledge evaluation practices. It seeks to identify patterns through systematic analysis in order to understand the meanings of participants in their context (Merriam 2009). One assumption framing this approach is that we are examining socially constructed knowledge claims, participants' subjective meanings of their experiences (Creswell 2009). Data reduction draws from discourse analysis (Gee 2005), employing the constant comparative method (Glaser and Strauss 1967). This means that the coding categories were elaborated from the interaction of dimensions from the literature about place-based approaches with data in successive iterations. The two coders independently identified codes that were later compared. The unit of analysis is the turn of speech, defined as each intervention by the participants.

3.1 Participants, Context, and Data Collection

The participants are 85 preservice primary teachers enrolled in the science education course taught by the second author in a Galician university. Galicia is an autonomous region in Northwest Spain, which has an economic development lower than the European average and where, given its high rates of unemployment, there are few immigrants. All the participants share a high cultural homogeneity; none of them come from an immigrant background. Galician schools are bilingual settings, where both co-official languages, Galician and Spanish, are used interchangeably

Table 2.1 Data corpus and distribution of participants in the study

Students' distribution (N = 85)	Seminar groups (N = 4)	Small groups (N = 20)	Analyzed data
	G1	G1–1… G1–5	G1–2 (Group A)
	G2	G2–1… G2–5	G2–2 (Group B)
	G3	G3–1… G3–5	G3–2 (Group C)
	G4	G4–1… G4–5	G4–1 (Group D)
Data corpus	Four final debates	Twenty written reports	Twenty written reports
		Eight oral recordings	Four oral recordings

and fully understood by everyone. The instruction and handouts were in Galician. The participants were distributed in four seminar sessions, five small groups for each seminar, making a total of 20 small groups, as summarized in Table 2.1. Participants are identified with pseudonyms.

In this chapter, the analysis focuses on the written arguments of the 20 small groups, identified with a number combining seminar sessions and groups within them (G1.1 to G1.5, G2.1 to G2.5, and so on), and the oral debates of four of these small groups, labeled A, B, C, and D. Data collection included student teachers' written artifacts (individual pretest, portfolio reports, final essays, and group arguments) and video recording of debates in the four small groups selected, one from each seminar session, in which all participants consented to be recorded.

The coding was conducted using the transcripts in the languages in which the discourse was originally produced (Galician and Spanish), and only selected quotes were translated to English for inclusion in the chapter. The coding process was carried out by both authors, which are fully proficient in the two languages. First, the transcriptions of the oral debates and the written reports were analyzed by both authors, and initial repertoires of categories drawing from the literature were elaborated. In a second phase, tentative codes were independently assigned to each unit of analysis. Then the coding was compared, the differences resolved, and the categories refined. The data were subjected to several cycles of analysis using the three revised categories: locally place-based (in the Galician context), regionally place-based (in the Spanish and Southern European context), and global approaches. These categories and the criteria for coding are summarized in Table 2.2 and further discussed in the findings section.

3.2 Task Design: Constructing Arguments About Diets

The main goal driving the task is to support teachers in implementing argumentation in their classrooms. In order to achieve this goal, it is necessary, first, that the student teachers engage themselves in constructing arguments and, second, that they reflect on how to build quality arguments, a reflection carried out collectively in the seminar final debates, as well as in their individual portfolios. The second

Table 2.2 Coding categories for contextualized argumentation

Code	Description	Examples
Locally place based (in the Galician context)	Participants' discourse is explicitly contextualized in Galicia, appealing to Galician economy, Galician culture, or any other dimension with a local focus	Here in Galicia… What is the problem? If the industry is organized for producing meat and fishing and all that, then a radical change toward a vegetarian diet would harm… at first, wouldn't it? (GB, oral debate)
Regionally place based (in the Southern European context)	Participants' discourse is based on personal experiences or social contexts implicitly placed in Spanish or South European societies	Currently, in our society, it is easiest to be omnivore, for instance, in restaurants […]. Besides it, not eating meat is a sacrifice, as evidenced by traditions as fasting. (G3.1, written report)
Global approach	Participants' discourse refers to data, information, or positions in general terms, which may apply to any society or country or to the whole planet	Reading about the ecology issues, the vegetarian diet is better. I mean, it is the one that causes less harm to the planet, they suggest there… (GB, oral debate)

G group

goal is to promote the development of the teachers' capacity of contextualizing their own lessons.

The task, which is the focus of this chapter, is part of a 15-week science method course (45 h, each session lasting 90 min) including six tasks about argumentation, which are summarized in Table 2.3 and labeled A1 to A6. Task A6, in week 10, is built around diet election and the omnivorous-vegetarian dilemma. This SSI context was chosen considering these reasons: (1) growing concerns on how to feed global population in the near future (FAO 2009); (2) the emergence of studies assessing the impact of diets on sustainability (Stehfest et al. 2009); (3) recent concerns regarding long-term impact of diets on health (IARC 2015); and (4) the shortage of studies addressing this topic in science education, as we have only identified one (Morin et al. 2014) on argumentative reasoning about diet in connection with sustainability.

In five previous sessions, the student teachers were engaged in tasks about evidence evaluation and criteria for strong arguments. For instance, they were required to relate data to competing explanations about the cause for infections (task A1, session 1.2), to produce hypotheses for unexplained phenomena attributed to ghosts and to retrace the path from data to explanations (task A3, session 6.1), to evaluate a range of pieces of evidence about Copernicus' remains (task A4, session 7.1), to compare pupils' arguments and propose criteria for evaluating their quality, and to evaluate the fit of claims with data from topographic maps (task A5, session 9.2).

The focus of this chapter is on the last task (A6, session 10.2). During a 90-min session, each one of the 20 small groups had to construct an argument about a chosen diet, followed by whole seminar discussion. The handout is reproduced in the box below. Before that session, during the two previous weeks, each group had to collect information about one of five dimensions of diets – nutritional, ecological,

Task Handout: Building an Argument About Diets

1. **The task** consists of producing an argument about the dilemma of dietary choice working in small groups. The goal is to reach consensus within the group about what diet is the best choice (conclusion). It may be noted the diversity of possible choices: vegan diet, vegetarian diet, omnivorous with meat, omnivorous with fish, meat-free days (e.g., Ghent's Thursday Veggie Day), etc. The conclusion must be supported by data (evidence), drawn from the information handouts (documents 1–5), the Wiki (online), and previous knowledge (justification), which may help to relate data and evidence. Your argument can take values into account.
2. **Dimensions:** Notice that this dilemma involves different dimensions (cultural-personal, ecological, ethic, nutritional, socioeconomic), so you can study the information handouts (data) and discuss partial questions separately such as the following: what is best from a cultural/personal point of view? What is best for the environment and the Earth? What is best for economy and society? What is best from an ethic point of view? What is best for health and nutrition? The answers to these questions (partial conclusions) can function as different lines of reasoning that can be integrated into a final conclusion.
3. **Criteria** for strong arguments are as follows:
   - Taking the available evidence (data, information) into account.
   - Stating the conclusion clearly.
   - Specifying which pieces of evidence support the conclusion and which ones refute or criticize the choices rejected.
   - Indicating what theories or knowledge were used to relate data and conclusions (justifications). If that is the case, specify what values support the conclusion.
   - Integrating as many dimensions as possible in the argument.
4. **Writing a persuasive argument:** Once consensus is reached, you must write down your argument in order to persuade, for instance, another student of the faculty that your choice is the best one.

ethical, cultural, and economic – and to share it with the class through a Wiki. Each group was assigned only one dimension, so they had a tighter focus.

In order to build the argument, they were directed to use a complex data set, consisting of their own selection of information, as well as five handouts elaborated by the authors, which are discussed below. These additional handouts, available to all students, were produced to minimize bias in the selection of information and to ensure that for each dimension there was available information supporting different choices of diets. The five dimensions were chosen since they embodied the main aspects of the multidisciplinary diet dilemma. Compared to the Sociology/Culture, Environment, Economy, Science, Ethics/Morality, Policy (SEE-SEP) model

Table 2.3 Tasks related to argumentation (A1 to A6) and to diets (D1 to D2) in the 15-week course

Week/ session	Tasks related to argumentation	Student teacher's performance
1.2 I	A1. *Semmelweis*: How to choose the best of several causal explanations? (Jiménez-Aleixandre 2010)	Relating data to phenomena explained in an example from history of science
2.2 I (lab)	A2. *The origin of sand*: Asking questions about explanations of natural entities or phenomena	Producing and refining questions about origin of sand. Comparing data about different sand samples
4.1 L	Concepts, models, theories, evidence	Discussing in pairs and proposing meanings for evidence
5.1 L	Scientific practices and competencies	Attend to lecture, ask questions
5.2 I (lab)	D1. Analysis of snacks' labels: What do we eat? It is different what they claim from what it contains?	Collecting wrapping of snacks eaten during 2 weeks. Analyzing the nutrients
6.1 L	A3. Mini-task: *The ghost in the laboratory* (Jiménez-Aleixandre 2010)	Producing hypotheses for unexplained phenomenon; going from data to explanations
7.1 L	A4. Mini-task: *Are these Copernicus' remains?* (Jiménez-Aleixandre et al. 2009)	Evaluating evidence
8.1 L	Health and nutrition in primary education. D2. Pretest about diets	Attend to lecture, ask questions; answer questionnaire
8.2 I	(a) Distribution of diet dimensions for the Wiki task; (b) criteria for comparing arguments	(a) Select information about one dimension and upload it to the Wiki (2 weeks); (b) compare pupils' arguments and propose criteria for evaluating their quality
9.2 I	A5. *Where do mushrooms grow?* Relating data in a map to claims	Evaluating fit of claims with data from topographic map
10.2 I	A6. *Which diet is more adequate?*	Building argument about diet, taking into account different dimensions

I interactive session in small groups, *L* lecture to the whole class

(Rundgren and Rundgren 2010), the dimensions cover up five of its six subject areas, all except Policy that was left out since the role of governments was not considered so relevant in this case compared to other SSI such as usage of nuclear energy or GMO, in which the central decision falls on the State. However, we acknowledge that some policies can influence the diet of the population such as those regarding food taxation, animal welfare, or educational policies.

The task design intended to provide students with conflicting pieces of information that could be used to support opposing options. Thus, on the one hand, most information related to nutrition, ecology, and ethics would support a vegetarian option over a meat diet. On the other hand, the data related to Galician economy and Galician food culture would point to some problems making difficult an extensive adoption of vegetarianism. Thus, conflict was embedded in the task design. From the local/global point of view, it must be noted that three dimensions, *nutritional*, *ecological*, and *ethical*, can be considered as being more general or universal, while two, *economic* and *cultural*, were contextualized in Galicia. Still, pieces of information combining both perspectives coexist, except for economy (only local). To illustrate the task content, next, we summarize the information contained in each information handout, highlighting conflictive pieces of information and emphasizing some aspects relevant from a local/global perspective.

Handout 1: Nutrition Two of the eight pieces of information included numerical data, for instance, about correlations between weight and vegetarianism, or recommended percentages of nutrients in a balanced diet (in average, 55% carbohydrates, 15% proteins, 30% fat), which contradicted previous beliefs of some participants who thought that the protein fraction in a healthy diet should be much higher. Also included were excerpts from reports of the *American Dietetic Association* pointing out health benefits of well-planned vegetarian diets, as well as from other authors criticizing vegan diets; extracts of the *European Food Information Council* with recommendations about eventual nutritional deficits caused by strictly vegetarian diets; and a newspaper headline about the trial of a vegan French couple accused of causing their daughter's death by malnutrition. All this information is framed in a global approach, with the exception of the newspaper headline.

Handout 2: Ecology The five pieces of information included numerical data, comparing, for instance, vegetable and meat production regarding greenhouse gas emissions and energy efficiency (e.g., soya 415% versus beef 6.7%, which means that eating soya is much more efficient). Also included were comparisons in the amount of land required for feeding people with vegetal versus animal diet (15/1), the total contribution of breeding to greenhouse gases (18%), effects of breeding on the environment as water pollution, deforestation or loss of biodiversity, and an estimation of global nutrition needs for 2050 from a *Food and Agriculture* Expert Meeting. Lastly, an extract of an article by an Australian researcher defended the idea that wild-hunted kangaroos are more sustainable than new crops of wheat or rice. With the exception of this last piece, contextualized in Australia, the environmental dimension was framed in a global approach that could be applied to the planet.

Handout 3: Economy This data set consisted of numerical data and tables about Galician economy, illustrating the dominance of animal breeding (66.6%) over agriculture (28.7%) in the livestock-farming complex, which is the reverse of the proportions in Spain (34% versus 62%) or in the European Union. It also included data about the employment share of the primary sector (10% of total employment) and the role of the food industry in Galician exports. All the information within this dimension was framed in a local perspective. It should be noted that this is the only handout that does not mention diet, either vegetarian or omnivorous. A reduced version of the economy handout is reproduced in Annex 1.

Handout 4: Ethics It consisted of excerpts from essays about animal rights, anti-speciesism, and sentience as the moral foundations for avoiding the consumption of animal products. Extracts from an article depicting veganism as a "trend" and highlighting humans' right to consume animals were also included, as well as information about animal suffering caused by extensive farming and an estimate of the number of animals of several species killed per hour, according to the *Food and Agricultural Organization*. Two pieces illustrated the inexistence of differences in the biochemistry of physiological and emotional states in humans and other animals, such as mice, and the findings of a study about fish behavior related to fear. Lastly, an excerpt of the same Australian article quoted on the environment handout defended that extensive crops are the indirect responsible of thousands of mice deaths per year, being less ethically acceptable than harvesting a comparatively lower number of kangaroos for the equivalent amount of food. Except for this last paper, this dimension was framed globally.

Handout 5: Cultural Dimension It comprised four pieces of information, three of them focusing in Galicia. Two discussed the "Atlantic diet," a recently created notion due to express food habits in Galicia, one listing its features and a second criticizing the notion as being historically inaccurate and potentially unhealthy. The high status of meat in Galician culture was highlighted in them. The third, about a traditional food market in Santiago de Compostela, the Galician capital, describes literarily the pleasure of eating meat. Lastly, an excerpt from an article reviewing studies proposing adaptive explanations for human preference for sweet and greasy food is included, being the only piece of information embodying a general or global approach. Hence, we consider this dimension as framed from a predominantly local perspective.

4 Contextualized Argumentation: Place-Based and Global Framing of Dimensions

This section discusses the findings about the research objective: *to examine how the dimensions of the task were framed in preservice teachers' argumentation in terms of place-based* versus *global approach.*

In order to answer this research objective, we explored, both in the written reports and in the oral discussions of the groups, how the arguments were constructed in terms of the balance among general (global) and place-based (local and regional) dimensions. We discuss this construction in two phases of the process: (1) the identification of the task's goals and (2) the decision about a diet and the justifications used to support their choice. This is an analytical distinction, and it does not mean that the phases are consecutive, because the process is not linear. We address first how the dilemma was framed in the written reports and then the debates in the small groups.

4.1 Construction of the Diet Dilemma as a Local Issue in the Identification of the Task's Goals

From the data, it can be said that the student teachers framed the diet dilemma as a locally relevant issue. This is found, for instance, in the oral debates about the identification of the task's goals, in the process of choosing an option, and in the justifications used to support their choice. Two dimensions in particular, economy and cultural, were characterized by participants from a predominantly local perspective. It should be noted that, as discussed above, the handouts about these two dimensions presented data about Galicia. However, the task (reproduced in the previous section) was worded in general terms, requiring preservice teachers to build an argument about a dietary option.

We begin by addressing which options were chosen or, in argumentative terms, which claims were defended. The 20 written reports discussed arguments about a range of dietary choices, summarized in Table 2.4: ten groups, that is, half of them, proposed omnivorous diet with reduced meat intake (compared with regular diet), seven omnivorous, two vegetarian, and one group a vegan diet.

A second issue is to identify which dimensions were used to support these claims (diet chosen). In argumentation analysis, there is a distinction between *evidence*, that is, observations, data, and facts used to evaluate (to support or to reject) the claim, and *justification* (called "warrant" by Toulmin 1958), that is, the statement that connects evidence to claim. However, in this study, our focus is not on these structural issues, but on the contextualization, so we will collapse these two components under the name of *justifications*. Authors as Erduran et al. (2004) have also collapsed them for analytical purposes. As an instance, Table 2.5 summarizes the claim and justifications found on the written report of group B.

Table 2.6 summarizes the number of dimensions employed to justify the options in the written report. Most written reports used all five dimensions (10 reports), or four of them (six reports), although there are two reports appealing to three and two appealing only to nutrition. For our research objective, it is pertinent to analyze which dimensions were used in order to justify the choices about diet, and from which approach. This analysis is summarized in Table 2.7.

Table 2.4 Final decision in the written reports (N = 20)

Diet option	Omnivorous reducing meat	Omnivorous	Vegetarian	Vegan
Number of reports	10	7	2	1

Table 2.5 Summarized claim and justifications on the written report of group B

Claim (diet chosen)	Justifications	Related dimension
The most appropriate option is an omnivorous diet with reduced meat consumption	Breeding causes pain to animals, and we should choose the moral option that causes lesser harm, so we should reduce the portion of meat in our diets and eat only products that come from adequately raised animals	Ethics
	Animal products are not strictly necessary to have an adequate nutrition, although its absence causes an eventual need of nutritional supplements that may be practically inconvenient	Nutrition
	Meat consumption in Galicia is high enough to cause an average intake of proteins way higher than the 15% that is recommended, so we defend a reduction on meat consumption	Nutrition
	Meat production is less efficient than vegetable production in terms of land and water use, so reducing meat consumption would positively contribute to sustainability	Ecology
	Breeding is relevant for Galician economy, so a mass adoption of a vegetarian diet would cause great economic losses; instead, gradually reducing meat consumption would be economically feasible	Economy
	Meat has a symbolic role in Galician culture, so completely abandoning its consumption would entail a loss of a cultural heritage, whereas a reduction of meat consumption would be culturally feasible	Culture

Table 2.6 Number of dimensions integrated in the written arguments (N = 20)

Dimensions	5	4	3	1
Number of reports	10	6	2	2

Table 2.7 Place-based, cultural, and global approaches used in the written arguments (N = 20)

	Dimension				
Approach	Nutrition	Ecology	Ethics	Economy	Cultural
Locally place based (in Galician context)	0	0	0	12	7
Regionally place based (in Southern European context)	1	2	2	0	3
Global approach	19	16	13	3	4
Number of reports	**20**	**18**	**15**	**15**	**14**

For coding the approaches, the following criteria, summarized in Table 2.2, are used.

Locally Place Based (in Galician Context) Participants' discourse, either paragraphs in the written reports or episodes in the oral debates, is coded as locally *place based* when it is explicitly contextualized in Galicia, appealing to Galician economy, Galician culture, or any other dimension with a local focus.

Regionally Place Based (in Southern European Context) Participants' discourse is coded as *regionally place based* when it is based on personal experiences or social contexts implicitly placed in Spanish or South European societies.

Global Approach Participants' discourse is coded as *global* when it refers to data, information, or positions in general terms, which apply to any society or country or to the whole planet.

It needs to be noted that in written reports and in the oral debates there are a few cases of combination of local and global references to one dimension. In the written reports, the discourse is coded as place based if there is at least one reference with a local or regional approach. In the oral debates, the different framing of some episodes is discussed below.

As seen in Table 2.7, from the two dimensions mainly concerned with scientific data, which were presented with a general approach in the handouts, one, nutrition, was used to support the 20 arguments, and the other, ecology, to support 8. ethics, which was also presented with a general approach, was used in 15 out of the 20 arguments. In contrast, the handouts about economic (used in 15 arguments) and cultural (used in 14) dimensions focused on the local Galician context. The question is *how* these five dimensions were used to build the written arguments.

Two dimensions, *economic* and *cultural*, were characterized predominantly from a local perspective, in particular the first one:

In 15 written group arguments, there are references to *economy*. In three of them, these references are global, for instance, "About the economic dimension, breeding animals for its consumption is much more costly than cultivating the land […] although afterwards, sometimes, buying ecological products is more expensive" (group A). In 12 arguments, the potential economic impact in Galicia – where cattle breeding is an important activity – of a change to a vegetarian diet was considered locally. Furthermore, in the oral debates of three small groups, economy was dealt with from a local approach, as addressed in the next section, while in the group A there were only general references to it. Group B had a long debate about the impact of vegetarian diet on local economy, discussed below.

In 14 reports, there are references to the *cultural* aspects of diets. In four of them, these references are global, and in three, they are regionally place based, for instance: "Culturally we consider that the historical context leaves a mark on diet, for instance in the middle of the last century some seafood was part of the diet of lower social classes, which took them from the seaside to complement their scarce diet. Currently in our society it is easiest to be omnivore in restaurants for instance […]. Besides it, not eating meat is a sacrifice, as evidenced by traditions as fasting" (Group 3.1). First, it explicitly acknowledges the influence of the historical context; second, there is also a reference to times of hunger and scarce food in the years after Spain Civil War; third, it highlights the difficulties for being vegetarian in Galicia and Spain (although these names are not mentioned); fourth, it points out that in (Catholic) tradition meat is forbidden in some periods as Lent Fridays, which is interpreted as a sacrifice. In other words, it is contextualized but rather in a regional Spanish or Southern European context (not mentioned explicitly) than in Galicia. The other seven arguments characterize the cultural dimension only from a local perspective, for instance, group D, "In the culture of the area where we are placed, Galicia, it is traditional to eat meat, fish and seafood." Furthermore, in two small groups, C and D, and in all the closing debates, diet was discussed in the context of Galician culture, while in groups A and B cultural references to diet were contextualized in personal experiences and social contexts about Spain or Southern Europe, not explicitly Galician. It needs to be noted that references to Galicia and to the Southern Europe regional context are jointly used in some reports, as the one from group B, in which the closing paragraph appeals to Galician culture. The process in small groups is discussed in detail below.

Three dimensions, ecological, nutritional, and ethical, were approached rather from a global perspective in written arguments, as seen in Table 2.7, and not from a place-based one. From these, ecology was framed in a global context in oral discourse in the four groups and nutrition as global in three groups, while in the group A there were scarce references to it and rather regionally place based in Southern European context. Ethics was framed as place based in Southern European context in the groups A and C and globally in B and D.

One instance of the construction of the dilemma as an issue clearly placed in the Galician context is the debate about task goals within group B, at the beginning of the session. The student teachers were negotiating whether the orientation of the task was to decide about a personal diet, or if it was about deciding on the best diet for a collective, in particular for Galician, society:

24 Bea: Should we choose as if… what we choose would be for huh… for everybody? I mean, imagine that…

25 Breixo: No, what we think… attempting to reach a…

26 Bea: Sure, because for instance… here [*handout*] it speaks about Galician economy, doesn't it? Concerning diets huh… What happens? That… for instance reading about ecology, the vegetarian diet is better. I mean, it is the one that causes less harm to the planet, they suggest there, in that sheet. But if everybody would choose the vegetarian option it would have a highly negative effect for Galicia. Then it is not the same to decide on a diet for everybody or only a personal diet.

27 Borja: No, huh, in each dimension we need to choose which one would be the more convenient diet, this is what I understood, that.

28 Bea: No, no, we need to choose one diet.

[…]

35 Bea: That is why I ask: Is this a personal choice or is it considering that all people should also choose that diet? Because if it is for a big group of people, there for instance huh… it would be detrimental for Galician economy.

36 Breixo: I understand that what you say is a general argument, look, it is a criticism that could be used for or against. I mean, what you say, you are right and I think that we should take it into account. Because otherwise it wouldn't be realistic, would it?

37 Bea: Yes.

The issue was raised by Bea, who suggested taking into account the intended target, either personal or social, of the diet. Bea acknowledged, in turn 26, the conflict between the inferences from the ecology evidence, suggesting than the vegetarian diet is better for the environment and the economic consequences for Galicia. One of the goals of the task was for student teachers to acknowledge that many socio-scientific issues involve conflicts and that it is not always possible to reach a solution that meets all interests. This acknowledgment is part of the development of critical thinking about complex, real-life issues. Bea pointed out the potential effects of a mass adoption of vegetarian diet for Galician economy, where cow breeding has a great weight. This conflict was framed in a local ("Galicia")–global ("the planet") tension and had consequences for the task orientation, in other words, for *whom* is the diet intended, which was not explicit in the task. Bea's statement originated an exchange of several turns about the goal of the task. Borja and Blas (turns omitted) interpreted that the implication was that they could choose several diets rather than one: a vegetarian diet favoring the ecological dimension and a second omnivorous diet favoring the economic dimension, thus ignoring the potential conflict between the two dimensions and simplifying the task. It needs to be noted that breaking the task in such a way would amount to eliminate its SSI nature, which is multidisciplinary, and requires combining and articulating different, and sometimes opposed, interests and values.

The exchange lasted until Breixo supported Bea in clarifying that they should choose only one diet, a doubt that emerged also in other groups. Then, in turn 35, Bea restated her suggestion, formulated as a question for the group. This time, Breixo (36) accepted it, confirming that they should take into account the potential change of diet of all or a substantial part of Galician society and not just an individual change, an issue that would resurface in later episodes. The question of the consequences of mass adoption of vegetarian diet for Galician economy was carried out to the written report, using it to support the option for reducing meat consumption while keeping an omnivorous diet. We interpret this as an attempt to reconcile conflicting options.

4.2 Contextualization in Choosing an Option and Supporting It

The final decisions of the 20 small groups and the dimensions articulated in the arguments are presented above in Tables 2.4, 2.5, 2.6, and 2.7 and discussed in terms of place-based versus global characterization. These choices can be considered the products, and now we turn to the process of choosing an option (claim) and supporting it with evidence and justifications in the four small groups, in particular how this construction of an argument reveals tensions between local and global approaches.

The four small groups analyzed opted for an omnivorous diet with reduction of meat consumption. About the articulation of dimensions in their written reports, B and D articulated the five dimensions; A integrated four, all except ethics; and C three, nutritional, ecological, and cultural. In this sense, they are representative of the dimensions addressed in the 20 reports. In the four oral debates, all these groups addressed the five dimensions.

The orientations in the handout suggested that they should (first) study the information; then decide which option was better aligned with a given dimension, in other words, which would be better for the environment, which one for health and nutrition, etc.; and integrate these lines of reasoning in a final conclusion (see the handout above). Ideally, the process of decision-making about a socio-scientific issue should follow a path from evidence and values to deciding an option. However, this was not always the case. For instance, in A, the group members agreed on an omnivorous diet with little meat in minute 4, dealing afterward with how to justify this decision with the data provided. In the group D, Daniel proposed the omnivorous option right at the beginning, in turn 6, but then they evaluated the evidence before reaching a decision. Groups B and C also evaluated the evidence before agreeing on the "omnivorous with less meat" option. The processes of negotiation in the small groups are analyzed elsewhere (Jiménez-Aleixandre and Brocos 2017). Here, we are focusing on whether the small groups approached each dimension from a locally place-based, regionally place-based, or global perspective.

The analysis of the oral debates suggests that, rather than framing the dimensions in two opposing approaches, global versus local, the dimensions were placed along a continuum from global context to regionally place-based context to locally place-based context. The different contextualization of the five dimensions is represented in Fig. 2.1, where ecology is framed in a global approach; nutrition rather in the global one, but with a few episodes of regionally place-based context in A; ethics in a global approach in B and D and in a regionally place-based context in A and C; personal-cultural dimensions in between regionally place-based and locally place-based contexts; and economy in a locally place-based context in three groups, although in the group A it is framed globally. Next, each dimension is discussed with excerpts.

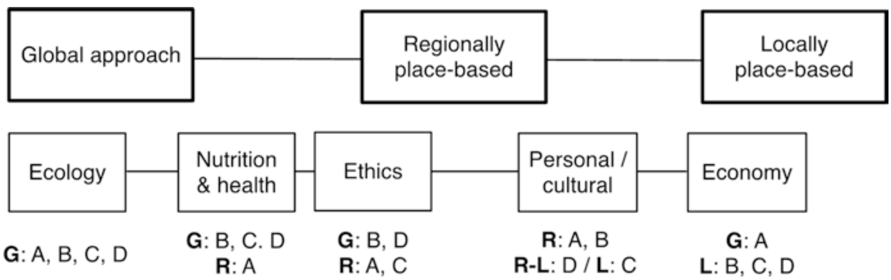

Fig. 2.1 Contextualization of the five dimensions, in the oral debates, on a continuum from global approach (G) to regionally place-based (R) to locally place-based (L) context

4.3 Ecology: Global Benefits for the Earth's Environment of Vegetarian Diets

The global–local tensions emerge in the choices of an option and in the evidence supporting it. In the oral discussions of the four groups, there is an explicit acknowledgment, framed in a global approach, of the benefits for the environment of a vegetarian diet. An instance is this excerpt from group B, in which the explicit recognition of the superiority of vegetarian diets from an ecological perspective is framed in a hot controversy when Breixo challenges the omnivorous option proposed by the other three participants:

162 Breixo:	Look, from the viewpoint of the ecology dimension: What happens?
163 Blas:	Well… we would look for support.
164 Breixo:	But it [*omnivorous diet*] is more harmful [*for environment*], isn't? That a…
165 Bea:	Yes.
166 Blas:	Of course.
171 Bea:	Look, a clear example is that it says [*handout*] that with a vegetarian diet you could feed fifteen people with the same amount of land that you need for a carnivorous diet of a single person. […]
172 Breixo:	Huh… in other words, as a summary, it requires more resources than a… a vegetarian one.
	[…]
180 Blas:	Here in Galicia… What is the problem? That if industry is organized for producing meat and fishing and all that, then a radical change toward a vegetarian diet would harm… at first, wouldn't it?

Bea's approach is global, for instance, when comparing land use for opposed diets. All students agree in considering a vegetarian diet better for the environment; nevertheless, the global-local tension emerges when Blas introduces the context of Galicia, pointing out the problems that vegetarianism would entail for Galician breeding sector. This is an issue carried out from the beginning, as shown in the excerpt above about the task's goals.

A global approach in the explicit acknowledgment of the benefits of vegetarianism is also identified in group A, after discussing the greater energy efficiency and lesser water footprint of vegetable production compared to meat production: "What is better for the environment?" (Abel, turn 379), "The vegetarian one" (Alicia, 381), and "Obviously" (Aaron, 382); in group C, after considering the implications for global warming and the greater land and water use derived from meat production, "Wow… right now I tell you that the vegetarian one is winning on every aspect" (Carlos, turn 307), and group D, after evaluating data regarding greenhouse gas emissions and land use caused by breeding, "Obviously, look… environment [will be] always favored by the vegetarian diet" (Daniel, turn 265), mentioning what is "better for the planet." The issue of environmental impact of diets is global by nature (although there are instances of local effects), so a global approach could be expected.

4.4 Nutrition: Advantages of Vegetarian Diets for Health in a Global Approach

Oral debates about nutrition data present patterns with similarities to discussions about ecology: global approaches and explicit acknowledgment of the advantages for health of vegetarian diets in B, C and D. For the student teachers, it came like a surprise that a vegetarian diet could be healthier than the western standard omnivorous diet: "You read this and you say: I will become vegetarian [she laughs]" (Carla, 172). We interpret her laugh as meaning that she does not contemplate it as a realistic option for her own diet.

Group D was the only one where there was, at the beginning, a clear conflict between four students proposing an omnivorous diet and Delia who defended vegetarianism and the possibility of replacing meat or fish proteins with vegetables. There were several episodes dealing with nutrition and health, most of them from a global approach, although there was an episode of implicit contextualization (turns 137–158) in personal experiences, with Daniel claiming that if someone had anemia they would be prescribed red meat, appealing to the case of a vegan friend who suffered from anemia, and Delia opposing it that her doctor gave her alternatives instead of meat. After briefly discussing ethics, they turn again to health:

183 Delia:	I mean that perhaps the healthiest one would be a vegetarian diet, including…
184:	Daniel: An omnivorous one, omnivorous balanced.
188 Delia:	… eating milk products and eggs, but it [*handout with nutritionists' report*] never mentions omnivorous diet. It says that the more recommendable is that one [*vegetarian*], and that well planned it should be healthy and it reduces a lot of diseases…
193 David:	… much healthier. But being healthier doesn't mean being balanced.
194 Daniel:	There you are.
196 David:	Yes, yes, I share this view [*that vegetarian is healthier*]. I share it but turning it up another notch.
199 Delia:	But for instance, what it says…
200 David:	I would, there, I would include… something meaty, as…
201 Daniel:	Of course.

Although Delia supports her defense of vegetarian diets in the available data, discussing aspects as longevity or the amount of fat, Daniel and David, rather than challenging the evidence, introduce new criteria, as the balance (we interpret that it refers to balance in nutrients proportions), or claiming to agree with a vegetarian diet, they propose to include meat in it. The episode is framed globally, without references to the local context.

In group C, the discussion combines appeals to nutrition and to ethics. In group B, where there is disagreement between three participants defending omnivorous diet and Breixo, challenging it, the approach is also global. In group A's debate, the focus is on ecology and cultural dimensions with very little discussion about nutrition and health in two short episodes that are in a regional place-based context: "You should also think about… about the kings and all that, that they always died because of eating meat all the time" (Alicia, 367), probably a reference to Spanish kings Charles V and Philip II who developed gout. We suggest that this points out to the potential of SSI to mobilize a range of knowledge from different domains, as in this case historical knowledge, to address these issues.

4.5 Ethics: Regionally Place-Based and Global Contextualization

The global contextualization of dimensions as ecology and nutrition could be related to their presentation in the handout. However, ethics was also presented with a general approach focusing on animals' sentience, without references to local issues, but its contextualization in two of the oral debates, A and C, is regionally place based. There is an acknowledgment of the consequences of omnivorous diet for animals and of the benefits of a vegetarian diet for their well-being. An example of regionally place-based approach, framing ethics in personal experiences, is an episode in group A about raising animals at home: "Everything you breed makes you feel sorry, doesn't it?" (Abel, 638). However, they do not carry out this empathy with animals to the end of the discussion, and they ignore the ethical dimension in their written report.

In group C, the issue of animal well-being emerges in several episodes, rather contextualized in personal experiences

184 Celia:	A friend of mine […] she became a vegetarian because she said that for her, like, to mistreat animals, to kill so many animals and lock them like, do you know? […] and she became a vegetarian and she is right as rain.
185 Carmen:	Is she?
186 Celia:	[…] since then she is… superhealthy, mate. She became vegetarian and superhealthy. She said… that the only animal product she eats are bees…[*she corrects herself*] honey.
187 Carmen:	Then she is rather vegan.
188 Celia:	Yes. […] But like, she is, you know? Because she feels like doing it. I mean, it is not that someone brainwashed her nor did she go into…

189 Carlos: But there is… there is too much people in the world as to not… breeding the animals in order to kill them and to eat.
191 Carmen: Yes, but you should realize that the ones killed rather stay in first world countries, not in third world… in the third there is more hunger than…
[…]
248 Celia: They [*animals*] are fattened up, clearly. Yes, you lock them up in a stable and come on, eat, eat, eat and die.
249 Carlos: [*at the same time*] … they are fattened up, they… intensive breeding, which is different from old family farms, current systems for…
250 Celia: Is like a chicken farm, man, that many of them die suffocated because some of them trample on others.

The first episode combines ethics and health, appealing to the example of a friend whose motivation for becoming vegetarian was care for animals. Celia's (188) reference to "brainwashing" may be interpreted as implying that other people became vegetarian because of indoctrination. To the ethics justification, Carlos opposes human well-being, appealing to hunger, an opposition between nonhuman animals and humans that emerges also in other groups like B. In the second episode, there is an explicit acknowledgment of the advantages of vegetarian diet for health and ethics, supported in concerns about breeding. Carlos (249) contrasts intensive breeding with "old family farms," implying that, in them, animals live in better conditions. This is interpreted as an implicit reference to Spanish and Galician rural contexts, where still some families raise their own chicken, rabbits, or pigs.

In the other two groups, B and D, the approach is global, for instance, "we should choose the way [of eating] that causes less harm," a reference to the ideas of Peter Singer in group B, or "From an ethics perspective the problem is that the market breaks morality" in D.

4.6 Cultural/Personal: Weight of Galician Traditions and Social Habits

The cultural dimension, in our perspective, includes personal preferences, because these are shaped by culture. Although it was the one missing in more written reports, six, a close analysis of the negotiations in the oral debates shows the weight of cultural traditions and personal preferences and its relevance in the final decisions (Jiménez-Aleixandre and Brocos 2017). In the four groups, participants appealed to these cultural and personal values in direct support of eating meat or to question the feasibility of vegetarian options. Group C frames it in a locally place-based context, with short references that do not originate discussion. D combines locally place-based, discussing Galician food habits, and regionally place-based episodes, while A and B frame it only in regionally place-based contexts. In several episodes, local and regional place-based approaches are intertwined.

The highest number of extended episodes, five, about cultural aspects of diets occurs in group D, from an early conversation about traditional food fairs in Galicia, when four of the five students contribute with instances of seafood or pork festivities. An instance of explicit appeal to the weight of culture happens after a defense of vegetarian foodstuff by Delia:

256 Delia:	[…] for instance quinoa, miso and… foods like these, which here are unusual, tofu and that, you can perfectly replace…
257 Daniel:	[interrupting her] And the whole cultural dimension and that…. you just ignore it, too.
258 David:	There! He is right.
259 Delia:	So, let's see, the cultural dimension. True that I sometimes like to eat a ham sandwich, because it is part of the culture […], but it is not essential for my life.

This acknowledgment of the relevance of social habits emerges again when Delia shares with the group difficulties for eating vegetarian, in Galicia or Spain (although the places are not mentioned):

320 Delia:	[…] At a cultural level, sure you experience pressure.
322 David:	Not, not pressure, you are conditioned.
323 Delia:	Me… for instance, you meet for dinner and what they order is barbecue, octopus and Spanish omelet. So, if you are vegan, what do you order? Home fries […] options if you are vegan, you don't have much.

In a later episode, they discuss again the dominance of pork and beef in Galician ways of eating, and two participants, Delia and Doris, share family experiences of vegetarian relatives forced to eat meat disguised in vegetable stews. Their conclusion is that culturally "we are conditioned to consume these products" (Daniel, 429), a claim that shifts the responsibility of choosing a diet and assuming the consequences of such choice onto society, rather than on themselves.

In the groups A and B, references to cultural and personal aspects are justified in experience or tradition in the regional context, in terms like "I have been eating meat all my life" (Bea, 146), without contextualizing it in Galicia.

4.7 Economy: Place-Based Approach

The relevance of livestock breeding over agriculture in Galician economy and consequently the problems posed by a potential mass adoption of vegetarian diets were acknowledged from a locally place-based approach in the debates of the groups B, C, and D, as well as in 12 reports. These inferences were drawn by participants, although the economy handout did not mention diets (see Annex 1). Only in group A, economic issues were discussed from a global perspective. Two excerpts from group B discussing the issue of potential negative effects, for Galicia, of vegetarian diet have been reproduced above. Another example is found in three episodes in group C, from an early assessment, beginning in turn 41, of the relevance of milk production for Galician wealth.

92 Celia:	For instance, I read this [handout], the economic one, and I tell you: a carnivorous diet because otherwise… Galicia would collapse.
93 Carmen:	In order to sustain economy.
94 Celia:	[…] however I read the ecological one and I say, jeez! You use more water, you know? There are more problems, like… I don't know, greenhouse effect…

They acknowledge the conflict among different facets of diet, which in the end they solve by opting for an omnivorous diet with less meat than the standard diet. In the three groups that focus on Galicia, discussions about economy are emotionally laden, as shown in Celia's utterances, an issue discussed in another paper (Brocos and Jiménez-Aleixandre 2016).

As a summary, the oral debates show that the student teachers framed the dimensions along a continuum from fully global to locally place-based contextualization, setting the issue in the Galician context. However, only the environmental dimension was uniformly framed in a global approach in the four groups. Regarding the other four dimensions, there were differences in the approaches, both between groups and within each small group.

5 Discussion

This study had the objective to examine how the dimensions of a group decision-making task were framed, in terms of place-based versus global approach, in preservice teachers' argumentation. Through the enactment of group-based decision-making and the argumentative interactions involved in the task, the student teachers considered the five dimensions (ecology, nutrition, ethics, cultural/personal, economy) explicit in it. They did it by framing each one into a level of contextualization, sometimes in more than one level in different episodes. This *scope* of framing, which we categorized in three levels one (global, regionally place based, locally place based), is better understood as a continuum rather than discontinued, separate levels.

In the continuum from a global approach to a highly contextualized local place-based approach, a pattern emerges. As summarized in Fig. 2.1, ecology was framed in a global approach in the four small groups and nutrition in a global approach in three groups and in a regionally place-based context in A. Ethics was framed in a global approach in B and D and in a regionally place-based context in A and C. Personal-cultural dimensions were contextualized as regionally place-based in A and B, locally place-based in C, and combining these two approaches in D. Economy was framed in a locally place-based context in B, C, and D and in a global one in A. It can be argued that this framing followed the approach in the handouts, which was global for ecology, nutrition, and ethics and locally place-based for culture and economy. However, although the pattern is more global for ecology and nutrition, for ethics it is regionally place based in two groups; for culture, the approach combines regionally place based and locally place based, and even in economy, the approach is global in one group. This means that each small group reinterpreted, to some extent, the dimensions, framing them differently.

In argumentation terms, conflict was embedded in the task design. The evidence and essays about values from the three dimensions framed globally in the handouts would provide support for vegetarian options (although in all the handouts there were also pieces of information against it). On the other hand, the evidence from the economy handout and the essays from the cultural dimension, framed in Galicia, would suggest problems for the adoption of vegetarianism. The findings reveal similarities, in particular in the option or argumentative claim, and differences in the process of balancing the local and the global to reach consensus and in the justifications. Being a case study, there are limitations: it is not possible to generalize our findings; however, a number of issues emerging from this work are as follows.

First, in all the small groups (and also in 15 out of 20 written reports), there was an explicit acknowledgment of the existence of *conflict* between different interests, dimensions, or values. It may be noted that this conflict was not explicit in the handouts. We argue that this is a relevant issue, for science classrooms and in particular for teacher education. Some approaches or teaching resources about Education for Sustainable Development (ESD) obscure conflicts, creating images of SSI where all stakeholders would have the same interests; thus, for instance, the financial pressures behind the continuity of fossil fuels are ignored, or the sacrifices involved in using public transport instead of private cars are not highlighted. As Ideland and Malmberg (2015) point out, this approaches would amount to "black-boxing" ideologies behind decisions and policies. We suggest that tasks promoting the identification of conflict have educational value, in particular, for teacher education. In order to prepare teachers for supporting the development of critical thinking in elementary classrooms, it is important, first, to model for them how to embed conflict in instructional design and, second, to engage student teachers in tasks that require them to deal with problems which involve conflicting interests.

Secondly, also in all groups, the multidisciplinary nature of the diets issue, and the need for integrating *conceptual knowledge*, *scientific data*, *and values*, was recognized. This feature of decisions about SSI, which results from the interaction between knowledge and values, has been highlighted by authors as Kolstø (2005). This integration is a goal, for student teachers as well as for their future pupils. It may be noted that this process of integrating evaluation of evidence and reflection about values was not always following an ideal path. Although the student teachers were directed to study the evidence and documents about values and then reach a decision, the findings show that in group A, and to less extent in D, their first moves were aimed to make a quick decision based on negotiating their already existing points of view and latter trying to figure out how to use the information to support their views, rather than to carefully analyze the evidence, as did, for instance, groups B and C. We suggest that this contextualized task, because of its conflicting nature, and the range of information provided, supported participants (at least from two groups) to step back and ponder the different sources of information before making an evidence-based decision.

Third, about the process of dealing with conflict, it seems that the need for resolving it led participants to create new scenarios or options, different from those provided in the handouts; thus, for instance, in the four groups and in half of the written reports, the option chosen was omnivorous with a reduction of meat intake, which we interpret as an attempt to *reconcile* conflicting evidence and values. This option was perceived as striking a balance between the benefits (for environment, for ethics) of vegetarian diets and the cultural and economic weight of meat diets. This is revealed also by labels used in the oral discussions: some students called these diets "partially vegetarian" (in D), "lactovegetarian with occasional meat consumption" (in B), or vegetarian "with fish and eggs," as in an excerpt from A reproduced in the findings. These labels seem to have a function in persuading themselves that they were choosing an environmental-friendly, ethical, and nutritionally adequate option but without calling it carnivorous diet.

Fourth, about how was this omnivorous (with less meat) option, justified in evidence and values, the processes of balancing the global and the local show that more weight was assigned to the *locally framed justifications*. Evidence and ideas from the globally oriented dimensions mostly supported vegetarian options, while evidence and ideas from the locally oriented dimensions suggested difficulties for adopting them. In the four small groups, there was an explicit acknowledgment of the benefits for the environment of a vegetarian diet, and its advantages for health and from an ethics perspective were also acknowledged. However, the problems that it could entail for Galician economy and in particular the weight of cultural traditions seemed to be decisive for choosing the omnivorous option. Participants explicitly acknowledged the influence of culture and the social resistance to vegetarianism. These tensions, and the compromise reached, can also be interpreted as a way to avoid some inferences from the global dimensions, pointing to the benefits of vegetarian diets, by appealing to local economy and cultural tradition.

Fifth, about how participants considered the consequences of their options, as may be the impact of lifestyles on natural resources (Traina and Darley-Hill 1995), their evaluation of cultural dimensions, which involved appealing to personal experiences, suggests that, particularly in group D, they *shifted the responsibility* of choosing a diet onto society and "the market [that] breaks morality." This implicitly disassociates the role of markets from individual consumers, as if consumers were completely powerless and "conditioned" to eat meat. This is a relevant issue, because in ESD it is necessary to assume personal responsibilities and identify ways in which local populations can contribute toward sustainability (Kates and Parris 2003). However, as Jickling and Wals (2008) point out, ESD may leave unchanged consumption patterns.

The question is then why these locally framed dimensions were given priority. We suggest two complementary explanations:

First, *personal concrete experiences* from their local environment were given relevance over knowledge that may be perceived as theoretical and that is difficult to mobilize, such as greenhouse effects or ethical statements. Thus, it may happen, for instance, with anecdotes of family resistance to one relative being vegetarian, which were framed as substantial obstacles. Although the limitations of a case study preclude generalization, we suggest that highly contextualized argumentation tasks may support learning and mobilization of knowledge better than tasks framed globally.

Second, prioritizing globally oriented dimensions, which mostly supported vegetarian options, over the locally oriented dimensions would imply accepting that taking local actions toward vegetarianism would be desirable. This would entail the consideration of putting to practice local changes that would affect the local culture and economy, changes that would be visible and perceived as detrimental. Additionally, many of the potential benefits of this behavior, which are global by nature (e.g., cutting greenhouse gas emissions to address climate change), rely on other agents or places following the same pattern of agency to take effect, and even if that is the case, it would be difficult to see the results of each agent's contribution to the whole. In this decision-making context, the participants' behavior of prioritizing local dimensions can be interpreted in terms of what in game theory and economy is called a rational agent, one that in contexts of uncertainty chooses actions with optimal results for itself, regardless of the optimal solution for all the agents involved. To address this issue, we suggest that raising awareness in educational contexts of the importance of global solidarity might be relevant for promoting a transition toward sustainability.

In a perspective related to critical geographies (Massey 1994), a further issue to be studied would be the *narratives*, images, or even stereotypes that participants hold about their own place, for instance, in this case about their cultural traditions. It would be necessary to evaluate whether these views and images have a correspondence with people's lives, whether they are connected to particular interests, and whether it would be useful to question them. For instance, local economy is not unchangeable, it could be transformed. Contextualized teaching would support student teachers in developing tools for engaging their pupils in applying argumentative reasoning to their real lives, and this could involve questioning the prevailing narratives.

A consideration of potential modification of personal actions and social habits about diet emerged also in the participants' arguments. It needs to be noted that action was not embedded in the task; nevertheless, the small groups addressed it in their arguments. Our findings suggest that contextualized tasks may promote students' agency, acknowledging that they may change their behavior toward the environment, an outcome aligned with the social and democratic goals of science education. As discussed above, in some cases, there was a tendency to attribute to society or local culture the responsibility over less sustainable diets. It needs to be noted that the task was about decision-making and did not imply taking action or changing diet. It is well-known that one thing is to acknowledge that some practices are more sustainable than others, and a different thing is to adopt them.

The educational implications of this study are related to the curricular design and implementation of contextualized argumentation and education for sustainability. By examining the processes involved in the production of locally grounded arguments, our findings could prove useful for designers and practitioners, in the planning of argumentative environments.

These findings raise an issue about the role of place-based education in a Western country and context, as Galicia, in which most students share a high cultural homogeneity. However, this homogeneity does not mean that science education approaches in Spain were contextualized. Far from it, until the end of Franco's dictatorship in 1975, science textbooks would, for instance, discuss sedimentary rocks with the example of oil fields, nonexistent in Spain, instead of coal, which is abundant. SSI was introduced by innovative teachers in the 1980s and in the science curricula in the 1990s. In other words, in cases like ours, the role of place-based education is related less to the identification of underrepresented knowledge and rather to the engagement of student teachers in contextualized problems that are personally meaningful for them. In order to educate teachers (and students) as sustainable literate citizens and, at the same time, being culturally responsible and engaged with the survival of their traditions and local ways of thinking, we suggest the need for designing contextualized tasks supporting the integration of local and global perspectives.

Annex 1. Economy Handout (Excerpts)

1. *The importance of the food sector in the economy of Galicia*

"The food sector […] holds a relevant position in the economy of Galicia […]. For 2010, the food sector accounted for the 9.6% of the total Galician economy, 6.5% of gross value added (GVA) and 120 000 jobs, 10% of total employment. Its weight in the economy is far higher than for Spain or Europe, specifically it is almost the double than for the EU-15" (E. López Iglesias e M. Varela Lafuente, "O sector alimentario en Galicia: Desafíos e oportunidades," Foro Económico de Galicia, 2013, page 3).

The 10% of total employment on the food sector can be broken down into:

Agriculture, livestock, and fisheries	7.3% of the total employment
Food industries	2.6% of the total employment

2. *The importance of livestock and milk production in the agricultural sector*

The main activity in the [galician] agricultural sector is the livestock industry, which accounts for the 66.6% of the whole sector, whereas the vegetal production accounts for the 28.7%. Within the livestock sector, cattle production is the most relevant activity, totaling more than 1 million cows. The main activity of the cattle industry is milk production (2500 million litres for 2012), accounting for the 38% of the total Spanish production, in contrast with the 15.7% beef production in Galicia of the whole Spanish production (Table 2.8).

Table 2.8 Structure of agricultural production in Galicia and Spain in 2008

Agricultural production (in %)	Galicia	Spain
1. Vegetal production	28.7	61.9
2. Animal production	66.6	34.1
2.1 Livestock	33.5	24.2
2.1.1 Beef cattle	15.8	5.3
2.1.2 Other livestock	17.7	19
2.2 Animal products	33	9.8
2.2.1 Milk	30.8	7.2
2.2.2 Eggs	2.1	2.4
2.2.3 Other products	0.1	0.2

Adapted from E. López Iglesias

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Chapter 3
Contextualizing the Ecuadorian National Science Curriculum: Perspectives of Science Teachers in the Galapagos Islands

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1 Introduction

The Galapagos Islands, a province of Ecuador, is a volcanic archipelago of 13 main islands located almost 1000 kilometers off the west coast of South America. In 1978, the Galapagos were declared UNESCO's first World Heritage Site, and in 1985, UNESCO also named the archipelago one of its biosphere reserves due to its endemic wildlife (Oxford et al. 2009). The unique flora and fauna of the Galapagos archipelago and its influence on Charles Darwin's theory of evolution have, over the years, attracted the interest of international and national tourists, scientists, and various private and public environmental conservation agencies (Durham 2008).

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Although the narratives around the Galapagos continue to emphasize its pristine nature and unique flora and fauna, the conservation of the archipelago has been the source of concern to the international community in the past few years (Cairns et al. 2014). In 2007, UNESCO put the Galapagos Islands on the list of World Heritage Sites in Danger mostly due to the negative impacts of the human population growth on the islands' ecosystems (Durham 2008). While the UNESCO removed Galapagos from the list of threatened sites in 2010 as a result of conservation actions taken by the Ecuadorian government (UNESCO 2010), UNESCO emphasized that the long-term sustainability and conservation of the Galapagos requires an education system "that incorporates elements of environmental management and heritage preservation, as well as natural resources conservation development" (UNESCO 2007, p. 10).

Prior literature, however, has not addressed how the education system and how local *Galapagueño* teachers, in particular, have contextualized the education provided in schools to address the unique socio-ecosystem of the Galapagos Islands, especially when in the past decade Ecuador has standardized the science curriculum taught in schools across the country. To shed light onto this topic, in this chapter, we use contextualization of instruction (Rodriguez 2005) to present a study that analyzed the voices of 17 K-12 teachers who taught science in Galapagos at the time of this study. Drawing on qualitative data collected through video/audio recording of focus groups with the teachers, this chapter discusses our participant teachers' perceptions of the challenges and opportunities they faced in contextualizing the Ecuadorian national science curriculum to address issues relevant to their unique context.

We start this chapter by providing an overview of the principles of contextualization in science that guided our theoretical perspectives. Then, we present a brief overview of the Ecuadorian education system and the Galapagos Islands as a socio-ecosystem. Afterward, we describe the methods we used to collect and analyze our data and follow with the discussion of the tension perceived by teachers in their attempts to contextualize the national curricula.

In our final section, we connect these topics with our theoretical approaches of contextualization to recommend ways in which the Ecuadorian education system can support teachers in contextualizing the national curriculum in a way that addresses the particular environmental conservation and social aspects unique to Galapagos. Specifically, in this chapter, we posit that addressing the long-term conservation of Galapagos requires the Ecuadorian education system to empower teachers via processes that provide them with training and resources for teachers to create productive ways to contextualize the national science curriculum to address science concepts in the unique context in which they work and live.

2 Conceptual Framework

In this chapter, we discuss the perceptions of 17 K-12 science teachers in the Galapagos Islands about the tension they perceived in contextualizing the national science curriculum to address issues relevant to the Galapagos. To address this topic, we use a contextualization theoretical lens, in which science instruction must connect the knowledge that is valued in schools to the one valued by the local communities served by those schools (Banks 1993, 2005; Gay 2010).

Contextualized instruction is an instructional approach that offers learning experiences that are relevant to students' contexts (Finkelstein 2005; Giamellaro 2014; Gordon 2014). In practice, contextualized instruction can happen in the classroom, through problem-based learning, or outside the classroom, through field experiences (Ballantyne and Packer 2010; Giamellaro 2014; Nashon and Anderson 2013). Contextualized instruction promotes students' positive attitudes toward science and increases their level of engagement (King and Ritchie 2012).

Because science curricula tend to be content heavy, contextualization offers teachers opportunities to make curricula and challenging science concepts accessible and relevant to students (Gough 2015; Rivet and Krajcik 2008; Rosebery et al. 1992; Warren and Rosebery 1995, 1996). Contextualizing science curricula can include making the curriculum meaningful to students' lives (Giamellaro 2014; Orpwood et al. 2010; Rivet and Krajcik 2008; Schwartz and Lederman 2008), promoting the skills necessary to apply the knowledge gained in science to real-life situations (Pearson et al. 2010; Gordon 2014), or establishing learning routines that foster equitable student participation (Johnson 2006; Paquette and Kaufman 2008). Furthermore, contextualizing the science curriculum could involve embedding real-life examples in science lessons that are meaningful to students' daily lives (Orpwood et al. 2010), real-world questions that connect the content with the doing of science (Krajcik 2015), and integrating knowledge of different disciplines to enrich the discussion of issues related to their students' contexts (Gordon 2014).

Yet, in order to contextualize curriculum, teachers need professional freedom and knowledge on how to adapt the content of their instruction to create meaningful lessons (Giamellaro 2014). Teachers, for instance, must know how to design lessons that ask students to apply scientific knowledge to everyday life situations (Upadhyay 2006) and consider the similarities, differences, and connections between everyday and science practices (Aikenhead 1997, 2001). In addition, contextualizing the curriculum entails that teachers are able to design activities in which students use science to address struggles in their lives or problems in the context in which they live to promote change (Sconiers and Rosiek 2000; Gallard and Antrop-González 2013). In this study, we built on the existing literature around contextualization of science education to explore whether our science teacher participants adopted the national science curriculum as given or have adapted it to the socio-natural conditions of the Galapagos.

To situate our discussion, and before we present the voices of both primary and secondary Galapagos teachers, in the next sections, we present a short overview of the Ecuadorian education context and a brief history of the Galapagos and the current state of its education system.

3 A Brief History of the Ecuadorian Educational Context

The common historical background of Latin America's education characterizes Ecuador's public education system. In particular, during the 1990s and the following decade, the global discourse led by the United Nations agencies (i.e., the *Education for All* program of 1990), accompanied by funding from the World Bank, impacted educational policies in Ecuador and the entire continent. This funding implied a liberal framework that assigned to education the goal of preparing students for a changing workplace by encouraging entrepreneurship and the use of technology (Torres 2002). Although using students' scores in large-scale standardized tests is a controversial measure of educational quality, Ecuador performed poorly in the areas of reading and mathematics in 2006 in UNESCO's *Segundo Estudio Regional Comparativo y Explicativo de la Calidad de la Educación* [Second Comparative and Explanatory Regional Study of Education Quality] (SERCE)—the first international test in which the country participated. In that test, Ecuador ranked at least one standard deviation below the mean in both reading and mathematics (Estarellas and Bramwell 2015).

The poor results on UNESCO's SERCE of 2006 and the emerging discourse around education quality were a wake-up call for the Ecuadorian government and prompted the administration to direct financial resources toward the decentralization of education management. Thus, starting in 2007, the current Ecuadorian government implemented a new series of normative changes to the education system prevalent during the 1990s. In addition, investment in the education sector grew from $1094.6 million dollars in the year 2000 to $2908.4 million dollars in the year 2014 (Estarellas and Bramwell 2015). According to the Ecuadorian think tanks Grupo Faro and Contrato Social por la Educación, the reforms implemented by recent governments have produced improvements in the educational quality of the Ecuadorian education system (Bellettini et al. 2015; Estarellas and Bramwell 2015). For instance, in 2013, the results of Ecuador in UNESCO's *Tercer Estudio Regional Comparativo y Explicativo de la Calidad de la Educación* [Third Comparative and Explanatory Regional Study of Education Quality] (TERCE) showed that Ecuador was one of the countries whose results have improved the most (UNESCO 2014). Even though Ecuador improved in TERCE, the results ranked the country only above the mean in both content areas (Estarellas and Bramwell 2015).

Yet, the standardization of the science curriculum also had another consequence. As the Ecuadorian public education system enforced that all Ecuadorian educators adhered to the national science education curriculum (Bellettini et al. 2015), educators lost some of the freedom they had traditionally and had to modify their lessons to meet the needs of their communities. Therefore, while innovation has been touted in reform documents and educational results seem to have improved, at least according to international standardized tests, little is known in regard to if and how science teachers in Ecuador have contextualized the national curriculum based on their students' needs and local realities (Román et al. 2015).

4 The Galapagos Social and Educational Context

After this short overview of the Ecuadorian education system, it is important to situate our discussion in the history and the condition of education in the Galapagos archipelago to understand its unique natural and social context.

The Galapagos archipelago amounts to a total land area of about 8000 sq. km. Although the Galapagos Islands were (re)discovered by Fray Tomás de Berlanga in 1535, they owe their worldwide reputation as a laboratory of evolution to an event that occurred 300 years later: Charles Darwin's visit of scientific exploration on board the HMS *Beagle*. Darwin's visit to Galapagos has had a powerful scientific and social impact that has even been described as "instrumental in forever changing the world view of life on earth, while making the small islands of Galapagos famous" (Darwin 2009, p. 16).

The history of the Galapagos as part of Ecuador starts in 1832 when the Ecuadorian state felt the need to officially integrate the archipelago into its national territory for ideological and political reasons (Grenier 2007). At the time of annexation, however, the Galapagos Islands were far from being considered important. In fact, the Ecuadorian government and society perceived the islands as worthless, cursed, and not suitable for farming due to their lack of fertile soil and fresh water (Tapia et al. 2009). Today, the islands constitute their own province subdivided into three cantons that correspond to the three most populated islands: Santa Cruz, San Cristobal, and Isabela.

The Galapagos province is governed by the Special Law for Galapagos (*Ley Orgánica para el Régimen Especial de Galápagos* [LOREG]) that has been part of the Ecuadorian Constitution since 1998. The Special Law regulates a variety of aspects related to urban planning, tourism, agriculture, quarantine policies, and waste management. One of the most important and controversial aspects regulated by the LOREG is human migration to Galapagos. Although the population of the islands grew slowly until the 1980s, the rate of population growth has increased significantly in the last three decades (Ramos 2015). According to the last official census, between 25,000 and 27,000 people currently inhabit four of the islands: 7500 in San Cristobal (30%), 15,250 (61%) in Santa Cruz, 2250 (9%) in Isabela, and 100 in Floreana (*Instituto Nacional de Estadísticas y Censos* [INEC], 2010). The areas designated for human settlement and agriculture comprise 3% of the total land area of the archipelago—the remaining 97% is a protected area—after the Ecuadorian government established the Galapagos National Park in 1959.

Given its worldwide reputation as a natural destination, tourism is the biggest employment sector in Galapagos and has contributed to the islands economic growth (Cairns et al. 2014). Epler (2007) estimates that 78% of employment in Galapagos is directly or indirectly connected to tourism, and Taylor et al. (2009) point out that between 65% and 71% of the total income in Galapagos is related to this industry. Although the rapid growth in the number of tourists has been contained to specific sites monitored successfully by the Galapagos National Park (Durham 2008; Martin et al. 2015), the increasing number of tourists and the economic growth in the islands has augmented the number of immigrants to the archipelago to provide services for tourists.

It is worth mentioning that in 2014 the Ministry of the Environment approved a new *Plan de Manejo de las Areas Protegidas de Galápagos para el Buen Vivir* [Management Plan of the Protected Areas of Galapagos for Good Living]. This new plan recognizes that Galapagos is a socio-ecosystem that requires for its conservation the integrated management of its protected as well as its urban areas (Calvopiña et al. 2015). In addition, this plan incorporates the concept of *Sumak Kawsay* (*buen vivir* or living in balance with nature in the Quechua language), which constitutes a fundamental component of the agenda of the political party currently in power in Ecuador. The incorporation of the human element in the management plan of Galapagos recognizes that the archipelago has been continuously inhabited since the mid-nineteenth century (Tapia et al. 2009) and identifies education as one of the mechanisms that need to be addressed for the conservation of the islands (Calvopiña et al. 2015).

The Ecuadorian Ministry of Education based in Quito, the capital of the country, regulates education programs in the Galapagos. The Special Law of Galapagos of 1998, however, gave the schools in the province greater local control than the ones in the mainland. The Special Law, for instance, allowed schools to use curriculum that addresses the needs of Galapagos and incorporated elements of environmental protection. The creation of the Special Law of Galapagos is a clear example of the tension that exists between Ecuadorian educational policies that seek to standardize curriculum and procedures, while creating a "special law" for the Galapagos province—the Special Law, for instance, provided teachers with higher salaries than their peers on the continent, given the higher cost of living in the Galapagos than in the Ecuadorian mainland.

The main regional office of the Ministry of Education is located in the capital of the province, Puerto Baquerizo Moreno, in San Cristobal. Yet, professional development for teachers in Galapagos is planned at the Ministry's central offices in Quito, the capital of Ecuador, and is delivered by Ministry's personnel from the mainland. Schools in the Galapagos follow the calendar of the coastal communities in Ecuador, in which classes go from May to February to respond to regional weather factors (e.g., amount of precipitation). The presence of local education offices to oversee Galapagos schools and the availability of a school calendar that responds to the climatic conditions of the area are another examples of the forces that, on the one

Table 3.1 Number of schools and approximate number of students and teachers in PK-12 schools in Galapagos

Location (island)	Number of schools	Number of students	Number of teachers
Santa Cruz	11	4585	184
San Cristobal	7	2186	86
Isabela	4	715	31
Floreana	1	28	3
Total	23	7486	304

Source: Ecuadorian Ministry of Education, 2014

hand, want to centralize educational initiatives (e.g., planning of professional development) and, on the other, contextualize some of its policies to the needs of the region.

The number of PK-12 schools, students, and teachers in Galapagos is small (Table 3.1). Schools are distributed in the four inhabited islands of Santa Cruz, San Cristobal, Isabela, and Floreana. In terms of higher education, only extension programs of four Ecuadorian universities serve Galapagos, and 10% of Galapagos youth attends distance (i.e., online) courses for their postsecondary education despite the unreliable Internet connection (Villacis and Carrillo 2013).

Of the approximately 304 teachers in Galapagos, almost 40% (i.e., 120 teachers) teach elementary school and the remaining 60% (184 teachers) teach secondary school. Yet, teachers' teaching assignments are in constant flux, and teachers could work in an elementary school and also teach at the secondary level. Secondary school in Ecuador is subdivided into *básica* (equivalent to middle school) and *bachillerato* (equivalent to high school in the United States). According to Ecuadorian education law, elementary teachers received their teacher certifications by majoring in education in college while secondary teachers need to have a degree in their field of expertise (e.g., science teachers could have a degree in biology, physics, or chemistry), but not necessarily a degree in education (Knab 2016). In terms of results in national standardized tests, *Galapagueño* students have historically had poor results in the national evaluations of academic achievement (Knab 2016).

The brief overview of the Galapagos history, its education system, and the Ecuadorian education context in which it is embedded reflect the complex characteristics of the Galapagos Islands not only as a natural environment but also as a unique social environment. In this socio-ecosystem, there is a constant tension between policy national-level initiatives mandated from the mainland and the perceptions of *Galapagueños* as to whether those policies respond to the needs of the archipelago (Cairns et al. 2014). It is in this unique natural and social setting in which science teachers must use the national curriculum in their practices. In the next sections, we present a study that investigated whether science teachers have contextualized the national science curriculum to address the complex social issues in the Galapagos.

5 Methods

As we have discussed thus far, our study explored whether our participant teachers have contextualized the national science curriculum to address the reality of the Galapagos Islands. In this section, we describe the study participants, our data sources, and the type of analysis we conducted to explore this topic.

5.1 Focus Group Participants

To gather the voices of the local teachers, this study included a group of 17 science teachers who participated in two focus group sessions. At the time of the study, participant teachers taught science-related courses in different grade levels including natural sciences (i.e., *ciencias naturales*) in elementary schools and biology, physics, or chemistry courses in middle school and high school classrooms. Seven teachers taught secondary school science and ten taught science in elementary schools. Teacher participants were recruited with the support of the local school principals. After receiving authorization from the Ecuadorian Ministry of Education, two of the authors of this chapter met with principals of schools of the two most populated islands in the Galapagos (i.e., Santa Cruz and San Cristobal) and asked them to refer teachers who were leaders in their schools to participate in the focus groups. In the end, there were 7 teachers in one focus group and 10 in the other. Both focus groups consisted of a mix of elementary and secondary teachers to capture their opinions and promote discussion.

Due to logistic limitations, only teachers from schools located in the two most populated islands (i.e., Santa Cruz and San Cristobal) were able to attend the focus group sessions. In total, these teachers represented 14 of the 23 schools in the Galapagos. All the conversations and focus groups were conducted in Spanish and were video and audio recorded to link quotes with speakers. Table 3.2 describes our participant teachers' pseudonyms, genders, the grade levels they taught, and their years of teaching experience at the time of the study.

5.2 Focus Group Purpose/Content

The focus groups described in this study are part of a larger research project that encompassed topics related to all the content areas (i.e., mathematics, social studies, English as a foreign language) and include classroom observations and parent interviews. The main purpose of the focus groups was to understand the context in which Galapagos teachers worked, their perceptions about their context and practice, and whether they adapted their curriculum to this context. To this end, the focus groups asked teachers a set of open-ended questions that addressed the following topics:

Table 3.2 Grade level/subject area taught and years of experience of participating teachers

Teacher	Gender	Grade level/subject area	Years of experience
Fatima	Female	Fourth	10
Ricardo	Male	Third	2
Juan	Male	Second	1
Concepcion	Female	Fifth	1
Cristina	Female	First	4
Esmeralda	Female	Fourth	2
Liliana	Female	Third	1
Nohemi	Female	First	12
Omar	Male	Fifth	9
Erica	Female	Second	2
Pablo	Male	Secondary biology	3
Alejandra	Female	Secondary biology/chemistry	2
Pedro	Male	Secondary chemistry	5
Arturo	Male	Secondary physics	8
Patricio	Male	Secondary physics	3
Luisa	Female	Secondary biology	9
Betty	Female	Secondary biology/chemistry	3

teaching as a profession; teaching in the Galapagos Islands; teachers' preparation; teachers' classroom resources; the science curriculum; and teachers' relationships with education authorities, other teachers, and parents (Appendix A). All participant teachers were informed of the study and signed consent forms.

5.3 Analysis

The focus group sessions were audio and video recorded, transcribed, translated, and coded using NVivo®. Videos were mostly used to identify the teacher who initiated the discussion of a topic and connect specific quotes with particular teachers. All the transcriptions were read and reread several times between two coders (who are two of the authors of this chapter) arriving to an 80% interrater coder agreement. We used constant comparative analysis and an inductive approach to coding. First, we created a set of open codes (Glaser and Strauss 1967) to capture the main trends mentioned by teachers during the focus groups. Next, we generated conceptual categories aligned with the open codes, in keeping with the literature regarding teaching science and contextualization. As can be seen in Table 3.3, the conceptual categories in which we focused for this study were Galapagos uniqueness and the ways in which this uniqueness is addressed in education and the environmental conservation of Galapagos and education. Table 3.3 also includes the codes that were identified in these categories.

Table 3.3 Categories and codes for teaching science in the Galapagos

Conceptual categories	Codes	Description	Examples of quotes
Galapagos uniqueness and education	Galapagos-based curriculum	Instances in which participants talked about education in Galapagos, the availability of educational resources and training, the reality of their communities (Cairns et al. 2014; Taylor et al. 2009), and the national curriculum (Calvopiña et al. 2015)	"The textbooks come from the continent … We should have local materials, too" (Betty, high school biology teacher)
	National curriculum		
	Educational resources (lab materials, textbooks)		
	Teacher preparation and professional development opportunities		"Students sooner or later have to go to the outside world and have to know general stuff …prepare students for what is global" (Pablo, high school biology teacher)
Environmental conservation of Galapagos and education	School discussions/ lessons around the Galapagos as a protected area	Instances in which teachers expressed ideas about conservation (Ardoin and Ryan 2011; Busch and Osborne 2013), tourism (Ardoin 2014), the environmental uniqueness of the islands (Oxford et al. 2009), and its affordances for science instruction	"The fact that we live in a place with special characteristics puts teachers as protagonists in the conservation effort" (Luisa, high school biology teacher)
	Language of conservation in schools		
	Living laboratory for students		"Here, we speak 'the conservation language' because we live in the Galapagos" (Nohemi, first grade teacher)

5.4 Galapagos' Uniqueness and Education

Out of the 10 elementary teachers and 7 high school science teachers who participated in the focus groups, 12 of them (six elementary and six secondary teachers) discussed issues related to the science curriculum and how it could be contextualized to address the characteristics of the Galapagos. Their comments reflected the feeling that for them the Galapagos is a unique place and that this natural environment should shape the science curriculum. Specifically, all of the 12 teachers who mentioned curriculum expressed that the topics taught in science classes should reflect Galapagos' natural uniqueness in relation to its flora and fauna. Fatima, a fourth grade elementary teacher, indicated that she viewed her role as: "Helping students understand what we have here, our unique animals and also plants."

Furthermore, those 12 science teachers pointed out that the Galapagos' unique natural surroundings and specific conservation issues warrant the inclusion of a strong regional focus into the national science curriculum. Yet, six of the secondary teachers and three elementary teachers reported a tension with this regional focus because they believed that one of the main purposes of education is to prepare students for university-level education. Because postsecondary education is not available in Galapagos, students need to migrate to continental Ecuador to further their education once they obtain a high school diploma. For this reason, these nine teachers thought that a regional science curriculum would hinder their students' possibilities for success. As Pablo, a secondary biology teacher, mentioned:

> Students sooner or later have to go to the outside world and have to know general stuff. Even though we know that in Galapagos everything has to do with conservation. But Galapagos has to prepare students for what is global.

When asked if it is possible to do both, that is, cover the topics in the national curriculum and address the characteristics of the Galapagos region, only four elementary teachers mentioned that the national curriculum is flexible enough to some forms of local adjustment. Yet, the 12 teachers agreed that the breadth of content in the national curriculum is too wide to cover within each school year, and therefore, they do not attempt to make many adaptations. Although 10 of the 12 teachers indicated that textbooks used as part of the national science curriculum do discuss some Galapagos-related issues, they indicated that these textbooks are designed to support a national-centered approach and local materials could be used to discuss local issues. Yet, their biggest concern was that they did not have enough time in their lessons to cover local issues when there were so many topics they were required to cover as part of the national curriculum. In the words of Betty, a high school teacher who teaches biology and chemistry:

> The textbooks come from the continent. We should have local materials, too. We have some resources produced by local organizations, but it is already hard to cover all the topics in the textbooks that I rarely used other materials in my classroom.

In addition, 8 teachers (2 elementary and 6 high school teachers) of the 12 teachers who discussed curriculum expressed that the difficulty of reconciling local and contextualized knowledge is limited by the restricted number of out-of-school visits due to schools' accountability measures (e.g., number of hours of instruction that need to be met). Alejandra, a high school biology and chemistry teacher, summarized this point in this way:

> The science period is so short! How can I take students out for a field trip and be back on time for the next period? Also, I would need to ask for permission to the principal and she may ask me when I am going to cover all the science concepts I need to cover according to the curriculum.

Although all of the 17 teachers pointed out the importance of practical activities inside and outside the classroom for students to really learn science utilizing their natural surroundings, they immediately mentioned several limitations that prevent them for including these types of activities in their lessons. Among the limitations they all reported were the lack of lab equipment and school supplies needed to conduct in-depth scientific explorations. As Pedro, a high school chemistry teacher, indicated:

> We do have a science lab, but we don't have enough working microscopes, test tubes, and other supplies and equipment. I guess I could take the kids outside to experience nature more often, but I would also love for them to continue doing investigations in the laboratory.

All 17 teachers mentioned that the geographical isolation of the Galapagos from the continent has always been an issue for not only in receiving the educational materials (e.g., textbooks, notebooks, workbooks, lab materials) but also in terms of receiving adequate training on how to implement the mandates from the central government. In relation to curriculum, the 12 teachers who mentioned this topic indicated that, given the costs for the Ministry of Education to send trainers and coaches to the Galapagos from the continent, the training they received about how to implement the new curriculum was very limited. According Liliana, a third grade teacher:

> I have colleagues who teach in the continent and they get much more training than we do here. Sometimes we don't get any training at all because it is very expensive to send coaches and trainers from the cities in the continent. When we were asked to implement the new curriculum, the trainers from the Ministry came only for a couple of days, but then they left and we don't have local coaches that can help us when we have questions.

As regards to the topics that should be covered in a Galapagos-based curriculum, the 12 teachers mentioned the need for students to understand that by living in the islands, they are, in their words, in "direct contact with nature" (Luisa, high school biology teacher), "here we all live in paradise" (Juan, second grade teacher), and it is "a special place" (Liliana, third grade teacher). Although 12 teachers acknowledged that the national science curriculum has topics (e.g., soil, biodiversity, landforms, climate, maritime ecosystems, forests) which are easily illustrated by visits to different parts of the Galapagos Islands, these teachers lamented that, as discussed earlier, they do not feel they had enough time and resources to take advantage of such opportunities as much as they would like.

All the 17 teachers who participated in the focus groups recognized the importance of protecting the Galapagos so future generations could also enjoy this unique natural environment. Among the 12 teachers who mentioned curriculum as an important aspect of teaching in the Galapagos, they reported that the curriculum should address ways to develop their students' conservation consciousness and to safeguard their students' general well-being. As Omar, a fifth grade teacher, puts it, "Teaching in Galapagos provides the opportunity to teach our youth the importance of our environment … and guide them to care for it, protect and conserve it." In this sense, teachers view themselves as "protagonists" of conservation efforts for future generations. According to Luisa, a high school biology teacher:

> The fact that we live in a place with special characteristics as the Galapagos put teachers as protagonists in the conservation effort. We can teach children to value the importance of our environment, of our ecosystem. Therefore, we have to use materials that guide them on how to do this, so they are able to look after it, how to protect it, and in this way to be able to

> keep the conservation efforts. Doing this is a reward in itself [for teachers] because we are the protagonists in protecting this paradise.

In addition, the 12 teachers, who discussed curriculum, indicated that, due to living in a national park and a protected area, the science curriculum that should be taught in the Galapagos has to use the “conservation language.” As Nohemi, a first grade teacher, puts it, “Here we speak ‘the conservation language’ because we live in the Galapagos.”

Finally, only Luisa, a high school biology teacher, mentioned a tension she perceived not about contextualizing the national curriculum necessarily, but about the lack of discussion of the social aspects that also influence living in the Galapagos. When asked to elaborate, she indicated that:

> We need to protect Galapagos because it is our home. People think that the Galapagos Islands are worth protecting because they are a paradise, but for us more than anything, they are our home. We need to protect the Galapagos because we live here and we need to protect them for our children.

6 Discussion and Recommendations

In this chapter, we discussed the challenges and opportunities that Galapagos teachers perceived in contextualizing the Ecuadorian national science curriculum to address the unique characteristics of the region in which they live and work. First of all, it is important to highlight that all 17 science teachers who participated in the focus groups mentioned that environmental conservation was central to teaching and living in the Galapagos and that science education in schools there should address the environmental conservation of the archipelago in depth. Second, although the topic of curriculum was not the only one mentioned during the focus group sessions, 12 of the 17 participant teachers indicated that the curriculum used in schools should address the unique characteristics of the Galapagos—making the topic of curriculum the most frequently mentioned among all the topics. The way in which curriculum was discussed by these 12 teachers, however, reflected some tension teachers perceived between using and adapting the Ecuadorian national science curriculum to reflect issues important to the Galapagos archipelago.

As we described in the first section, during the last decade, Ecuadorian teachers have dealt with a number of important normative modifications (e.g., school and teacher evaluation measures, longer teaching days) intended to improve the quality of education in the country (Bellettini et al. 2015). One of those modifications was a reform to the national science curriculum as well as producing new textbooks to accompany it (Estarellas and Bramwell 2015). Yet, given the Galapagos isolation from the continent and the unique natural characteristics of this region, 12 participant teachers reported challenges in contextualizing the national curriculum. The challenges these teachers reported were related to training, availability of educational resources, national-level textbooks that do not address the particular issues affecting the region, time to cover regional topics and the science topics covered in the national curriculum, and ways to integrate their natural surroundings into their teaching of science.

When referring to the curriculum, our participant teachers did mention that the national science curriculum discusses topics related to the Galapagos as well as concepts that could be addressed using the natural context of the islands (e.g., soil, biomes). However, educators expressed a tension around the time needed to cover in their lessons the breath of topics included in the national science curriculum *and* discuss topics relevant to the Galapagos. Teachers also reported this tension as, on the one hand, needing to prepare students for postsecondary education outside the archipelago where students will have to go if they want to attend college and, on the other hand, spending instructional time in addressing science issues relevant to the local region.

However, addressing fundamental science concepts and regional issues does not have to be an either-or situation. In fact, science instruction should include a broad range of tasks designed to meet the students' learning needs and their future science learning. According to Sánchez-Tapia and colleagues (2018), students have the right to an education aligned with their local culture, the context beyond their own realities, and diverse opportunities for science learning. By making connections of the science lessons with other realities, teachers can focus on the opportunities provided by a contextualized curriculum to pursue questions and seek answers at the local level while addressing key scientific ideas in this process.

Because science curricula and standardized testing can limit opportunities to offer lessons that value local knowledge and diverse ways of knowing science communities (Rosebery et al. 1992; Warren and Rosebery 1995, 1996), the particular natural and social realities of the Galapagos due to their isolation make contextualizing the national science curriculum a necessity. Yet, there is much work to be done in Ecuador at the teacher training, research, policy, and practice level in identifying the essential scientific knowledge and skills students need to construct and at the same time give teachers the freedom they need to adjust them to their distinct instructional contexts.

Identifying where, when, and how teachers can contextualize the national curriculum would, first of all, require professional development that targets the specific needs of the educators in the islands. Our participant teachers, however, reported not having enough training due to the isolation of the Galapagos and the costs of sending teacher educators there from the mainland. Nevertheless, if *Galapagueño* teachers are to create lessons that address local issues *and* apply scientific concepts and practices (Upadhyay 2006), the Ecuadorian government would need to invest more resources in targeted teacher training (Aikenhead 1997, 2001). Focusing on the contextualization of the national curriculum, the type of training needed would guide teachers on how to create lessons that a) cover science concepts, b) ask students to apply scientific knowledge to everyday life situations, and c) respond to their local reality (Giamellaro 2014; Upadhyay 2006).

Providing teachers with training will not be enough, however. Training must be connected to providing *Galapagueño* teachers with adequate educational resources (e.g., lab materials, workbooks, textbooks) that teachers can receive on time—lack of resources and long delays in receiving them was an issue our participant teachers reported as a challenging aspect of teaching in the Galapagos due to the distance of the islands to the mainland. Furthermore, the central government must develop educational guidelines that allow the freedom to teachers to contextualize the science curriculum according to the issues that are relevant to the Galapagos. Those guidelines must allow teachers to identify areas in the existing national curriculum that not only could be modified, expanded, or adapted but that can also be challenged based on their own knowledge and experiences (Rodriguez 2015) of living and teaching in the Galapagos. Because it has been noted that conservation strategies often "ignore the needs and the perceptions of the local inhabitants" (Celata and Sanna 2012, p. 979), an effective contextualized approach to teaching and modifying the science curriculum in the Galapagos must involve local science teachers in the contextualization process. As mentioned earlier, the creation of policy that has a local focus has a precedent in the Galapagos as reflected in the Special Law developed by the central government to address the particular needs of the region.

Lessons that use a contextualized approach to the national curriculum to the Galapagos, for example, could discuss the natural and social aspects associated with the tourism industry in the Galapagos Islands from scientific, economic, and cultural perspectives relevant to particular realities of its inhabitants. Teachers can ask their students, for instance, to conduct observation on various touristic sites and collect data that analyzes the impact that people have on the environment. Then, teachers can facilitate classroom discussions to identify problems, opportunities, and potential solutions that are appropriate to the Galapagos as a social and environmental setting. By addressing topics such as the impact of tourism, the contextualized Galapagos curriculum could break the cycle of colonial histories that have traditionally shaped approaches to teaching and learning, bring the local culture into the science classroom, and honor the many ways of scientific reasoning (Bangs 2016).

In addition, using a contextualization of the science curriculum lens, science teachers can present science to their students as a problem-solving tool and a powerful resource to promote local change (Sconiers and Rosiek 2000; Gallard and Antrop-González 2013). In discussing the impact of tourism from scientific and social perspectives, for example, science teachers could embed participation practices that promote not only students' academic performance but also identity development (Brown 2004, 2006; Furman and Calabrese Barton 2006). Furthermore, as posited by Delen et al. in one of the chapters of this book, when teachers make science lessons culturally relevant to the students, teachers increase students' motivation and empower them as active learners.

Finally, it is important to indicate that all our participant teachers agreed that the Galapagos must be protected for future generations, and they as educators have a responsibility in addressing conservation topics in their lessons. Yet, when science teachers were asked about the types of environmental conservation topics that should be addressed, they mentioned environmental threats and conservation strategies only in general terms within a discourse of shared responsibility for the future of the islands and the planet. The lack of specific mention of conservation strategies that could be embedded in science teaching reflects the results found in other studies (Ardoin and Ryan 2011; Busch and Osborne 2013) that have found that conservation, when mentioned, is presented in abstract terms rather than in concrete actionable items. Much more work, however, needs to be done in the area of working with science teachers around the best ways to develop their own knowledge about effective conservation strategies and ways to include the discussion of conservation issues in the teaching of science.

As part of our larger project, we are integrating elements of teachers and students' interests, needs, and dreams to study ways to learn from and work with science teachers in the Galapagos. Our greater project seeks to tap into the identity of teachers and students in the unique Galapagos setting while developing with them critical conservationist discourses that connect their science learning within their environment and their communities. Finally, we advocate for more science and interdisciplinary educational research to be done in the Galapagos to enlighten how the discussions around science education, conservation, and social issues are instantiated in schools in the archipelago. Echoing the UNESCO's (2015) recommendation, we are convinced that only when issues around education become central, meaningful and sustainable conservation efforts will take place in the Galapagos Islands.

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Chapter 4
Learning Science as Border Crossing: Experiences of Nahua Secondary School Students

Ingrid Sánchez Tapia

1 Introduction

This chapter analyzes the experiences of Mexican Nahua grade 7 students when border crossing between traditional indigenous knowledge (TIK) and Western science knowledge (WSK),[1] supported by a contextualized curriculum on inheritance and natural selection. Nahua indigenous communities in Mexico consider education fundamental for improving their quality of life. Science education in public schools, however, has historically undermined their worldviews, creating tension between their culture and school science and threatening their existence as a group (Gómez-Lara 2008). Learning environments that push students to give up their cultural identity actually impede science learning and, ultimately, scientific literacy (Agbo 2004; Cajete 1994; Castagno and Brayboy 2008; Pewewardy 2003; McKinley 2007). One approach to addressing this issue is using contextualized science curricular materials designed to be relevant for students whose culture is not the dominant Western culture. This paper explores the experiences of Nahua science students engaged in

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)

[1] TIK always depends on a specific context and particular local conditions, and it values observation and oral tradition (Mazzocchi 2006). WSK, in contrast, refers to a particular way of creating knowledge rooted in European traditions and philosophy (e.g., logical empiricism). Western science favors analytical and reductionist methods. It isolates its objects of study from their context, aiming to create simplified experimental settings where variables can be controlled. Because science is a subculture of Western (Euro-American) culture, the worldview of science is often Eurocentric (Aikenhead 2001). TIK and WSK have differences as well as commonalities, and they can certainly be complementary.

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a border crossing approach to facilitate the learning of challenging WSK concepts while simultaneously becoming more culturally competent in their own culture and traditions.

2 Education for Indigenous Children and Adolescents in Mexico

Indigenous peoples in Mexico make up 21.5% of the total population, close to 25 million people (INEGI 2015). Indigenous peoples experience profound inequality, with limited access to often poor-quality services, including health services and education. The Nahuas are the largest indigenous group in Mexico, constituting 23.4% of the total indigenous population (INEGI 2015). Because there is no education data disaggregated by indigenous group, no information exists about the specific situation of Nahua adolescents, but we know that indigenous adolescent school attrition, starting in middle school, is 10% higher than the rest of the Mexican population, and overage school attendance reaches 17% among indigenous adolescents in rural communities (UNICEF 2016). Furthermore, the most recent national learning assessment shows that while 14.4% of grade 6 general public school students reach satisfactory and outstanding levels of performance in language, only 4% of grade 6 indigenous school students reach these levels. A similar gap occurs for grade 6 students in math, with 18.3% of general school students reaching the highest levels of performance and only 7% of indigenous school students reaching these levels of competency (INEE 2018).

Two recent education reforms in Mexico specifically address access to education for indigenous children and adolescents. The curricular reform of 2006 included an intercultural approach to reflect Mexico's cultural, ethnic, and linguistic diversity and a goal to protect the right of indigenous children to learn in their mother tongue up to grade 6, which marks the end of primary education in Mexico. An additional subject was added in indigenous schools, once per week for 50 min, titled Indigenous Culture and Language, but the materials, provided by the government, did not include teacher guidance to connect the history and culture of indigenous peoples with other subjects, including science. These efforts did not necessarily translate into a more culturally relevant approach to teaching and learning across subjects (Aguirre et al. 2013).

The more recent 2015 education reform built on lessons learned from the 2006 reform and proposed pedagogies and teaching practices to lead to valuing diverse TIK and to create linkages between the study of the mother tongue, indigenous ways of knowing, and the subject areas included in the national curricula (DGEI 2015[2]). As in 2006, these guidelines are mostly applied during primary education; indigenous adolescents continue to have limited opportunities to learn in culturally relevant ways in secondary schools, especially in subjects such as science.

[2] http://dgei.basica.sep.gob.mx/files/fondo-editorial/marcos-curriculares/mc_primaria_00001.pdf

Mexican Nahua indigenous communities consider education a fundamental right. They believe it is important for social cohesion, an improved quality of life, and access to wider political and civic participation in decision-making processes that lead to improved quality services (health, education, social protection) for all Nahuas (Gómez-Lara 2008; Sánchez Tapia et al. 2018). Nahua communities embrace Western education but feel that education should be enriched by their culture's values and tradition rather than be disconnected from them.

3 Theoretical Framework

Border crossing is defined as the movement from an interpretative frame rooted in one culture to a different frame rooted in another culture that occurs in response to cues in the social environment (Aikenhead 2001; Hong et al. 2000). Because this definition embraces the hybridity and overlapping that can exist between different epistemologies or arise when individuals fluidly navigate cultures, criticisms of border crossing driving a wedge between indigenous cultures and WSK and "othering" TIK (Carter 2004) do not apply. In this study, border crossing was used in a contextualized biology curricular unit designed to ensure that learning WSK would not silence students or prompt them to abandon their critical voices and lived realities (Kinloch 2012). The approach encouraged students to use their TIK and lived experiences within the science classroom as valuable tools for learning. They were encouraged to question the devaluation of Nahua knowledge by the Mexican educational system, due in part to the higher status and exclusive validity conferred on WSK. Here, however, WSK was portrayed as one way of knowing; it does not require students to give up their identities, and it has the potential to facilitate and motivate learning (Bang and Medin 2010). By referring explicitly to WSK as one way of knowing, we avoid hierarchical categorizations that delegitimize other ways of knowing, such as Nahua TIK.

4 Context of the Study

This study was conducted in a small Nahua town located in the highlands of Veracruz, Mexico, in the town's only secondary school, a middle school. Most adults in the village are bilingual in Nahuatl and Spanish, but not all children are proficient in Nahuatl, especially if they attend an all-Spanish public school. The people lead lives that rely on the use of natural resources for subsistence. Many grow corn and use small plots of land adjacent to living spaces to grow vegetables and raise chickens. The village, where women commonly wear traditional attire, is about 50 min via public transportation from an intermediate city, where it is less common to see women traditionally dressed. Adults may travel to nearby towns and cities to sell agricultural products or to access medical or social services, but the cost of public transportation often prevents children and adolescents from doing so.

Most of the adolescents who participated in the study previously attended community primary schools. Community primary schools are usually located in indigenous communities where an indigenous language is still spoken. They are fully bilingual, using both the indigenous language and Spanish for all subjects, and often have high levels of community participation. In contrast, in the lower secondary[3] school where this study took place, instruction is exclusively in Spanish with elements of English language being introduced. Because it is the only lower secondary school serving a large territory of rural communities, some students who previously attended community primary schools in their villages now travel up to 2 h by bus to attend school. This represents a drastic change for many students in terms of language of instruction and learning context. Students face the challenge of learning increasingly complex content across all subjects but perhaps especially in science and technology.

5 Methods

An ethnographic approach was used to understand the different subjective experiences of Nahua students when learning science as border crossing. A contextualized unit on inheritance and natural selection was taught during 12 weeks in two grade 7 classrooms in a Nahua school (Sánchez Tapia et al. 2018). All collected data was integrated chronologically using the software NVivo 10.

5.1 Data Sources

The school serves primarily indigenous adolescents, and at the time of the study, there were two designated grade 7 biology teachers and three grade 7 classes, with an average of 23 students per classroom. Only one of the two teachers volunteered to participate in the study, so data comes from the delivery of the contextualized biology unit in two classrooms (n = 42 students). A biology teacher who is a member of the community taught one class, while the author taught the other. The two teachers planned the lessons together and observed each other's classes. This did not represent a change or disruption for the students; grade 7 is the first grade of secondary school in Mexico, and students met the two science teachers on their first day of lower secondary school.

To better understand how the contextualized unit supported students in learning science concepts as well as their ability to border cross between the two cultures

[3] Lower secondary school is referred to junior high school or middle school in some countries.

(Nahua and WSK), data was collected during the delivery of the unit from the following sources:

- Running records derived from ethnographic observations of all the classes taught by Teacher 1 and produced by Teacher 2
- Field notes, reflections, and memos written by Teacher 2 after class
- Semi-structured individual interviews with 25 students in week 5 (midpoint interviews)
- Semi-structured individual interviews with 27 students in week 12 upon completion of the unit about their experience learning science through the contextualized biology unit
- Student notebooks (n = 24); 24 students of various levels of proficiency and engagement volunteered to submit notebooks

5.2 *Ethnographic Analysis of Running Records/Field Notes, Student Interviews, and Student Notebooks*

The goal of the data corpus analysis is to understand both the different subjective experiences that indigenous students may have had when learning school science and the instructional practices and curriculum-contextualizing features that ease indigenous students' border crossing when learning science.

5.2.1 Running Records and Field Notes from Classroom Observations During the Enactment of the Biology Unit

The initial conceptual model of border crossing (Table 4.1) guided the ethnographic observation of two grade 7 classrooms. Observations focused on student experiences of border crossing between their TIK and WSK when learning about natural selection. Daily in-class observation for 12 weeks made it possible to document the impact of the contextualization principles included in the unit (Sánchez Tapia et al. 2018) on the student border crossing when learning science. All classes taught by Teacher 1 were observed by Teacher 2 (the author), who produced handwritten running records of dialogues and interactions that occurred in the classroom with a focus on the border crossing experience. The researcher minimized distraction by sitting in the back of the classroom. Students were aware that the teachers were a team and were conducting a study; they understood the nature of the note-taking and were comfortable when approached during group or paired discussion in the process of taking notes. Because my role as teacher did not allow me to produce running records of my own classes, I wrote reflective notes and memos about events following my class.

Table 4.1 Initial conceptual model that oriented the design of contextualization features for the science unit and the selection of data to be analyzed within the complete data corpus

Category definition/example
Category 1: Including explicit comparisons between Nahua culture and Western science as a mechanism for border crossing
This category refers to Western science content or practices that, when learned, favor discussion or reflection about the differences between Western science and Nahua culture, making it possible for students in this traditional setting (i.e., an indigenous school) to have easier access to science through overt comparisons of their worldview with that of Western science. Boundary crossing is defined here as transition and interaction between indigenous cultural explanations of natural phenomena and the ones offered by Western science.
Rationale for this example: The dialogue below is an overt, teacher-moderated discussion concerning how what a healer told them is like or different from a reading about athletic performance included in the biology unit. Because healing is a central theme in the Nahua culture and is present in the day-to-day life of every member of the Nahua community, children and youth learn that healing is a gift that runs in some families (that it is inherited). This explanation contrasts with the explanation of Western science that some skills and behaviors are learned and are not coded in our DNA. When a Nahua student learns genetics at school, she may conclude that the ability to heal others is in our genes, thus confounding both Western scientific and Nahua explanations. Unless students can explicitly discuss both explanations and understand the rationale behind each one as well as the contexts and moments that are appropriate for each (border crossing), the learning of science may lead to misconceptions. By conducting this overt comparison between healing and athletic performance, the teacher is facilitating student border crossing between their culture and that of Western science.
Example of field notes on lesson 1: Visit of a healer to the classroom Student 1: Is healing learned or inherited? Healer: Well, both, I think both, it is inherited. Student 2: How do you do it, how do you heal? Healer: Well, to heal from frightening, I prepare the tea first, or I dip the frightening herb in alcohol and after boiling it, with the vapor I rub it in the body and it comforts the person. Student 3: Mrs., does anyone else in your family know how to heal or is it just you? Healer: From my family? Just me. Student 4: I still want to know, is healing inherited or learned? Healer: I think it is inherited. Student 4: But why is that? Healer: Because one can inherit it and then one can learn.

(continued)

Table 4.1 (continued)

Category definition/example
(At this point, students continued to ask questions to the healer about how and when she learned to heal others, until the healer had to leave.) Teacher: Thank you Doña Juanita. Well you all have your own ideas now. Let's go to page 20. There are a few questions related to this visit and with the prior reading. We are going to read them and to try to answer them. Who wants to start reading? (Student starts reading the questions) Student 5: How is healing like athletic performance? Teacher: I am going to write down your ideas on the board. Student 6: That both are traits? Student 7: Inheritance. Teacher: Inheritance for athletic performance or for healing? Student 8: For both. Teacher: What else? Student 9: That athletic performance can change over time. Teacher: And what about the ability to heal, does it change over time? What do you think? Student 10: Yes, it can improve. Student 11: The healing lady can still learn more about the different ways used to heal others. Student 12: Yes, her knowledge can change over time.
(The class continues to discuss additional questions.) Student 13 (reading one more question): How are the explanations similar or different from my parents and neighbors about healing to those of scientists that we learned in reading 1,3? Student 14: My family's explanations are based on what they believe and know and scientists' explanations are based on what they study. Teacher: So, scientists base their knowledge in their studies and their research and your families base their knowledge in their daily experiences and knowledge. Let's talk again so we gain clarity about what scientists think and what our family and our community think. Scientist say … what do scientist say? That healing is …? Student 1: That it is learned. Teacher: Someone else? Student 2: Does it come from the genes? Teacher: From genes? Is that what scientist say? Well, and why is it that some people in our community think that healing is both inherited and learned?
Category 2: Students use Nahua knowledge in science class
This category refers to specific instances in class, in their work, or in their explicit statements in interviews where students used the narratives or traditional knowledge of the Nahua culture as a gateway to make sense of Western science concepts, thus facilitating the border crossing between the two cultures.

(continued)

Table 4.1 (continued)

Category definition/example
Rationale for this example: A video was created and showed to students to provide them with an opportunity to talk about a popular traditional narrative in Nahua communities (Nahuales). The video was narrated by a young woman of the community in the Nahuatl language. The ways in which students made sense of this video and used it as a gateway for continuing to make sense of the genotype-phenotype relationship (a concept from Western science) are examples of how students' traditional knowledge functions as a resource for learning in the science classroom. The video serves the function of a boundary object because it supported students in connecting a common and familiar folk story to what they had learned about inheritance and population change. In this example, students used their home language, their beliefs (about Nahuales), and their specific forms of interaction (storytelling in the Nahuatl language) in the context of the science classroom as resources, thus maximizing their opportunities to make comparisons with the explanations of Western science. A segment of the discussion as it occurred after watching this video and a student worksheet are shown below as examples of critical events that were coded within this category.
Example: Field notes Teacher: Let's see, what was the video about. Juanito, Imanol, and Gregorio [these students were raising their hands]. Juanito: That a man could turn into an animal, that animal could be a donkey or a hen. Imanol: That some people can turn into animals at night. She told us the story of a man who once saw a huge dog but he kept on walking and then forgot. The next day when going home from work, he saw the dog again and he got scared. Next day he grabbed a stick. When he got home, no one was there, so he went out to look for everyone and he saw the big dog walking away with his donkey that was loaded with corn. The man ran towards the dog and started hitting the dog with the stick until the dog screamed "stop hitting me!" and ran away. Next day a lady told the man that one of their neighbors was badly beaten and recommended that he would go visit his "compadre" to find out what happened to him. That way, the man realized that his "compadre" was a nahual.
(The teacher then asked one student from each of the remaining groups to add to the story and share what he or she understood from the video and knew about it.) Teacher: Why is this story important in the Nahua culture? Silvana: Because it is told by grandparents. Daniel: It has been told generation after generation. Ronaldo: It is part of our traditions. Teacher: Ok, so what is this story trying to explain? Laura: Why there was such a big dog stealing a donkey. Teacher: Ok, and stories of Nahuales in general, what do you all think those explain?

(continued)

Table 4.1 (continued)

Category definition/example
(There are a few seconds of silence.) Teacher: Not all at the same time! Ok, you have heard many stories of Nahuals; what is common to those stories? Yareli: There is always a strange animal in those stories. Teacher: Ok, I see. Would you agree if I say that in all those stories there are animals with unusual traits? Yareli: Hmmm, yes, I guess so. Teacher: What about the others? Christopher: Yes, the animals in the stories are always somehow different to normal animals. Teacher: What kind of explanation do you think scientists would give in the same case? If they find an animal that is somehow different to other animals of its kind? Laura: That it has a different phenotype? Teacher: What do other people think? Cesar: Maybe it has a gene that it received from its grandparents and is showing in its phenotype, but it looks different than its parents and other animals in the same area. Teacher: Interesting. I am not 100% clear though. Can you or someone else please tell us more about this idea that an animal may not show its parents genes?
(The conversation continues and students discuss the nature of recessive genes by referring to the pedigrees that they had previously completed. During the class that followed this discussion, students worked in groups and produced comparative charts followed by questions that required them to use both their traditional knowledge and Western science knowledge.)
Category 3: Students use Western science knowledge to make sense of social issues that affect their lives
This category refers to specific instances in class, in their work, or in their explicit statements in interviews where students used the inheritance and natural selection concepts from the unit to critically analyze situations outside of the classroom that affect their lives.
Rationale for this example: The following excerpt from my field notes refers to a case in which other groups of indigenous people were denied health insurance because of claims that inherited diabetes type II was prevalent in their community. After analyzing this case, students used their knowledge that the traits that human beings express are influenced both by their genes and by the environment in which they live (Western science knowledge). Students related to the experience of discrimination of the Havasupai and shared their own experiences, concluding that genetic testing should not be used to discriminate against them, the Havasupai, or any other group of people. This example shows how students became engaged in using their scientific knowledge when the case under discussion was directly related to their lives in a meaningful way.

(continued)

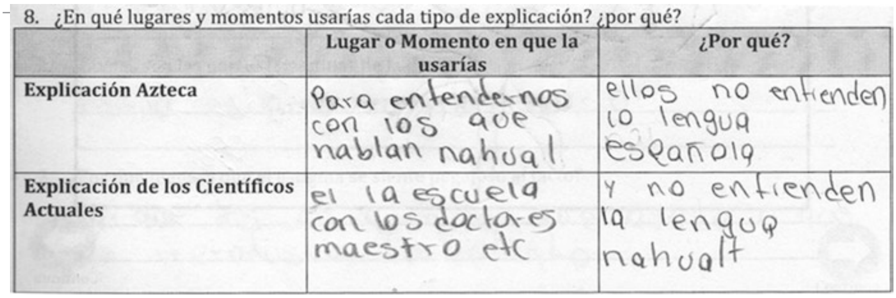
Table 4.1 (continued)

Category definition/example
Example: Field notes The teacher asks all students to read reflection 3.1 in their teams. While they work on making sense of the reading, she walks around and stops by every group, observing what they are doing. Students are on task. (Here, I am listening to the interactions of the group that is closest to where I am sitting.) Fabiola is discussing and sharing her understanding of the reading with the team, insisting that malnourishment needs to be part of the evidence and that the explanation provided in the worksheet is wrong. Alfonso replies that what is important in the reading is that the Havasupai were discriminated against by the health insurance companies, but he is not sure where to use that information because he does not understand what evidence is. Other members of the group seem equally confused. The teacher addresses the whole class and asks each group to share its ideas first (before critiquing the explanation presented in the student guide). Nieves raises her hand immediately and says that diabetes type II is an inherited disease. Ruben A replies that malnourishment is making the Havasupai sick, not only their genes. He adds, "Not everything that is true is evidence." The other members of his team nod. Students in other groups seem confused by this statement, and Alfonso asks (now so all the class can hear), "Teacher, what is evidence?" The teacher goes to the board and writes the claim from the student worksheet. She says that evidence is what supports the claim; it is proof. She asks, "Is the picture in the reading evidence?" Students do not agree. The teacher says, "Look at your facts sheet. What information there supports your claim? Ruben was right that not everything that is true is evidence, but only those pieces of information supporting the claim. Continue discussing in teams and use your facts sheet." In one group, Fabiola and Lisbeth disagree with Alfonso that the right evidence to support the claim (diabetes type II is inherited among the Havasupai) was the high level of consanguinity among the Havasupai. Fabiola and Lisbeth insist that consanguinity is not included in all the risk factors for diabetes type II included in the facts sheet. Alfonso raises his hand, calling the teacher. The teacher approaches the group and Alfonso asks (while the other three members of the group watch attentively), "Teacher, I do not understand. Diabetes type II is an inherited trait. Why isn't that included in the risk factors of the facts sheet? I mean, the companies should not deny insurance, but they are kind of right, no?" (Fabiola and Ruben C shake their heads.) The teacher says, "Remember when we talked about athletic performance? We discussed whether it was an inherited or acquired trait. What did we conclude?" Alfonso says, "It is both because you can inherit some stuff, but you have to train too." Teacher says, "How is that like diabetes? Can you see the similarity? Think about it and try to reach agreement." She leaves for a different group. Ruben C tells the team that the risk factors are part of the environment and Alfonso nods. He starts reading what Lisbeth wrote in her worksheet and starts working on his own. The teacher continues having small conversations with different groups. After 17 min, she goes to the front of the classroom and asks the class to be silent. Then she asks, "Ok, we have discussed what is evidence. So, do the insurance companies have evidence to deny insurance to the Havasupai only based in the fact that diabetes is inherited?" Carmen says that the facts sheet mentioned poverty and malnourishment as risk factors for diabetes, and those were not included in the companies' explanation, so they were wrong. Fabiola eagerly raises her hand. She says that the Havasupai were discriminated against, as she was discriminated against when she went to the city with her mom and people looked down at her mom when she was speaking in Nahuatl.

(continued)

Table 4.1 (continued)

Category definition/example
(About 10 students are raising their hands waiting for their turn to participate.) Sergio says that the Havasupai are being discriminated against because they are fat and sick. Ruben A says that what is just is to provide help to all families with inherited diseases. Nieves says, “When using genetic testing, we need to respect everyone regardless of their clothing.” [The use of traditional garments by Nahua people is heavily discriminated against in that region.] Carmen says that the insurance companies were wrong because people get diabetes because of their genes and their environment, so they must give insurance to the Havasupai. (The bell rings.) The teacher says, “Ok, it seems we understood. As homework you will have to use your scientific knowledge to write recommendations for the Arizona Secretary of Health, where the Havasupai live. We will discuss this on Friday.” (Class dismissed.)
Category 4: Difficulties in border crossing between cultures
This category refers to specific instances in class, in their work, or in their explicit statements in interviews where students expressed that Nahua knowledge belongs solely to their communities and that science knowledge belongs only to the school.
Rationale for this example: The following student worksheet is from an activity where students compared how Aztecs and Western scientists explain the fact that we find chocolate bitter. This worksheet shows that the student establishes a separation where the two types of knowledge are used exclusively in one context. The student adds that because of language science cannot be used in their community and traditional knowledge cannot be used at school because people would not be able to understand. This is an example of a difficulty in border crossing between cultures, where a student compartmentalizes her or his cultural knowledge and school knowledge and understands the two forms of knowledge as incompatible.
Example: Student’s artifact



8. ¿En qué lugares y momentos usarías cada tipo de explicación? ¿por qué?

	Lugar o Momento en que la usarías	¿Por qué?
Explicación Azteca	Para entendernos con los que hablan nahual	ellos no entienden lo lengua español
Explicación de los Científicos Actuales	el la escuela con los doctores maestro etc	y no entienden la lengua nahualt

Biología. 1 de Secundaria Reflexionemos 2.1

	Place or moment where you would use it	Why?
Aztec explanation	*To communicate with those who speak Nahuatl*	*They do not understand the Spanish language*
Explanation from current scientists	*At school with doctors, teachers, etc.*	*And do not understand the Nahuatl language.*

5.2.2 Student Interviews

To understand the experience of the students while learning within the contextualized unit, at midpoint and post-enactment, semi-structured interviews were conducted in an empty classroom, audio recorded, and later transcribed for analysis. The same students were interviewed during the midpoint and final interviews. Ten students volunteered to be interviewed from each classroom, about half of the total students learning the contextualized unit.

The midpoint interviews were conducted by two members of the community, a young female and male attending an indigenous college in the area. This was meant to ensure that the students felt free and safe to talk about their opinions and experiences regarding the science class. I conducted the final interviews after they had received their grades for the first term, and I had ceased to be their science teacher and the college students were not available. One of the limitations of the final interviews as a data source is that students may have been reluctant to share their criticisms, having developed a bond with me as their former teacher. The midpoint and final interview questions are presented below:

Midpoint interview, generative questions:
What is your favorite class? Why?
How is this science class like or different from other classes?
What is your favorite thing about this science class? Why?
What is your least favorite thing about this science class? Why?
What are the easiest and hardest things in this science class? Why?
Do you share what you learn in the science class outside of school? With whom do you share it?

Final interview, generative questions:
Do you think that it is possible for you to use the knowledge that is characteristic of your culture in the science class? Tell me more about how and when you use it.
How does it make you feel when you can use the knowledge of your culture in the science class?
What do you think science is?
Do you think science is worth learning? How are you planning to use this knowledge?
What would you add or change to the science class so that you like it more and you are always happy during science classes?
What makes you feel best during science classes?

5.2.3 Student Notebooks

All students in the two classrooms received a notebook or student guide that contained readings, activities, worksheets, and assessments. During all classes, students registered their own evolving knowledge and conclusions in a specific section of their notebooks. The main student artifacts of this analysis are the notebooks donated by 24 student volunteers at the end of the unit enactment. The notebooks provide evidence regarding how students made sense of the content they were learning and whether certain activities within the unit facilitated border crossing or not. Thirty-five worksheets in each of the 24 notebooks were considered critical events for border crossing, and the 840 worksheets were incorporated into the corpus of data to be coded and analyzed.

5.3 Coding and Data Analysis

The sources of data were integrated chronologically using the software NVivo 10. All data was analyzed in its original language (Spanish) by the researcher, whose native language is Spanish. The analysis focused on student experiences in comparing natural phenomena from the point of view of their own TIK and that of Western science culture, in deciding how and when to use these two types of knowledge, and in identifying and understanding when learning opportunities either emerged or were denied when the contextualized unit was enacted in the classroom.

Throughout the corpus of data, critical events were selected in which students engaged in border crossing between the Nahua culture and Western science culture. Critical events as defined by Powell et al. (2003, p. 416) are "connected sequences of utterances and actions that, within the context of our a priori or a posteriori research questions, require explanation by us, by the learners, or by both." Within the framework of this study, events were considered critical in relationship to the following research question: "What does it mean to contextualize science curricula in a culturally relevant manner for indigenous lower secondary school students so that the learning of challenging concepts is facilitated?" Because one of the main hypotheses of this study is that the new curricular features would better facilitate border crossing between the Nahua culture and Western science culture, events that were selected as critical either confirm or disaffirm this hypothesis.

Critical events fell into four broad categories: (1) explicit comparisons between Nahua culture and Western science culture as a mechanism for border crossing, (2) student use of Nahua knowledge in science class, (3) student use of WSK to make sense of social issues affecting their lives, and (4) difficulties in border crossing between cultures. These four categories constituted the initial conceptual model of border crossing between the Nahua culture and Western science culture and guided the identification of critical events (Table 4.1). By connecting all the events representative of those categories, a narrative of the border crossing experiences of students in the science classroom could emerge and be analyzed through an ethnographic lens. I then moved away from this deductive stage to engage in an inductive ethnographic stage of reading and rereading through the artifacts, interviews, and field note excerpts in each category. This allowed me to group them in smaller thematic categories by comparing and looking for co-occurrences, absences, and linkages between events (Glaser and Strauss 1967; Strauss and Corbin 1998; LeCompte and Schensul 2010), all of which would allow for a richer understanding of the students' experience of border crossing.

The selected critical events were organized chronologically using the software NVivo 10 (QSR International Pty Ltd., Victoria, Australia) to create a narrative account of the phenomenon of border crossing as it occurred while learning about inheritance and natural selection within the contextualized unit. This deductive approach allowed for the location and analysis of data specifically related to border crossing among a vast corpus of student worksheets, running records, and student interviews to find patterns within and across events of border crossing (Derry et al.

2010). To select these critical events and to document this process and proceed to coding required searching through the complete corpus of data several times to find representative instances of border crossing.

6 Results and Discussion

While learning within this unit, students were supported in analyzing ideas and information from the points of view of WSK and the TIK of the Nahua culture. Activities in the unit presented Nahua narratives familiar to students, providing opportunities for them to see two types of discourses side by side, think about the value and utility of each discourse, and realize they can use both in different contexts.

7 Comparing Worldviews: A Path Toward Accessing Multiple Ways of Knowing

The most common category in the analysis of the data corpus was comparing worldviews. One of the activities included in the unit was watching a video about a traditional Nahua story told by a member of the community in the Nahuatl language. In this activity, students were supported in analyzing the story from the points of view of WSK and the Nahua culture. Because of this activity and others, most students started to see Western science and their own culture as different ways to approach knowledge that they could use depending on the context. These reflective processes were scaffolded with comparative charts and prompts included in student worksheets that supported comparison but discouraged hierarchization. Most students achieved some degree of border crossing between Nahua TIK and Western science, although students made sense of these comparisons of worldviews differently. For example, Laura was a smooth border crosser, placing both Nahua TIK and WSK in the contexts of community/family and school. In the worksheet below (Fig. 4.1), Laura assigns worth to each type of knowledge by describing the different purpose these types of knowledge have in different contexts with different groups of people.

In reasoning why her family would use WSK, Laura envisions them engaging in the same activity she does in science class: making comparisons between explanations coming from different worldviews. This may indicate (a) a willingness to use WSK in her everyday community life and (b) that using WSK makes sense for her when her family can also use it in the ways she has learned in school. Laura border crosses while still making it explicit that she is proud of her traditional knowledge and enjoys traditional narratives. That Laura can understand science as relevant for her family and community will likely have a positive effect on her engagement in

	Place or moment where you would use it	Why?
Explanation from the Nahua oral tradition	In the family when we are talking	Because a story about Nahuales is more interesting, because it has fantasy and that makes it more interesting.
	With my peers and friends	Because that way they know what beliefs the Nahua culture has.
Explanation from current scientists	In the classroom with any teacher who wants information about Nahuales.	So that they know scientists' opinion about this topic.
	With my family	So that they can make comparisons of the two explanations.

Fig. 4.1 Laura's worksheet after analyzing how the Nahua tradition and Western science would explain a different-looking dog

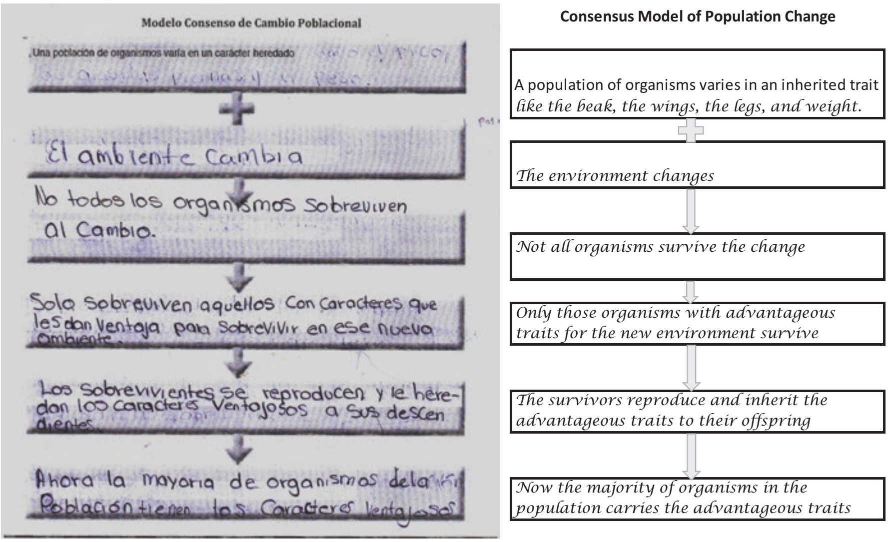


Fig. 4.2 Laura's model of population change (left side original scan from student's notebeook, right side translation into English)

school science throughout her school life (Aikenhead 2006; Bang and Medin 2010) and constitutes a good example of border crossing.

Laura's experience of border crossing was successful because she was able to hold the two points of view throughout the enactment of the unit, showing cognitive engagement and successfully completing challenging tasks such as pedigrees of different family traits or the population change model (Fig. 4.2. below).

However, for an even smoother border crossing, a student should also be able to place Nahua knowledge in the context of school and show openness to opportunities to share it with teachers and scientists (Costa 1995). This type of border crossing is exemplified by Carmen's experience. Carmen understood Western science as an exercise of studying and understanding the world and that, therefore, scientists would benefit from understanding her culture and other cultures in the world. She also sees WSK as useful to her community in complementing what they already know and have known for generations. The understanding of WSK as complementary to her own knowledge shows that she is not hierarchizing these types of knowledge but discovering ways to use them in varied contexts, thus successfully border crossing between different ways of knowing (Snively and Corsiglia 2005).

Smooth border crossing was common among the students. For example, most students were able to think about phenomena such as the healing properties of chocolate or the biodiversity of corn from the points of view of Nahua TIK and WSK without experiencing conflict. In another example, students learned about phenylthiocarbamide (PTC) and that only some people inherit the ability to taste this bitter compound. Students were given the opportunity to find out who was sensitive to PTC with PTC strips and then observe their reactions to unsweetened coffee and bitter chocolate diluted in water. These beverages are commonly consumed in the students' communities, but they are usually sweetened. Student curiosity was piqued; they asked their parents why they always sweetened these beverages and carefully read the story about how ancient Aztecs used chocolate. The discussion in class focused on the Nahuas belief that unsweetened chocolate causes a stomachache; therefore, people would prefer it sweetened. However, scientists would say that people who reject unsweetened chocolate might have inherited the trait of sensitivity to PTC. When asked what they had heard about chocolate, a lively discussion ensued. Student answers included that chocolate makes people happy, gives us energy and protein, is a medicine, and is a hot plant. When asked where they heard this information, most students answered that they heard it at home or in the community. The excerpt from field notes below responds to the teacher question, "How do you think that scientists would explain that Aztecs and Mayas disliked bitter chocolate?"

Teacher: Ok, let's get together in teams, and we are going to think as scientists now. Let's imagine we are scientists and think about it. Two more minutes. Let's work!
Teacher: I will give you a hint. Do you remember the video we saw?
Daniel: About PTC?
Teacher: That's right; what did we learn?
Alejandro: It is bitter.
Laura: That the ability to taste PTC is inherited.
Teacher: Ok, very good. And that ability depends on …?
Silvana: On the traits.
Ronaldo: Some people can feel that flavor and others can't.
Imanol: Some people have traits that allow them to have the PTC strip in their mouth and not feel that it is bitter (three more students share similar ideas).
Teacher: Ok, we are close to the answer to the question "how would scientists explain that Aztecs and Mayas disliked bitter chocolate," so take a few minutes and work on your worksheet.
(5 minutes later)
Teacher: Each team is going to share now.
Alejandro: Maybe Aztecs had a trait for being sensitive to bitter flavors.

Daniel: Some Aztecs were sensitive to PTC so they disliked bitter chocolate.
Sergio: Because they had traits that made them sensitive to the bitter flavor of chocolate.

In the discussion, the teacher prompted students to think about the bitterness of chocolate first from the point of view of Nahua knowledge and then from the point of view of WSK, but without any hint of judgment or "correctness," so neither type of knowledge was placed above the other. During class discussions, readings, and videos, students were able to practice taking different perspectives when thinking about a situation or a phenomenon, thus becoming more and more proficient at border crossing.

Another example of successful border crossing occurred when students learned about how their ancestors domesticated corn and about the Western science concept of selective cross-breeding (artificial selection). Students were able to analyze the phenomenon of corn cultivation and corn diversity using the two perspectives without experiencing conflict. Furthermore, analyzing the traditional Nahuales story where one species turns into another and comparing interpretations did not affect the students' ability to understand the Western science concept of population change and selective pressures; when students studied the case of the British carbonaria moths, they did not claim that the white moths were turning into black moths or vice versa, but they used the Western science concepts they had learned.

These examples are representative of most students. Their border crossing experience most often occurred in analyzing a traditional narrative or a natural phenomenon from two points of view (Nahua and WSK) or in sharing these types of knowledge in multiple contexts (school, home, community).

Another less common experience of border crossing, however, is also worth discussing. Carmen and Ruben placed themselves in a position of agency to use each type of knowledge for their own convenience rather than for the benefit of their community. In this example, Carmen decides when and how to use the traditional narrative characteristic of her culture and when to use Western science to serve her own interests to avoid "endless discussions" (Fig. 4.3). Carmen prioritizes how she can best communicate with different people (elders, city people, people at school) instead of engaging in comparing and sharing different types of knowledge as in the

	Place or moment where you would use it	Why?
Explanation from the Nahua oral tradition	At home with elders, with neighbors, with indigenous people	Because they understand more in this way than if you talk to them in a scientific manner.
Explanation from current scientists	At school, with city people	Because they do understand if you talk to them in a scientific manner and that way you do not get into endless discussions.

Fig. 4.3 Carmen's worksheet after analyzing how the Nahua tradition and Western science explain a different-looking dog

previous examples. Carmen and Ruben's experience indicates that understanding multiple ways of seeing the world can empower them in various contexts.

Being able to negotiate multiple perspectives while developing a sense of ownership and agency as producers and users of both Western science and their own traditional indigenous knowledge is a hallmark of equitable science classrooms (Barton and Tan 2010; Carlone et al. 2011; O'Neill 2010). Providing opportunities for students to compare worldviews with a critical lens in the context of the science classroom can have positive spin-off results.

These examples of successful border crossing facilitated by the design of a contextualized biology unit using activities, scaffolds, and instruction suggest that incorporating narratives from student culture and supporting students in taking multiple perspectives to analyze natural phenomena in the science class do indeed facilitate border crossing. The results also suggest that a border crossing approach has a positive effect on student learning of Western science concepts, since they were successful at explaining processes such as inheritance, natural selection, and artificial selection during classes and on worksheets.

8 Discovering New Possibilities: Nahua Knowledge in Science Class and Western Science Knowledge in Everyday Life

The second most common category in the analysis of the data corpus was "using Western science knowledge for social justice," illustrated by field notes documenting student experiences of discrimination. The activities designed to engage students in critical thinking were cognitively challenging, requiring students to comprehend complex readings, make sense of multiple sources of data, and critique explanations, including biased claims, evidence, or reasoning (see Table 4.2). Students persevered in completing these activities even when they required multiple rounds of feedback from the teacher. Students actively participated in small group and whole class discussions, indicating that they were cognitively engaged while learning with these activities (Blumenfeld et al. 2006).

This field note excerpt shows how students like Alfonso (lines 7–10 and 28–44) persevere to complete the task of critiquing the explanation used by insurance companies to deny insurance to the Havasupai, even when repeatedly struggling to understand a definition of evidence and what constitutes evidence. Furthermore, during the enactment of this contextualized unit, students had multiple opportunities to practice agency and to adopt a critical stance toward the social injustices they experience. These opportunities triggered cognitive engagement, easing their learning of science. Students showed sustained cognitive engagement exactly in the activities where they could use Western science concepts to critique social inequalities they had faced.

Table 4.2 Field notes describing the discussion after a reading on health and the Havasupai people

October 3, Class: 1A. 8:00 AM

- The teacher asked all students to read reflection 3.1 in their teams; while they work on making sense of the reading, she walks around and stops by every group observing what they are doing. Students are on task.

- (I am listening to the interactions of the group that is closer to where I am sitting). Fabiola is discussing and sharing her understanding of the reading with the team, insisting that malnourishment needs to be part of the evidence, so the explanation provided in the worksheet is wrong. Alfonso replies saying that what is important in the reading is that the Havasupai were discriminated against by the health insurance companies, but he is not sure where to use that information because he does not understand what evidence is. Other members of the group seem equally confused.

- The teacher addresses the whole class and asks each group to share their ideas before going into critiquing the explanation presented in the student guide.

- Nieves raises her hand immediately and says that diabetes type 2 is an inherited disease.

- Ruben A replies that malnourishment is making the Havasupai sick, not only their genes. He adds, "Not everything that is true is evidence." The other members of his team nod.

- Students in other groups seem confused by this statement and Alfonso asks (so all the class can hear), "Teacher, what is evidence?"

- The teacher goes to the board and writes the student worksheet claim. Then she says that evidence is what supports the claim, a proof. She asks: "Is the picture in the reading evidence?"

- Students do not agree.

- Teacher says, "Look at your facts sheet. What information there supports your claim? Ruben was right that not everything that is true is evidence, but only those pieces of information supporting the claim. Continue discussing in teams and use your facts sheet now."

- In one group, Fabiola and Lisbeth disagree with Alfonso that the right evidence to support the claim (diabetes 2 is inherited among the Havasupai) was the high level of consanguinity among the Havasupai. Fabiola and Lisbeth insist that consanguinity is not included in all the risk factors for diabetes type 2 included in the facts sheet. Alfonso raises his hand, calling the teacher. The teacher approaches the group and Alfonso asks, (while the other three members of the group watch attentively) "teacher, I do not understand. Diabetes type two is an inherited trait; why isn't that included in the risk factors of the facts sheet? I mean, the companies should not deny insurance, but they are kind of right, no? (Fabiola and Ruben C. shake their heads). The teacher says, "Remember when we talked about athletic performance? We discussed whether it was an inherited or acquired trait. What did we conclude?" Alfonso says, "It is both because you can inherit some stuff but you have to train too." Teacher says, "How is that like diabetes? Can you see the similarity? Think about it and try to reach agreement." She leaves for a different group. Ruben C tells the team that the risk factors are part of the environment and Alfonso nods. He starts reading what Lisbeth wrote on her worksheet and starts working on his own.

- The teacher continues having small conversations with different groups. After 17 minutes, she goes to the front of the classroom and asks the class to be silent. Then she asks, "ok, we have (About 10 students are raising their hands waiting for their turn to participate.) discussed what evidence is, so do the insurance companies have evidence to deny insurance to the Havasupai only based on the fact that diabetes is inherited?

- Carmen says that the facts sheet mentions poverty and malnourishment as risk factors for diabetes, and those were not included in the company's explanation, so they were wrong.

- Fabiola eagerly raises her hand. She says that the Havasupai were discriminated against, as she was discriminated against when she went to the city with her mom and people looked down at her mom when she was speaking in Nahuatl.

(About 10 students are raising their hands waiting for their turn to participate.)

- Sergio says that the Havasupai are discriminated against because they are fat and sick.

- Ruben A. says that what is just is to provide help to all families with inherited diseases.

- Nieves says, "when using genetic testing, we need to respect everyone regardless of their clothing" (the use of traditional garments by Nahua people is heavily discriminated against in that region).

- Carmen says that the insurance companies were wrong because people get diabetes because of the genes and the environment, so they must give insurance to the Havasupai.

(Bell rings)

- The teacher says, "Ok, it seems we understood. For homework, you will have to use your scientific knowledge to write recommendations for the secretary of health of Arizona, where the Havasupai live. We will discuss this on Friday."

(Class dismissed).

This is illustrated by Fabiola's determination to use science concepts she had learned to back up her ideas, even when her peers disagreed (lines 28–37 and 25–32). Because Alfonso was popular and Fabiola tended to be shy during science classes and recess, Fabiola's participation and adamant defense of her point of view in this class indicate that her personal experience with discrimination (lines 46–48) provided the motivation to become engaged and find new tools to question her experience. Fabiola's positioning during this interaction shows how learning within the contextualized unit allowed students to construct an identity of expertise through agency and empowerment by selectively using knowledge of multiple worldviews to assert their individual positions in the science classroom (Barton and Tan 2010). This has important implications for Fabiola's future educational attainment: these skills can become critical when she is negotiating the pursuit of higher education within her family.[4] The development of student agency becomes an essential goal of science curricula that is committed to providing all students, especially those who are marginalized in their societies, with access to science learning.

These results are further supported by the final student interviews and worksheets. During the final interview, when students were asked to name their favorite moment or activity of the science classes, most of them mentioned the opportunity to discuss discrimination. Through discussions about discrimination, students realized there is no foundation to the idea that some people are more intelligent or better than others based solely on phenotype or ethnicity. Juanito, for example, provided a particularly interesting answer in his interview:

Interviewer: From all what we have done in science class, what have you liked the most?
Juanito: The activity about not discriminating [against] people.
I: Why did you like that one?
J: Because not discriminating [against] people is important for the maintenance of the culture [Nahua traditions].

Juanito links discrimination with the survival of his own culture. It is logical that a student takes great interest in learning new ideas and tools that help to combat a social reality that is detrimental to his or her way of living. When asked what activity she liked best, Nieves also chooses "not discriminating [against] people." When asked why she liked this activity, she responded, "Because I learned that it is not because of being indigenous that we can't progress." Nieves makes a personal connection with the idea of discrimination, implying that she has gained confidence in accomplishing her goals because there is no scientific basis for discriminating against indigenous people. When students can view Western science as playing a role in the achievement of their own goals, such as fighting discrimination, they are more likely to see science as personally relevant and value this type of knowledge, increasing their motivation to learn it (Bang and Medin 2010).

Feeling empowered to use Western science concepts to question discrimination was also evident in student worksheets. For instance, students were asked to write a

[4] In Nahua communities, it is still common for young girls to have to engage in complicated negotiations with their families to pursue higher education because it means leaving their communities and departing from traditional gender expectations.

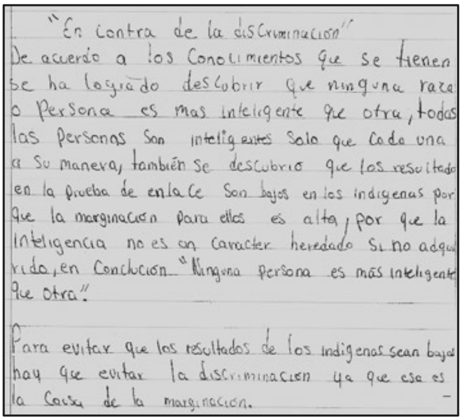
short article they would like to see published in a local newspaper about what they had learned in the science class, and many students chose to mention what they learned about discrimination. Laura, for example, uses her science knowledge to conclude that intelligence is not an inherited trait but an acquired trait (Fig. 4.4), understanding discrimination as an environmental factor that affects individual traits.

That Laura and other students started thinking about marginalization and discrimination as environmental factors affecting individual traits shows that lower secondary school students are capable of an expanded understanding of environmental factors. Current research in public health and epidemiology reveals that social environment affects health over the life course (Williams et al. 2010), making this type of reasoning extremely relevant. These studies further demonstrate that discrimination and racism have detrimental effects on a broad range of health status indicators, including poor sexual functioning, abdominal fat, coronary artery calcification, the incidence of uterine fibroids, and breast cancer (Williams et al. 2012). Discussing discrimination in the science classroom and learning about up-to-date genetics or public health issues empower students not only to pursue science; it is an ethical imperative to educate citizens to become fully aware of how to care for their health and acquire the tools to advocate for themselves.

Students also became more confident in using their traditional knowledge in class and took pride in doing so. When asked "How do you feel when we use the knowledge of your community in the science class?" Daniel, Imanol, and Juana gave the following answers:

Daniel: Happy, because it comes from my community.
Imanol: Well … proud of maintaining the tradition of storytelling.
Juana: I feel happy to share what I know.

Their interviews reveal the multiple opportunities to use and share their traditional knowledge during the enactment of the contextualized unit. All mentioned


"En contra de la discriminación"
De acuerdo a los conocimientos que se tienen se ha logrado descubrir que ninguna raza o persona es mas inteligente que otra, todas las personas son inteligentes solo que cada una a su manera, también se descubrio que los resultados en la prueba de enlace son bajos en los indigenas por que la marginacion para ellos es alta, por que la inteligencia no es un caracter heredado si no adquirido, en conclucion "Ninguna persona es más inteligente que otra".

Para evitar que los resultados de los indigenas sean bajos hay que evitar la discriminacion ya que esa es la causa de la marginacion.

"Against Discrimination"

According to the knowledge science has, it has been discovered that not any human race is more intelligent than the other. All people are intelligent, but each one in their own way. It was also discovered that the results of the ENLACE assessment are low for indigenous students because marginalization for them is high, because intelligence is not an inherited trait but it is an acquired trait. In conclusion, "not a single person is more intelligent than the other." To avoid low scores in indigenous students, we have to prevent discrimination because that is the cause of marginalization.

Fig. 4.4 Laura's short text about how she would use her science knowledge to combat discrimination

4. Do you think that your culture's knowledge can help scientists better understand the world? Why?
Yes, because that way they would know how to use honey for healing.
5. According to what you have learned so far, do you think that scientific knowledge can help your community to better understand the world? Why?
Yes, because this way we would know more medicines.

Fig. 4.5 Translation from Ruben's worksheet after discussing how Aztecs and Nahuas have traditionally used honey for healing

that they experienced a positive affect when using and sharing the knowledge of their community, including pride in their ethnic identity (being Nahua or being indigenous) while learning Western science concepts and comparing how their traditional knowledge overlapped, complemented, or contrasted with Western science. Cultural pride facilitated successful border crossing experiences because they could value the two types of knowledge without considering them antagonistic (Aikenhead 1997; Aikenhead 2002; Snively and Corsiglia 2001).

Figure 4.5 illustrates how worksheet questions supported students in reflecting on the possibility that their knowledge was valuable to Western scientists and that Western science was valuable to their community. Ruben identifies a case where traditional Nahua knowledge helped advance Western science and a case where Western science can advance a relevant aspect of Nahua culture (traditional medicine). Ruben's answers are representative of most student responses, further supporting the idea that the contextualized unit had a positive effect on student ability to cross borders between their TIK and WSK.

9 Difficulties in the Border Crossing Experience

Thus far, I have described successful stories of border crossing; however, engaging in border crossing was challenging for some students during the enactment of the unit, and not all succeeded. While the difficulties in border crossing were less common, they still represent an important pattern that can suggest ways to refine and improve the contextualization principles proposed by Sánchez Tapia et al. (2018). When making sense of the worksheets and interviews in which students demonstrated difficulties transitioning from their culture to Western science or struggled to analyze a phenomenon from multiple perspectives, I classified this pool of sources into four categories: internalized oppression (believing that WSK is better than their TIK), language, school-home separation, and epistemology.

Internalized oppression is the idea that students have been exposed through school discourses and mass media to the belief that their traditional knowledge is inferior to Western science, meaning only explanations and reasoning based on Western science have validity (Gómez-Lara 2008). Multiple entries in my field notes journal record instances of science teachers telling students that their traditional beliefs are superstition, and they go to school to learn what is true. This is a common discourse experienced by Nahua people in Mexico, and students constantly exposed to these ideas may internalize this oppressive discourse early in their lives. The contextualized unit introduced traditional Nahua narratives in the curriculum and portrayed them as a legitimate way of knowing along with elements of the Nahua language to challenge oppressive narratives that negatively impact student self-esteem and the development of healthy ethnic identities. This combination of narratives and mother tongue was effective in facilitating border crossing for the majority, but it was not enough for all students to be successful border crossers.

Believing in the validity of their own knowledge was difficult for high achievers, while students who were reported to be average or academically struggling did not show this pattern. One possible explanation is that high achievers have been well served by this oppressive narrative throughout their schooling process. They may have been praised for memorizing WSK concepts, demonstrating competence in Western ways, and avoiding mentioning their traditional knowledge or speaking their native language. The four students who maintained that WSK was "better" than their TIK throughout the unit were high achievers. For example, after analyzing the traditional story of Nahuales, which created a feeling of pride and pleasure in most students, Ronaldo wrote that he would only use that traditional narrative with children or elders, but not with teachers, who need "a better explanation" that he can only provide using WSK.

Ronaldo may have internalized the belief that the knowledge of his community is somehow "inferior" throughout his 6 years of elementary school by being rewarded for not using his language and traditional knowledge at school (Gómez-Lara 2008). This internalized oppression not only makes it difficult for students to cross borders between science and their traditional knowledge, but it can also lead to problematic relationships between adolescents and their families, which can be detrimental to student academic achievement and future adjustment to postsecondary education (Bernal 2002; Castagno and Brayboy 2008).

The oppressive narrative that delegitimizes Nahua knowledge includes a devaluation of the Nahuatl language. Although most students who participated in this study attended bilingual elementary schools, they learn very early that Nahuatl is not spoken in the city, in media, or in school after elementary. Whereas elementary school has a single teacher for all subjects, secondary school has specialized subject-matter teachers, and all instruction occurs in Spanish. They receive the implicit message that science and academic subjects are learned in Spanish and that Nahuatl only belongs to the family/community realm. In other words, Nahuatl is not a language to produce knowledge that would be valued by their teachers or would help them to succeed academically. This makes it difficult for students to believe that they can use science in their lives; they believe that their ethnic identity is incompatible with doing/learning science, impeding border crossing between student TIK and Western science. The belief that WSK is incompatible with speaking Nahuatl is exemplified in Nieves' worksheet, completed after discussing how Aztecs explain the bitter flavor of chocolate compared to scientists (Fig. 4.6).

	Place or moment where you would use it	Why?
Aztec explanation	To communicate with those who speak Nahuatl	They do not understand the Spanish language
Explanation from current scientists	At school with doctors, teachers, etc.	They do not understand the Nahuatl language.

Fig. 4.6 Nieves' worksheet after discussing how Aztecs and current scientist explain the bitterness of chocolate

Nieves communicates that she would only use WSK at school with teachers and with medical doctors because they do not understand the Nahuatl language and that she would not use WSK in her community because they do not understand Spanish. This suggests that she indeed believes WSK can only be communicated in Spanish (although she is bilingual Spanish-Nahuatl). This belief may not keep students from obtaining high grades, but it has the potential to make it difficult for students to see the value in learning and using Western science in their communities, thus decreasing their motivation to engage in the science class. Nieves demonstrates this in her midpoint interview. She indicated that science class was the class she liked the least because it was boring and too long. When asked if she understood the ideas in the science class, she said yes, but that she did not like science. When asked whether she shares her science class knowledge with family or friends, she replied, "Only with my sister, but she thought it was boring too."

Nieves, described as a high achiever by other teachers, was always engaged in class, completed all assignments, showed no difficulties completing complex tasks, and frequently helped her friends to complete various tasks in the science class. This suggests that though students like Nieves may have learned the behaviors that are rewarded at school, it does not necessarily mean they develop true interest in learning science. It is therefore unlikely that they would pursue science in the future. Nieves' idea that what she learns at school would not be understood in her community makes it difficult for her—and others who think like her—to cross borders between their culture and Western science, ultimately reducing their access to science.

Moreover, these results suggest that for successful border crossing to occur between a student's culture and Western science, when students are bilingual, the two languages should be present in the science classroom, an idea aligned with critical and culturally relevant pedagogies (Bernal 2002; Cajete 1994; Castagno and Brayboy 2008). Even if the science teacher is not bilingual, asking community members to get involved in translating some worksheets that students can complete with their families can introduce the idea that science has a place in their day-to-day lives, thus increasing their motivation. Although only three of the four students experiencing difficulties in border crossing mentioned language, language is an important variable, playing an essential role in how we understand the world, interact with others, and build knowledge (Lemke 2001; Rogoff 2012). Denying indigenous students the opportunity to use their bilingualism for academic achievement in science risks disengagement and the marginalization of indigenous students.

The use of the Nahuatl language in the enactment of the unit was underdeveloped, a clear limitation of this study. I do not speak Nahuatl, and it would have been extremely difficult for me to analyze the enactment of the unit had it contained a large instructional component in the Nahuatl language. Furthermore, none of the teachers in the school were Nahuatl speakers. The teacher who participated in this study is a community member who understands spoken Nahuatl, but she is not a fluent speaker of the language. This limitation points to the need to emphasize partnerships with Nahua indigenous researchers and communities in future iterations of the unit or in contextualizing other science materials to allow multilingual and multicultural student access to science.

A final aspect that could have facilitated student border crossing would have been more opportunities to understand how knowledge is created in the students' own tradition and in the Western science tradition. Engaging in comparisons between multiple ways of knowledge is a cognitively challenging activity, and it can be greatly facilitated by supporting students in understanding the nature of Western science. Learning about the nature of different types of knowledge should be a precursor for successful border crossing between different ways of knowing from different cultures. However, epistemology is complex and would require time and multiple exposures to be taught and learned (Khishfe 2008), making it implausible to include those contents and practices in a single biology unit, typically 8 weeks in duration. In this study, the enactment of the contextualized unit took 11 weeks, too little time to include an epistemological component. Taking time constraints and the complexity of the subject into consideration, a possible way to support students in gaining a working understanding of the nature of science would be to provide students with foundational knowledge of epistemology, applied and refined throughout multiple thematic units, during lower secondary school. This approach would prepare students to be smoother border crossers. It would give them the tools to easily identify which contexts call for a particular way of knowing, thus increasing their agency and their chances of access to both science learning and a healthy development of their ethnic identities.

10 Significance of the Study

The results discussed thus far confirm what research on science education for indigenous students shows, namely, that student TIK belongs in the science classroom (Aikenhead 2001, 2002; Snively and Corsiglia 2001, 2005). Creating opportunities for students to use their TIK becomes a powerful learning trigger that increases student willingness to invest cognitive resources in studying narratives they are familiar with from alternative perspectives (WSK) without experiencing negative effects. A border crossing approach to curriculum design and instruction has the potential to support students from minoritized communities to master complex science concepts while at the same time developing pride in their ethnic identities, thus operationalizing the principles of Culturally Relevant Pedagogy (Ladson-Billings 1995) and cross-cultural science education (Aikenhead 2006; Aikenhead 2001, 2002).

Developing ease in border crossing is fundamental for indigenous students to learn another culture's knowledge of nature and to choose which worldview better fulfills their goals at any given moment (Aikenhead 2001). This skill is an advantage when living in a multicultural society, facilitating student success in multiple contexts and encouraging them to become effective agents of social change. Considering the important benefits of becoming proficient at border crossing, students from minoritized communities or those whose beliefs seem at odds with Western science should not be left to manage this crossing on their own; rather, they should count on teachers using contextualized science curricula that scaffolds and facilitates this process.

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Chapter 5
The Need for Contextualized STEM Learning Environments for Refugee Students in Turkey

İbrahim Delen, Seydi Aktuğ, and M. Akif Helvacı

1 Introduction

Today, not only our lives but also educational systems need to be dynamic to adjust to the rapid changes influenced by the knowledge and technological growth. As a developing country, Turkey closely monitors and adjusts to these changes. In a ten year span, science curriculum has been updated several times based on recent development in science, technology, and pedagogy. In the first update, curriculum started to focus more on students' understanding of science with an emphasis on constructivism. In constructivist approach, students learn by incorporating new information into what they already know. This idea is also connected with inquiry since inquiry-based science teaching encourages students to use their knowledge for solving problems and they learn with the facilitation of the teacher (Delen and Kesercioğlu 2012). To acknowledge the growth in educational technologies in this process, science classes were called "Science and Technology" in Turkey. More recently, with the rise of science-technology-engineering and math (STEM) studies, Turkish educators started discussing how to adopt engineering practices, and the Ministry of Education (MOE) revised the science curriculum in 2018 (Delen and Uzun 2018) to align more with STEM. In addition to these updates, the MOE distributed ten million tablets with the goal that all students and teachers will have tablets when the project is completed. The MOE also aims to provide smartboards to all classrooms. All teachers can access materials developed by the MOE using Education Information Network (named as EBA).

Having a national curriculum and a national technology initiative helps all students and teachers accessing the same materials since the MOE also provides textbooks free of charge to all students. When the school year starts, students have their

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books ready on their desks. One critical aspect, however, was left out during all these developments and continuous curriculum revision process: How Turkish science curriculum and Turkish teachers adapt and differentiate science instruction for different student groups? This question has taken on another dimension with the large number of refugee students currently being served by the Turkish public education system. Once we look at the statistics published by Directorate General of Migration Management, in 2016 there were 461,217 refugees with residential permit in Turkey. In this group, there were 55,983 people from Iraq and 48,738 people from Syria in addition to 166,482 Syrian students continuing their education in Turkey. When we add 293,039 students studying in Temporary Education Centers (TECs), the total number of Syrian students in Turkey reaches 459,521. By the end of 2016, more than 2.8 million Syrian refugees received temporary protection from Turkey. Istanbul hosts the biggest number of Syrian refugees with 438,861 refugees. Kilis, a town located on the Syrian border, had a population of 130,825 Turkish residents. By the end of 2016, there were 122,327 Syrian refugees in Kilis, almost equal to that of the Turkish population. Although these numbers vary across cities, it is important to note that there were Syrian refugees receiving temporary protection in all 81 cities across the country (Migration Report 2017).

In summary, the humanitarian crisis in Syria has led three million people migrating to Turkey, and all around the country, many schools have enrolled refugee children. When considering the possibility of students transferring from TECs to public schools, (Aras and Yasun 2016), this possibility urges teachers to make changes in their practices. This process will be described as contextualization in this study. In the following section, we will investigate the nature of refugee education and then discuss why contextualization of science education requires special attention.

2 The Need for Contextualized Science/STEM Education in Refugee Education

In Australia, refugee students initially enroll in Intensive English Centers and then transfer to formal classrooms (Ferfolja and Vickers 2010). In Turkey, there are two school options for refugee students, Temporary Education Centers (TECs) and public schools. In the Turkish education system, TECs are usually located in cities that host big number of Syrian refugees (e.g., Istanbul and cities close to Syrian border). As described by Aras and Yasun (2016), the Ministry of Education created the first set of guidelines in order to support refugee students' educational opportunities in 2013. Syrian students who completed high school in their countries are also allowed to continue their college education in Turkey. To understand the current situation in TECs, the researchers interviewed the heads of 12 TECs in Istanbul. Two education center leaders were of Turkish origin, and ten were of Syrian origin. The authors found that any student (even without an ID) can enroll in a TEC, but students need to obtain IDs in order to be able to graduate or receive grades. When a student arrives to at a TEC, each TEC checks the students' academic background with their own test. In this process, they also review the courses students took in their home country. If a student is eager to transfer to a public school, she/he can enroll in the nearest public school. That being said, the authors reported low level of transfer from TEC to public schools (Aras and Yasun 2016).

To describe students' challenges during this training, Ferfolja and Vickers (2010) worked with students attending to TECs (Refugee Action Support [RAS] in Australian context). When students attended classes regularly, this continuity induced a better improvement in their English skills. When looking at the students who did not attend regularly, the pattern showed that none of these students had substantial improvement in their English skills. On the other hand, teachers working in RAS described the transition to regular school system as challenging since students start schools in a context that they are not familiar with (Ferfolja and Vickers 2010).

TECs or RAS provide a transition environment with specialized programs for refugee education that primarily focuses on literacy. However, we are not interested in revealing how these perform on their own; on the contrary, we try to understand finding ways to support these students when they are not isolated from native students. Previously, Aras and Yasun (2016) described the current state of TECs in Turkey without paying close attention to what happens inside the classrooms. In this study, our emphasis will be on the public schools. In the public education system, a similar method of intensive language classes as described by Ferfolja and Vickers (2010) is used. When students enroll in a public school, students receive an intensive language support in their schools. During language education, they also continue to attend other classes such as science, math, arts, etc. The amount of language support gradually decreases as they increase their ability in Turkish.

To examine what happens when refugee students are studying in the same school with native students, MacNevin (2012) collected data from seven experienced teachers (7 years to 35 years of experience) working in Prince Edward Island. MacNevin (2012) found that teachers enjoy working with students with refugee background, even though they did not receive professional development about refugee students' education. That led teachers to finding their own solutions for students in EAL (English Additional Language) program. Teachers described the support they received during professional development (PD) focused on understanding EAL students, but not necessarily students with refugee background. Teachers also underlined the need to focus PD sessions around trauma experiences refugees might experience. During the interviews, teachers also stated that they are facing challenges in addressing students with different social needs and English proficiency. To support students, teachers pointed out the need to know more about students' background (previous experiences and education). MacNevin (2012) summarized teachers' needs as learning new skills and pedagogy associated with refugee education, providing emotional support, creating social and academic environments for refugee students, thinking students' history, and providing PD for teachers on these issues.

To present this story from a different perspective, McBrien (2011) studied Vietnamese, Somalian, and Iranian mothers in the USA. These families described their path to the new country as a challenging journey, and unfortunately they faced problems after arriving in the new country. These problems were linked to financial and language barriers. Among these families, only Afghan/Iranian parents reported communication with US schools as a challenge. McBrien (2011) summarized that parental involvement is a key for students' success.

Family involvement is an important aspect of refugee education (McBrien 2011), but there is a big emphasis on understanding teachers' practices (Aras and Yasun 2016; Ferfolja and Vickers 2010; MacNevin 2012) since there are no ground rules created to support refugee students in the classroom.

To help begin to fill this need for teachers, the main research question in this study primarily focuses on understanding what Turkish teachers do for supporting refugee students: "What is the current level of support and contextualization for refugee students provided by STEM (science, technology, engineering, and mathematics) teachers and teachers from other disciplines?"

The main research question presents teachers' perspective from different disciplines and also specifically compares what STEM teachers do for supporting refugee students when these students arrive at Turkish schools. After defining what happens when refugee students arrive to schools, then we focus on teachers' practices inside the classroom. Contextualization in this study refers to making changes in classroom settings to respond to the needs of refugee students. However, defining the big picture will not be enough for understanding what is really happening inside STEM classrooms. We will describe Turkish teachers' efforts to create new learning environments in science education by following Miller's (2009) model. When developing new science education materials for refugee students, Miller (2009) worked with teachers, students, and research assistants with science education background. Students who participated in Miller's (2009) study presented concerns about understanding science contents because of their limited proficiency of the new language. After creating a small science vocabulary for refugee students, Miller (2009) suggested that science teachers need to be aware of the language barrier, and they need to collaborate with language teachers. Miller (2009) defined science learning as a combination of understanding literacy and science content. This situation creates an additional challenge; teachers need an extra support (e.g., professional development) in order to overcome this challenge. Since all students need to take the same national assessment, supporting students' understanding in other disciplines becomes really crucial for refugee students' all-around success in school (Miller 2009).

Similar to another example presented by Román, Rosal, Rahim, Rossi, and Gates (in this issue), we will focus on how teachers make contextualized changes to national science curricula to meet students' learning needs and to adjust to new school dynamics. Due to the fact that refugee students in Turkey often have to learn a new language along with a new alphabet, we will discuss teachers' initial perspective by looking at STEM teachers and teachers' from different disciplines. Later we will specifically analyze the gap in the context of science learning. While most support programs for refugee students in Turkey focus on language learning only, in this paper we explore what we can do in a science classroom to support refugee students' learning science while learning a new language. Thus this study serves as a baseline for building an understanding about how to effectively support Turkish teachers to contextualize science education for refugee students.

Shifting the emphasis to contextualization by adapting the teaching process to respond to the context of the students requires supporting students' scientific learning via instructional support that is responsive to learners' needs (Fortus and Krajcik 2012; Roseman et al. 2008). To connect this need with the importance of preparing new learning environments in science education for refugee students (Miller 2009), in this study our second goal is to find out how teachers provide instructional support based on refugee students' needs. When specifically analyzing the need to contextualize STEM education in the context of science learning, the second research question will investigate *how middle school science teachers create contextualized learning environments for refugee students.*

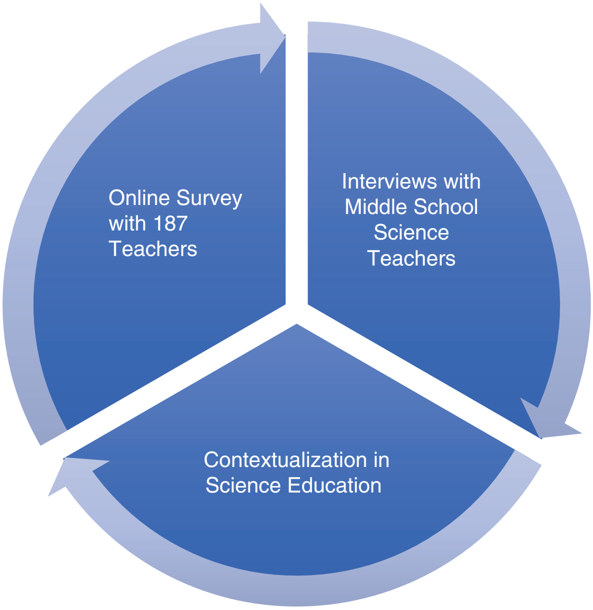
While we see science education as a starting point to support STEM education, it is important to note that how to contextualize STEM education for refugee students, so that they have equal opportunities to learn and succeed as any other student, is not only a new question for Turkish science, technology, and mathematics educators but is an urgent issue that needs to be addressed by the STEM education global community. Failing to provide contextualized STEM education for refugee students may lead to inequality of opportunities for these students to pursue their interest in STEM (Covington et al. 2017).

3 Methods

To explore the current situation of refugee education, we conducted a case study (Yin 2014). Similar to previous studies, we depicted the study from teachers' perspective (Ferfolja and Vickers 2010; MacNevin 2012; Miller 2009). This case study was conducted in one Turkish city and focused on a smaller number of teachers. As illustrated in Fig. 5.1, we collected three sources of data. First, to describe the level of support for refugee students provided by teachers, an online survey was prepared in conjunction with the Provincial Directorate of National Education. Second, we conducted a focus group interview (Kelly 2003) with two science teachers. Third, we organized several meetings with these teachers and observed how they started contextualizing science instruction in their classrooms.

All of the data were collected in the same Turkish city. There are 1202 Syrian refugees (0.34% of the city population) who have received temporary protection from Turkey (Migration Report 2017) in this city. This city is located in between Turkey's second (Ankara) and third (Izmir) largest cities of the country. The city can be considered a college town since almost 15% of the population is university students. There are no official numbers about the total number of refugee students, and the numbers continuously change each year.

Fig. 5.1 Data sources



The online survey was sent to 187 K-12 teachers (123 female and 64 male). We had 78 teachers from primary education (kindergarten and elementary teachers) and 85 teachers from lower secondary from different disciplines (Turkish, English, math, science, technology, social sciences, arts, religious studies teachers). The remaining 24 teachers were from upper secondary level (Turkish, English, math, biology, chemistry, engineering, arts, philosophy teachers). Twelve of the teachers have a master's degree, and none of them have a Ph.D. To teach at primary and secondary institutions in Turkey, teachers are required to complete a 4-year degree program in college. Very few of them pursue a graduate-level specialization, since this is not required. Among the teachers who took the survey, 19 of them have experience up to 5 years, and 26 of them have experience between 5 and 10 years. 76% of them have been teaching for more over a decade (88 teachers have experience between 11 and 20 years, and 54 of them have been teaching for more than 21 years). In Turkey, new teachers usually start in rural areas, and then as the years pass by, they become eligible to be transferred to city centers. Since the majority of refugee students are enrolled in primary and lower secondary school, we primarily sent the online survey to these schools. The multiple-choice survey questions consisted of the following themes:

What teachers would like to know about refugee students?
What schools do to help refugee students' adaptation?
What teachers do to help refugee students' adaptation?
Do teachers from different disciplines contextualize educational opportunities for refugee students?

When analyzing online survey data, we only looked at frequency analysis (Bowen 2009), since teachers were asked to choose from the options provided to them.

In the survey data, we first looked at the data for teachers from different disciplines to find out the supporting refugee students. To specifically examine STEM teachers' perspective for supporting refugee students, we separated technology, mathematics, science, and engineering teachers from the entire group. In the STEM group, there were 15 mathematics teachers (10 of them teach at lower secondary, 5 of them teach at upper secondary level), 7 technology teachers (all of them teach at lower secondary level), and 13 science teachers (10 of them teach at lower secondary level. There were one chemistry and two biology teachers from upper secondary level and 3 engineering teachers. All engineering teachers work at vocational technical schools (at upper secondary level). Within this group, there were two electricity teachers and one construction teacher. In lower secondary schools, there is no specialization for science teachers in Turkish educational system. In upper secondary schools, on the other hand, teachers start discipline-based teaching. So, we included one chemistry and two biology teachers into science teacher group.

After collecting and analyzing the survey data, we interviewed two science teachers (Su and Nil) from the same lower secondary school. We selected this school because of the partnership with the refugee education project supported by Erasmus+ program[1]. The school has 10 refugee students and 380 students in total. The school has an established system for refugee students. They welcome these students with a welcoming party every year. Therefore, the attendance rate in this school is very high for refugees. Since our initial findings revealed a lack of emphasis on contextualization, we decided to emphasize on teachers who are actively working on better serving the learning needs of refugee students. We only had one focus group interview with the teachers since they asked to be interviewed together (Kelly 2003). Su was the younger teacher, and she generally took the lead during the interviews. It is also important to note that Nil was appointed schools' vice-principal at the end of the school year. This means she will teach fewer classes, but she can concentrate on providing more opportunities for refugee students. Both teachers were teaching seventh and eighth grade and they had similar training. The teachers had not taken an action on supporting refugee students before, but they wanted to explore what they could do to better support the learning of refugee students in their classrooms with the research team. Both these female science teachers have more than 15 years of teaching experience. During the interview, the project team decided to ask the following questions after looking at other examples done in Europe (e.g., videos published by the German School Academy):

1. What are your experiences with refugee students?
2. What do you do to involve refugee students more effectively in science classes?

[1] Erasmus+ Project 2015–1-TR01-KA201–021464: Ensuring equability in Education for Migrant and Refugee Pupils

Finally, we tried to identify what is happening in science classrooms. To achieve this goal, we continued to work with the same teachers to understand what they can do to better support refugee students in their science classes. We closely worked with these teachers for 6 weeks and organized weekly meetings with them. One of the tasks that the teachers were assigned was to summarize their experiences with refugee students by emphasizing on how their ideas changed over the weeks. During the intervention, we followed Miller's (2009) model in six steps: (1) the research team met with teachers to design activities, (2) the research team translated activities, (3) teachers implemented activities, (4) the research team collected feedback from teachers, (5) the research team and teachers met with a refugee student in eighth grade, and (6) teachers finalized activities and we had another focus group interview with teachers. The research team did not visit any classroom to make sure they did not interfere with regular class flow. As stated above, we interviewed teachers before and after the intervention. During the intervention, teachers continued to design activities with the research team. At the end of the intervention, we asked teachers about their experiences. Teachers once again participated together in the interview. In the second focus group interview, we asked the teachers to describe "How this intervention helped you to involve refugee students more effectively in science classes?" When a refugee student arrives to school, the biggest challenge is to make sure that they attend classes. In Turkish system, administrators are responsible for making sure refugee students regularly attend to all enrolled courses, so administrators consistently track and report students' attendance.

To analyze the interview data and teachers' experiences, we created categories linked to the questions and then examined the patterns in these categories (Bowen 2009; Yin 2014). Categories for the interviews were linked to the interview questions listed above. In the first focus group interview (pre-interview), we emphasized on teachers' previous experiences with refugee students in science classes. In the second focus group interview (post-interview), we examined how working with the research team helped teachers to support refugee students in science classes. In addition to online survey and focus group interviews, we analyzed the field notes (Bowen 2009) taken during the meetings. The first author recorded all of the field notes.

4 Findings

In this section, we first focus on quantitative findings, and then we described how these findings led to a case study exploring potential ways to contextualize science education for refugee students.

4.1 Online Survey Findings

We divided the data into three sections: (1) What does happen when refugee students arrive to school? (2) What does happen when refugee students arrive to classroom? (3) What do teachers do to contextualize their teaching? We first presented what Turkish teachers want to know about refugee students and how they welcome refugee students to the school. Second, we looked at what teachers do for helping these students' orientation. Finally, we looked at the extent to which they contextualize their teaching. In all of these sessions, we made comparison between STEM teachers' responses and all teachers' responses.

4.1.1 What Does Happen When Refugee Students Arrive to School?

When we asked the teachers what they would like to know about refugee students (see Table 5.1), 32 teachers (17%) selected the need for additional information about their culture. 31 teachers (17%) selected the need to understand/know refugee students' language, and 1 teacher selected the need to know more about refugee students' religion. As stated by McBrien (2011), Islam is the most common religion accepted by the Middle East countries, but it is not the only religion in the region. This is why we added this option. When looking at what teachers need to know about students, a big majority (123 teachers – 66% of the teachers) stated that they need additional information about students' culture, language, and religion. Once we specifically looked at STEM teachers' perspective, we saw most of the teachers

Table 5.1 What does happen when refugee students arrive to school?

What do teachers need to know about refugee students?			What do schools and teachers do to help refugee families' orientation?		
	All teachers	STEM teachers		All teachers	STEM teachers
Need additional information about refugee students' culture	32 teachers (17%)	5 teachers (13%)	Welcome letter	1 teacher	–
Need to understand/know refugee students' language	31 teachers (17%)	8 teachers (21%)	Welcome meeting	4 teachers (2%)	2 teachers (5%)
Need to know more about refugee students' religion	1 teacher	–	Orientation sessions	44 teachers (24%)	9 teachers (24%)
Need to know about culture, religion, and language	123 teachers (66%)	25 teachers (66%)	Noting	138 teachers (74%)	27 teachers (71%)

(25 teachers – 66% of STEM teachers) selected the need for information about students' culture, language, and religion.

Besides what teachers initially would like to learn about refugee students, we were also curious to find out the existing level of support/orientation when students arrive to the schools. As presented in Table 5.1, a big majority does nothing for families as a welcoming program (74%). Only one school sends a welcome letter and few organize a welcome meeting for the parents. 24% of the teachers mentioned having orientation sessions for describing the educational resources to families in their schools. Once we looked at to STEM teachers, we once again recognized similar patterns compared to other teachers. Majority of the STEM teachers (27 teachers – 71% of STEM teachers) said they do nothing for families as a welcoming program.

4.1.2 What Does Happen When Refugee Students Arrive to Classroom?

As depicted in Table 5.1, when students arrive to schools, majority of the schools do nothing to support families' orientation. Once in the classroom, the reported support to students increases modestly. 75 teachers (40%) said they do nothing to support students' orientation. 80 teachers (43%) selected the option for presenting classroom and school rules. Thirty-two teachers (17%) also help students explore what is around the school (e.g., finding groceries, transportation). STEM teachers provide less support (60% of the teachers selected no support) for refugee students.

When students arrive to the classroom, teachers try providing more support students' orientation. On the other hand, when supporting refugee students by providing additional activities, 70% of the teachers stated that they do not plan additional activities. The most common activity selected by 21% of the teachers was playing games. Unfortunately, 44% of the teachers reported that they have never tried to support/provide guidance to refugee students in terms of navigating them in a new school or in their learning process. Teachers usually rely on school counselors. In Turkey, there is at least one counselor in each school. Consequently, when these teachers were asked to respond whether or not they are getting additional support to better serve the needs of refugee students (e.g., from an expert or institution), very few of them said they have benefited from professional development opportunities (20%), and a big majority (78%) reported that they have never asked for support (see Table 5.2). Once we looked at STEM teachers' perspective, we found that they provided less support when compared with the entire participants in all cases. Unfortunately, 16% of the STEM teachers provide additional activities to support students' orientation, only 5% of the STEM teachers always try supporting refugee students, and not many of them (13%) seek for support to better serve the needs of refugee students.

Table 5.2 What does happen when refugee students arrive to classroom?

What do teachers do for orientation?			Type of additional activities for refugee students			Frequency of support/guidance			Do teachers receive additional support?		
	All teachers	STEM teachers		All teachers	STEM teachers		All teachers	STEM teachers		All teachers	STEM teachers
School and classroom rules	80 teachers (43%)	11 teachers (29%)	Playing games	39 teachers (21%)	4 teachers (11%)	Always support when students have a problem	43 teachers (23%)	2 teachers (5%)	Continuous support	5 teachers (2%)	1 teacher (3%)
Explore what is around the school	32 teachers (17%)	4 teachers (11%)	Sports activities	10 teachers (5%)	2 teachers (5%)	Sometimes, I help if I can	62 teachers (33%)	10 teachers (26%)	Get support when they face challenges	37 teachers (20%)	4 teachers (10%)
Nothing	75 teachers (40%)	23 teachers (60%)	Art activities	8 teachers (4%)	–	Never support. Send to school counselor	82 teachers (44%)	26 teachers (69%)	Never ask for support	145 teachers (78%)	33 teachers (87%)
			No activities	130 teachers (70%)	32 teachers (84%)						

4.1.3 What Do Teachers Do to Contextualize Their Teaching?

Only 6 teachers (3%) mentioned the importance of contextualizing their practices. The remaining 181 (97%) said they do nothing different in their curriculum in terms of providing additional learning opportunities to meet specific students' needs. Connected with this finding, we found few teachers trying to understand the previous knowledge of refugee students. As presented in Table 5.3, the most common strategy used to explore refugee students' previous knowledge was asking questions. On the contrary, only 2% of the teachers think students arrive to class with

Table 5.3 Contextualization and determining refugee students' previous knowledge

The level of contextualization			Understanding refugee students' previous knowledge			What teachers do when the refugee student cannot communicate with them in Turkish		
	All teachers	STEM teachers		All teachers	STEM teachers		All teachers	STEM teachers
Trying to find ways to contextualize	6 teachers (3%)	–	The school conducts an exam before enrolling refugee students	4 teachers (2%)	1 teacher (3%)	Students arrive to class after learning the language	4 teachers (2%)	2 teachers (5%)
Nothing different in their curriculum	181 teachers (97%)	38 teachers (100%)	Teacher conducts an exam when refugee students come to their class	18 teachers (10%)	2 teachers (5%)	School organizes a language course	16 teachers (9%)	5 teachers (13%)
			Teachers asks several verbal questions to understand the student's knowledge	85 teachers (45%)	14 teachers (37%)	Refer students to a language classes organized by MOE	13 teachers (7%)	1 teacher (3%)
			Do nothing to determine students' previous knowledge	80 teachers (43%)	21 teachers (55%)	Nothing, students continue to attend the regular class	154 teachers (82%)	30 teachers (79%)

sufficient Turkish language proficiency, and 82% of the teachers said they do nothing to support refugee students when they struggle to communicate with them in Turkish.

Among STEM teachers, there were not any teachers stating that they have tried to find ways to contextualize STEM courses to serve refugee students' needs. In fact, these teachers could not communicate with some refugee students, and 79% of STEM teachers attribute this issue as doing nothing when students struggle to communicate with them in Turkish. Very few STEM teachers believe students arrive to class with sufficient Turkish language proficiency, and 18% of STEM teachers try supporting refugee students' language development by stating the role of school's language course and the courses supported by the MOE. When it comes to evaluating students' previous knowledge, 55% of STEM teachers said they did nothing to determine students' previous knowledge. 37% of STEM teachers stated that they asked several verbal questions to understand the student's knowledge. Only one math and one science teacher stated that they conducted their own exam for refugee students to determine their background. Considering STEM teachers limited action to address language barriers, their strategies to assess students' previous knowledge may raise some concerns.

4.2 Pre-interview with Middle School Science Teachers

When conducting the first focus group interview with the science teachers, one theme emerged as clear: they know these students escaped from a war zone, and all teachers want refugee students to be more included and involved; however, they often do not have enough resources to make this happen. Since teaching refugee students was a sudden change, there are still not many available resources for teachers. Science teachers try to teach Turkish and also try to support students' adaptation to the new classroom environment. The participant teachers described the main challenge that they face when teaching refugee students as the language barrier. Teachers also added that their limited knowledge about students' background was another problem. When students enroll in public schools, they are placed by looking at their age (e.g., if the student is 12 years old, she/he will be placed in fifth grade). Since students' language ability is not taken into account when starting in a new education system, this brings additional challenges:

> "Difficulty in understanding the lessons, struggling in note taking, communication problems, people and friends in different cultures, teachers having insufficient information about them create problems for refugee students. Refugee students' individual differences, readiness, sense of responsibility, culture, language, communication problems, coming to classes prepared, revising what is learned in the classroom, Math understanding, socio economic status, ability to inquire and research become problems for teaching Science." (Su, pre-interview)

Besides the great need for socio-emotional supports, facilitating the adaptation of students summarizes the main theme brought up by teachers: not only focusing on the potential role of curricular contextualization but also supporting refugee students to learn and succeed at school.

4.3 Digging Deeper: A Brief Case Study Highlighting the Importance of Students' Lived Experiences

All interventions aimed supporting the educational success of refugee students need to pay close attention to their socio-emotional and language needs. However, this will not be enough for them to have equal learning opportunities as non-refugee children. Teachers' adaptation of their teaching and contextualization of the national curriculum to support refugee students is a central piece for refugee students' success. Based on the results of the online survey, most teachers did not make many changes in the curriculum. Unfortunately, none of the STEM teachers tried making many changes when implementing their instructional plan. However, we had an opportunity to work with two science teachers who wanted to change this pattern, embarking in an interesting journey for them and the research team. To facilitate students' learning, the research team and the teachers discussed creating new activities for refugee students in their own language. Similar to Miller's (2009) study, teachers initially wanted to create a dictionary for students. Science teachers designed an activity with a dictionary they thought it was contextualized for their refugee students and shared it with the research team for translation into Arabic. Teachers knew that they had students coming primarily from Syria but they did not consider the fact that some of these students previously migrated to Syria from other countries. They were initially planning to have activities translated into Arabic, but then they realized that some students' native language was Persian. These students had an Afghan origin. After finding out this new piece of information, the research team and the teachers decided to discuss with students what they learned in science lessons in their homeland and how they learned it, as a way to create activities that are more meaningful for students beyond simply translating activities.

The research team, teachers, and a refugee student in eighth grade (last year of lower secondary school) who is fluent in Turkish discussed the science education in his homeland. During the meeting, we looked at one of the students' translated transcript. His lowest grade was Math with 75 over 100. All other grades were 90 or over. Once we discussed his previous science experience, we found out that science education in student's homeland primarily linked to life sciences, whereas Turkish middle school science curriculum emphasizes physics, chemistry, and biology. This student was clearly motivated and engaged in learning in his previous context. Now, he is doing a remarkable effort to master a new language and new subjects and trying to navigate learning in this new context. Learning about this student's life and journey changed the perception of teachers, who now not only perceive him as a hardworking student but also as a young person able to succeed academically.

4.4 How Did This Experience Help Teachers to Understand the Need for Contextualization?

After spending 6 weeks with teachers, they realized that although many students migrated from the same country, they had different countries of origin; therefore, they had learned science in the context of different curricula. As described earlier, teachers tried to design new contextualized science activities for students in six steps: (1) the research team regularly met with teachers to design activities, (2) the research team translated activities into their native language(s), (3) the teachers implemented these science activities, (4) the research team collected feedback from teachers, (5) the research team and teachers met with a refugee student in eighth grade, and (6) the teachers finalized activities. Since the teachers found out about refugee students' science background, which is primarily focused on life sciences, they started making several adaptations for these students when they implement contextualized activities. As a starting point, teachers created small visuals for the body organs related to digestion system. They later connected this to another activity in which students can match states of the matter with several figures and link their ideas to energy transfers when breaking down complex molecules during the digestion process. In this activity teachers primarily focused on physical changes with an emphasis on changes happening during digestion. At the end of this experience, teachers shared their experiences and how contextualization of science teaching changed their ideas about what effective teaching looks like. They stated that the language barrier is still a huge factor for students' adaptation: "Without knowing Turkish, students would not understand the content. They cannot do homework since they do not understand the teacher" (Nil, post-interview). However, it is also positive to see that they are becoming more thoughtful about providing diverse learning opportunities in their classrooms:

> "In science classes we need to be more sensitive to refugee students. We need to provide equal opportunities. Teachers need professional development for this. Students should bring a dictionary to school, and the basic terms during the class should be matched by looking at the dictionary. We need to prepare special visuals. To facilitate students' confidence, we need to assign them roles during activities and classes." (Su, post-interview)

5 Discussion

Considering how refugee students arrived to Turkey, we realized that they all experienced harrowing journeys in dangerous routes. When teachers understand students' lived experiences (e.g., coming from a war zone), they are more likely to show willingness to know more about their refugee students and to support their learning process. Unfortunately, based on the online survey, very little has been done so far to support refugee students' learning science, in general, adapting to a new environment. Almost none of the surveyed teachers contextualized their instruction, assessed refugee students' previous knowledge, or communicated with these students about their experiences and needs.

The current situation in Turkey, where schools have seen a significant increase in the enrollment of refugee students, is a sudden change that calls for urgent support for teachers to be effective in this new context. Language support alone, although much needed, is not enough. Teachers will need tools and resources to teach STEM to Turkish language learners and to use STEM teaching to support Turkish language learning.

Education is a right for all students, regardless of nationality (Universal Declaration of Human Rights Assembly 1948), and quality education goes beyond language learning. Since STEM education is central to quality education in the twenty-first century, by contextualizing STEM education, not only we are guaranteeing refugee children's right to quality education, but we are also benefitting Turkish children with opportunities to develop intercultural competence[2] (UNESCO 2013).

As STEM educators, we need to make sure that all students, regardless of their background, have the opportunity to experience quality education (Covington et al. 2017). Acting on this issue would not be without a challenge. Teachers need professional development to respond to this new situation (Guskey 2002; MacNevin 2012). Since understanding what students already know plays a vital role in learning, lack of contextualization will render learning environments ineffective to support the students who need it the most.

Our findings are aligned with what other authors have found about contextualization of STEM education. Contextualization of STEM education starts by knowing students' lived experiences, uncovering their prior knowledge, and using this information to adapt teaching and curricular materials to better serve students' learning needs (Jiménez-Aleixandre and Brocos in this issue; Román et al. in this issue; Sánchez Tapia et al. 2018). Moreover, we found that when teachers spend more time with students trying to understand their story and lived experiences, their expectations of students' performance change as well as their teaching practices. Successful science instruction can only be possible when teachers adapt their language and practices (Fortus and Krajcik 2012), and as we observed in the case study, this was only possible when teachers focused on the students' background and their learning needs (Roseman et al. 2008; Sikorski and Hammer 2017). Another important aspect that we want to underline as a conclusion is the potential of collaborative teaching teams to favor language learning in disciplinary contexts. This study initially started with creating a dictionary (Miller 2009) but this was not enough. When STEM teachers, research teams and language teachers work together, refugee students have a greater chance to be supported beyond language barriers and succeed academically (Miller 2009).

Finally, it is important to highlight that to support refugee students' scientific understanding, we need to pay special attention to the language support (Miller 2009). To master STEM subjects, refugee students need to learn the language of the home country and to navigate a new education system.

[2] Intercultural competence is the idea that different groups need to find a way to live together harmoniously.

We hope that this exploratory study will raise awareness of the importance to add refugee education into the STEM education research agenda. We do know the conclusions of this study are limited, given its small sample. However, it still brings important issues on how to better support teachers to contextualize STEM education for refugee students open for educational researchers and stakeholders.

We are confident that the dynamic nature of Turkish curriculum will respond to this sudden change, and then future studies will take initiative for further research to explore the contextualization of STEM education in the context where refugee students are welcomed.

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Chapter 6
Contextualization in the Assessment of Students' Learning About Science

Hendrik Härtig, Jeffrey C. Nordine, and Knut Neumann

1 Introduction

In the assessment of students' learning about science, contextualization has become increasingly important. In times when students were learning about science mainly for academic reasons, assessments were focused on students' knowledge of science ideas. Now students are learning about science to be prepared for the challenges of a life increasingly permeated by science and technology (National Research Council 2012; for an overview see Waddington et al. 2007). In order to be able to meet these challenges, a mere knowledge of science ideas is not enough. Instead, individuals need to develop a knowledge that is organized around the core ideas of science; that allows for a quick retrieval of the knowledge relevant to a particular challenge, enabling individuals to effectively apply their knowledge to challenges in their everyday lives (Bransford et al. 2000); and that prepares them for challenges they may encounter in their future lives (Bransford and Schwartz 1999). Such knowledge is also referred to as knowledge-in-use (Krajcik et al. 2008) or integrated knowledge (Fortus and Krajcik 2012). Assessments of students' learning about science need to reflect this shift in the aims of science education. Instead of simply assessing students' knowledge of science ideas, assessments need to assess students' integrated knowledge, that is, students' ability to use their knowledge in the context of the actual challenges that students may face in their everyday as well as their future lives.

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2 Contextualization in Assessments

The contextualization of science education is one prominent way to support students in developing an integrated knowledge. In order to support students in developing integrated knowledge, science education needs to help them relate science ideas to each other, connect these relationships to observations of the real world, and establish such connections across multiple contexts (Bransford et al. 2000; Fortus and Krajcik 2012). Science education that supports this kind of learning should be based on a sequence of problems to guide students in the successive development of a relational network between science ideas in the light of one or more core ideas of science (Fortus and Krajcik 2012). To convey connections between such networks of science ideas and the real world, the problems should stem from the real world and hold relevance for students (Bulte et al. 2005). However, the real world is complex, and not every aspect of it bears the same relevance to every student. It therefore is important that science ideas are explored across diverse problems. Knowledge that is taught only in the context of a single problem is less likely to support flexible transfer than knowledge that is taught in multiple contexts. With multiple contexts, students are more likely to abstract the relevant features of concepts and develop a more flexible representation of knowledge (Bransford et al. 2000). Science education that is built around real-world problems with relevance to students – i.e., contextualized science education – is more likely to support the ability to use knowledge to solve known and unknown problems (Fortus et al. 2015).

In the same way that contextualized science education is expected to support the development of integrated knowledge, contextualized assessments are expected to provide a better assessment of integrated knowledge. Instead of assessing students' knowledge about individual science ideas in selected domains of science, contextualized assessments must identify the extent to which students have developed knowledge of the relationships between science ideas and were able to use this knowledge to solve a wide range of (real-world) problems (Bernholt and Parchmann 2011; Quellmalz et al. 2012). This is illustrated by Fig. 6.1. In Fig. 6.1a, a traditional assessment task assessing students' knowledge about kinetic energy is displayed; in Fig. 6.1b, a contextualized task assessing integrated knowledge of the relationship between several ideas about energy as a disciplinary idea (i.e., kinetic energy, gravitational energy, and energy transformation) is shown. The most obvious difference between both tasks is the use of a real-world scenario in the contextualized task.

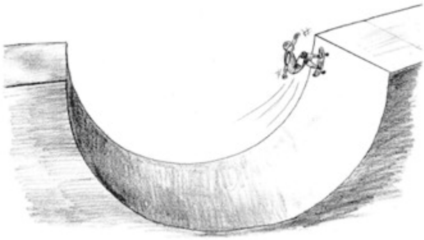
2.1 Scenarios as a Means to Contextualize Assessments

The main purpose of using scenarios in assessment tasks is to create a connection to the real world. Shannon (2007) suggests that in order to create a connection to the real world, scenarios do not necessarily have to be real-world scenarios. In fact,

(a) What is the relationship between the kinetic energy of an object and its speed?

- Linear
- Quadratic
- Polynomial
- None of the above

(b) A skater goes back and forth in a half-pipe without pushing on the half-pipe with her feet. How can skateboarding be described using energy?



- The kinetic energy of the skater is converted into gravitational energy when the skater is moving up the walls of the half-pipe. This gravitational energy is converted back into kinetic energy while the skater is moving down the walls of the half-pipe.
- Gravitational energy of the skater is converted into kinetic energy while the skater is moving up the walls of the half-pipe. This kinetic energy of the skater is converted when the skater is moving down the walls of the half-pipe.
- The skater gets power out of chemical energy of his food. The skater can convert this power into kinetic and gravitational energy without having to push.
- The gravitational energy of the skater is converted into kinetic energy while the skater is moving down the walls of the half-pipe. As a result, the skater gets power to go up the walls on the other side of the half-pipe.

Fig. 6.1 Assessments of students' knowledge of kinetic energy (**a**) and students' integrated knowledge about energy as a disciplinary core idea (**b**)

fictional scenarios can also help fostering a connection between relational networks of science ideas and the real world. In "The Physics of Superheroes," for example, Kakalios (2005) uses a scenario from a Spider-Man comic book to discuss what happens if a human body is suddenly brought to stop after falling from a great height (see Fig. 6.2). This scenario offers the possibility to not only connect different

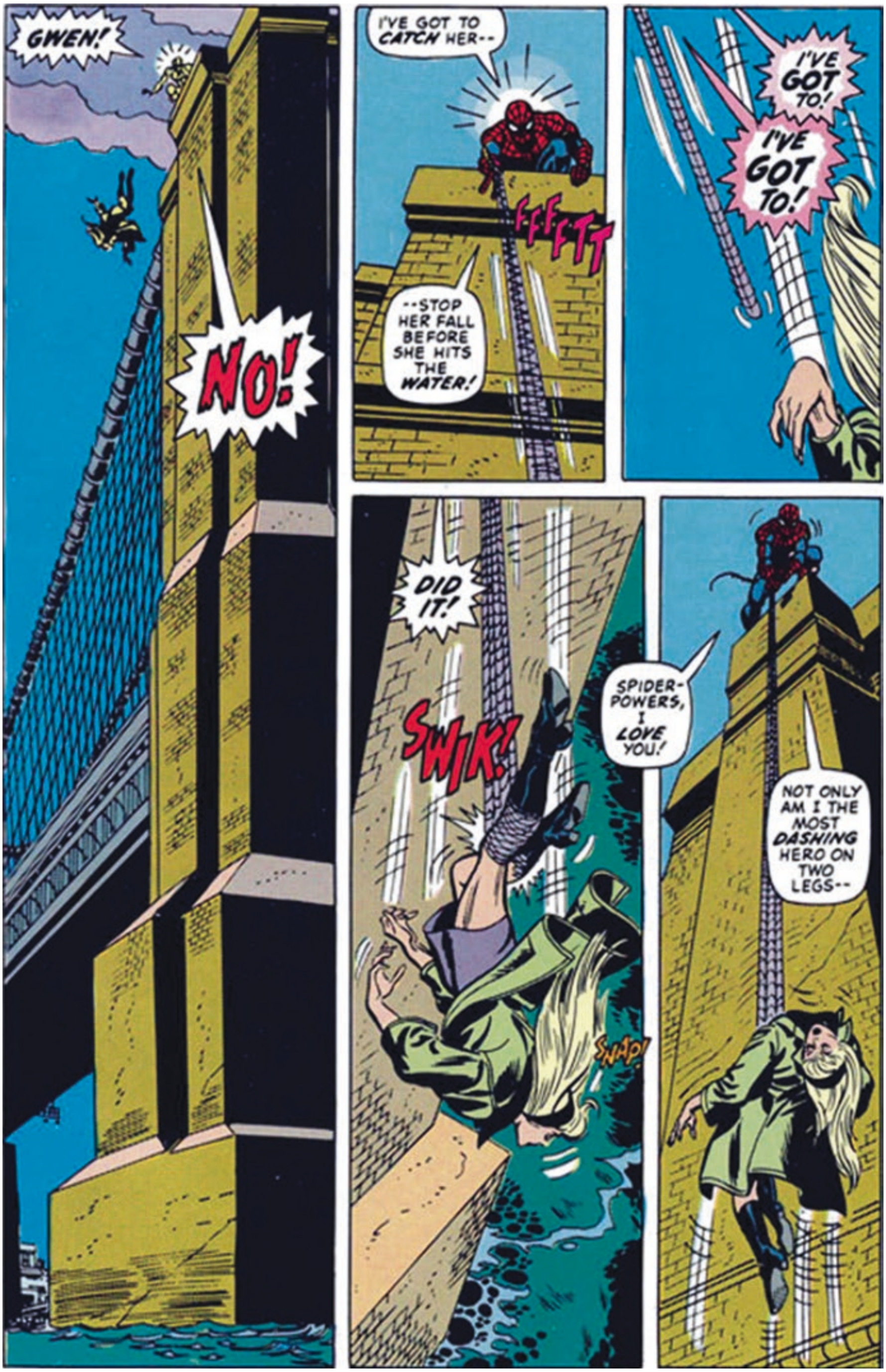


Fig. 6.2 Gwen Stacy's fatal plunge from the George Washington bridge as used by Kakalios (2005) for teaching ideas about impulse and momentum

physics ideas such as gravity, energy, or speed but also allow for connections to biology and chemistry. Namely, a (full) discussion of the problem would have to include ideas about how the human body works – specifically how the head is connected to the rest of the body (and why) – and how spider webs work, specifically the extent to which spider webs can potentially expand without snapping. Thus, although the scenario is purely fictional, it can support establishing relationships between science ideas and connecting them to the real world. Another purpose of scenarios is to engage students. In order to do so, they need to be relevant to students (Shannon 2007). Relevance can occur on different levels. Bybee et al. (2009) differentiate, for example, between personal, social, and global levels. That is, scenarios can have personal relevance to students, relevance to the community students are living in, or global relevance to mankind. Last but not least, scenarios are expected to help setting up richer assessments. If the tasks are not simply presented in the context of a scenario but well integrated with it – that is, the task emerges from the scenario – they can provide students with a richer opportunity to use their knowledge about science ideas in context (Shannon 2007).

The benefits of setting tasks in rich, relevant, and real-world scenarios have been pointed out by many different researchers (Shannon 2007). However, researchers have also identified negative effects of contextualizing tasks through scenarios. Bock et al. (2003), for example, found students to perform significantly *worse* on contextualized tasks in comparison to non-contextualized tasks. Other researchers have found students to perform differently on contextualized tasks – depending on students' familiarity with the scenario (Griggs and Cox 1982; Johnson-Laird et al. 1972). From a theoretical point of view, an influence of familiarity with the scenario on students' performance seems reasonable. Those familiar with a particular scenario have to only identify the relevant aspects and ignore everything else; those unfamiliar with a scenario may not even be able to answer it (Ahmed and Pollitt 2007). If we take the contextualized task in Fig. 6.1b, for example, the task may be suitable to assess urban students' integrated knowledge about energy as a disciplinary core idea. For students from a more rural environment, who may not be familiar with such a half-pipe – or even skateboarding at all – the task may not work. In fact, the task may not only not work but disadvantage those students as they might have the integrated knowledge to answer the task but not have access to sufficient knowledge about how skateboarding in a half-pipe works (i.e., students may not know that "to push" in a half-pipe means to accelerate). Similarly, asking students to solve items within the context of public transport which was an actual task in the PISA 2012 study (OECD 2014) may not be a real-world scenario for students in more rural areas of the world. Additionally Boaler (1994), for example, suggested that a greater involvement with the scenario may lead students away from the actual problem, in turn leading to a lower achievement. And Mevarech and Stern (1997) concluded that scenarios may not only divert students' attention from the task but can activate inappropriate reasoning patterns. Especially assessment tasks which make use of everyday-life scenarios seem to elicit inappropriate reasoning patterns (Baumert et al. 1998). These specific reasoning patterns have been verified for different science concepts such as evolution (Nehm and Ha 2011), force (DiSessa and

Sherin 1998), or light (Chu et al. 2009). In some cases, specific features of the scenario were found to directly influence the way students respond. For example, matter-specific ideas are bound to features like the mass or the shape (Potari and Spiliotopoulou 1996). In summary, scenarios may invoke cognitive processes other than the intended ones that can positively or negatively affect students' performance and thus compromise validity (Ahmed and Pollitt 2007).

2.2 *Response Format as an Often Neglected Feature of (Contextualized) Assessments*

In addition to the scenario, tasks often vary in other characteristics that can influence students' performance. Such characteristics include, for example, the response format. The contextualization of tasks often involves extra text to introduce the scenario and focusing on what actually students need to do. If students have to read more text to understand the scenario and to answer a question, their reading ability is assessed in addition to their integrated knowledge (Ahmed and Pollitt 2007). In a similar way, the response format is likely to affect students' performance. Students were found to receive a lower score if a task requires the construction of a response in the place of the selection of a response in the context of a multiple choice task (DeMars 2000). The magnitude of the effect differs, however, between studies and seems to depend on the similarity of the tasks between both response formats (Rodriguez 2003). In particular, language learners (i.e., students whose mother tongue is not identical with the langue of instruction) seem to be disadvantaged by the use of multiple-choice tasks (DeMars 2000). One likely reason for this bias in multiple-choice tasks lies in how such tasks are designed. Typically, the incorrect response options are worded in a way that is very similar to the correct response options. For language learners that may create an obstacle as they may fail to catch the subtle differences between the different answering options (see Fig. 6.1b as an example). Also the language used in contextualized tasks can be more complicated (see Fig. 6.1b in contrast to Fig. 6.1a as an example). Tasks may, for example, involve culturally specific terms that language learners or students stemming from a different cultural background (than the one presented in the task is drawing on) may have difficulties with (Ahmed and Pollitt 2007).

Even in the light of such arguments, multiple-choice tasks are still favored in many test instruments, for one, because they are more efficient in the large scale, which makes them an economic choice in international comparison or larger research studies. Many concept inventories such as the Force Concept Inventory (Hestenes et al. 1992) or the Concept Inventory of Natural Selection (Nehm and Schonfeld 2008) are based on multiple-choice tasks. Recently, however, item formats other than multiple-choice have received increasing attention. Briggs et al.

(2006) have, for example, suggested an enhanced version of multiple-choice tasks – so-called ordered multiple-choice tasks (Hadenfeldt et al. 2014). Constructed-response tasks are gaining renewed attention, too, as correlations between constructed-response tasks and interviews have been found to be higher than correlations between multiple-choice tasks and interviews (Opfer et al. 2012). These findings have also fueled a debate about performance tasks. One reason lies in the discussion around the influence of students' language skills or cultural background. Any form of written or oral assessments will always penalize students that are language learners. Performance tests do not (necessarily). Also, while written as well as oral assessments are standard in many societies or cultures, they are not everywhere. Thus when it comes to assessing students' integrated knowledge (i.e., students' ability to use their knowledge about science ideas to solve real-world problems), using performance assessments can help provide a better picture on students' ability to use their knowledge in the context of real-world problems. However, so far, little research exists how such formats affect students' performance.

In summary, there are different characteristics of tasks that can affect students' performance in an assessment, the most important one in contextualized tasks being the scenario. However, the scenario is not the only feature affecting students' performance. Other factors include the response format such as the mode of administration (i.e., paper-and-pencil vs. performance assessments). Focusing on selected response formats will narrow down the construct assessed (Messick 1994). In light of the changes in the aims of science education from the knowledge of individual science ideas towards a knowledge of relationships between ideas and the ability to use this knowledge across a wide range of problems, the modern tasks build the context for the assessment of student learning. In the following sections, we will further develop this idea and illustrate the role of the scenario and the response format (when controlling for the scenario) in developing assessments or assessment tasks, respectively.

3 The Role of the Scenario

For our illustration of the role of the scenario – more specifically, how the scenario affects students' performance even when carefully attending to the issues known about the use of scenarios – we are using data from two previous studies (Hadenfeldt et al. 2014; Neumann et al. 2013). These studies were originally designed to explore students' progression in developing an integrated knowledge (i.e., understanding) of energy and matter, respectively.

3.1 How the Scenario Affects the Assessment of Integrated Knowledge

Science education research has identified four science ideas underlying an understanding of energy as a disciplinary core idea: (1) energy is manifested in different forms and stored in different places; (2) energy can be transformed from one form into another or be transferred from one place to another; (3) whenever energy is transformed or transferred, some energy is converted into heat that spreads out (dissipation); and (4) the overall amount of energy in an isolated system is conserved (Domenech et al. 2007; Duit 1984; Quinn 2014). The ability to relate these ideas to each other and use these relationships in the context of a wide range of problems is considered to form students' integrated knowledge about or understanding of energy (Chen et al. 2014; Lee and Liu 2010).

The extensive research on students' understanding of the energy concept, however, suggests that students have trouble mastering an understanding of energy as described above (Vosniadou 2008). Among other findings, this research found that students enter formal science education with a variety of non-normative ideas about energy (Lijnse 1990; Trumper 2007). DiSessa and Sherin (1998) suggest that these non-normative ideas are the result of students developing mental models that are deeply rooted in their own experiences. These mental models are tightly connected to the specific context (or features thereof) in which they have been developed (DiSessa et al. 2004). That is, each context is connected to a unique mental model. Through purposeful science education, students' ideas are explicated, discussed with respect to their (potential) limitations, and related to each other to be refined into scientifically appropriate (i.e., more normative) ideas or relational networks of ideas (Duit et al. 1992). As a result, in contextualized assessment tasks, students with higher expertise should be able to use their integrated knowledge to solve problems and ignore (irrelevant) features of the concrete scenario, where novice students are easily distracted by selected features of the scenario (Chi et al. 1981; Nehm and Ha 2011).

In our study of students' progression in developing understanding of energy, we examined the extent to which 1856 students from grades 6, 8, and 10 in German middle school developed an integrated knowledge about energy (Neumann et al. 2013; Weßnigk and Neumann 2016). In order to do so, we used contextualized tasks – that is, tasks in which students were presented a scenario that they had to explain or model using their integrated knowledge about energy. Authoring of the tasks followed a rigorous procedure in order to consider the known issues with contextualizing tasks. The first step in this procedure was to identify a scenario involving a scientific phenomenon or other process students would know or have observed in their everyday lives. These scenarios included, for example, a stone being dropped on the ground or an airplane taking off (for an overview of all the scenarios used, see Table 6.1).

In the second step, the energy story underlying this scenario was explicated in a way analogous to the one described by Papadouris and Constantinou (2013). That

Table 6.1 Scenarios used in the tasks used for assessing students' understanding of the energy concept

Scenario	Short description
Car (AT)	Car(s) driving on a road, running out of fuel, crashing into a wall
Bow and arrow (BO)	Arrow being shot from a bow, flying through the air
Bike (FR)	Student riding a bicycle
Airplane (FL)	Airplane taking off, flying, and landing
Power station (KW)	Different power plants producing electricity
Milk (MI)	Two glasses with milk of different temperature, being mixed
Miniature golf (MG)	Ball rolling across a miniature golf course
Pendulum (PD)	Pendulum being deflected, swinging back and forth
Skater in a halfpipe (SK)	Skater standing atop a half-pipe, riding a half-pipe
Stone (ST)	Stone being dropped from the hand
Flashlight (TL)	Flashlight running out of battery
Trampoline (TR)	Gymnast jumping up and down on a trampoline
Wind turbine (WK)	Wind turbine generating electricity

is, the phenomenon or process presented in the scenario was described in terms of energy (using normative ideas about energy). This was done to create focus. Ahmed and Pollitt (2007) pointed out that sometimes in the way scenarios are presented, there is a particular risk that features of the scenario irrelevant to the problem are foregrounded. The authors introduce the idea of focus: "a question in a given context is focused to the extent that it addresses the aspects of the context that will be most salient in real life for the students being tested. A more focused context will then help activate relevant concepts, rather than interfering with comprehension and reasoning" (p. 201). Based on the energy story, in the third step, multiple-choice tasks were created requiring different levels of knowledge integration, from the knowledge of energy forms to an understanding of energy conservation. Each task, in addition to the correct response option, offered students response options addressing typical misconceptions about energy. For each scenario, multiple tasks were developed assessing 16 levels of knowledge integration with 4 major levels and 4 minor levels for each major level (Neumann et al. 2013). In total, 120 tasks assessing 16 levels of knowledge integration about energy in the context of the scenarios listed in Table 6.1 were included in the study. The contextualized task shown in Fig. 6.1b is one of these tasks. The 120 tasks were distributed across 12 booklets each containing 20 tasks using a linked design. Each student received one booklet. The dataset was analyzed using Rasch analysis to obtain information for how difficult the tasks were (or how well students performed) as a function of the level of knowledge integration required to solve the task and the scenario in which the task was presented (Neumann et al. 2013).

In a first step of our analysis, we examined the extent to which tasks requiring a higher level of knowledge integration were more difficult. We found a noticeable effect of the (major) level of knowledge integration on task difficulty, F(3,

98) = 12.85, $p < 0.001$. The variance explained by the level of knowledge integration was about 28%, suggesting that the more ideas about energy need to be integrated, the more competent students need to be. In a second step, we investigated the effect of the scenario on the difficulty of the tasks (see Fig. 6.3). As the results shown in Fig. 6.3 suggest, we found the scenario to have a remarkable effect on task difficulty, $F(12, 89) = 2.34$, $p < 0.05$. More specifically, 24% of the variance in the difficulty of the tasks were explained by the scenario.

Obviously, the scenario has almost the same effect on task difficulty as the level of knowledge integration. This suggests that the scenario has an influence on task difficulty that cannot be neglected. In order to further explore this finding, we analyzed the interaction between the scenario and the level of knowledge integration and found a noticeable effect, $F(15, 71) = 14.73$, $p < 0.001$. This suggests that two tasks assessing the same level of knowledge integration may differ considerably in difficulty if they stem from different scenarios. A task requiring the application of only one idea about energy may even require higher student competence than a task assessing students' ability to relate multiple ideas to each other – just because the scenarios are different. One possible explanation for this finding lies in DiSessa and Sherin's (1998) idea of mental models (or p-prims) being connected to particular situations. According to DiSessa and Sherin (1998), learning corresponds to the development of increasingly decontextualized mental models, that is, models that are applicable across a wider range of contexts. This suggests that in assessing students' progression in developing an integrated knowledge about core science ideas, the scenario (or context) may play a bigger role than previously expected. If knowledge is specific to the context at first, we do not only need different tasks for different levels of knowledge integration, but tasks to assess different levels of knowledge integration across a wide range of scenarios. If this is the case, there are implications for the research on learning progressions, such that in order to determine students' level of understanding of a particular core idea, many more tasks would be needed than are typically utilized at the moment.

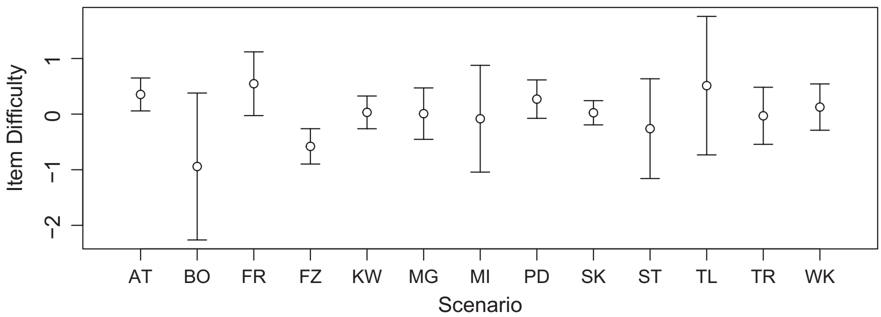


Fig. 6.3 Task difficulty as a function of the scenario (see Table 6.1 for the meaning of the abbreviations and more detailed descriptions of the scenarios)

3.2 How to Account for the Effect of the Scenario on the Assessment of Integrated Knowledge

The assessment of students' integrated knowledge – that is, students' ability to identify relations between science ideas and use these relations to solve a wide range of real-world problems – would require not only tasks involving a wide range of different scenarios but also a large number of tasks within one scenario. Only then can we assess whether students can reliably identify relationships between ideas – and whether they can reliably connect these relationships to the real world. Typically, the number of tasks needed to do this exceeds that number of tasks that can be meaningfully administered to students in a given period of time. A potential solution to this dilemma is tasks that allow for assessing the extent to which students were able to identify science ideas and relate them to each other in the context of one scenario – such as open-ended tasks. Another format that can assess the extent to which students can identify science ideas and relationships between them are ordered multiple-choice (OMC) tasks (Briggs et al. 2006). Another solution might be constructed response tasks.

In order to illustrate how OMC tasks can be used to more reliably assess students' level of integrated knowledge in the context of a particular scenario, we will draw on data from a study originally designed to assess students' progression in developing integrated knowledge about (or understanding of) matter (Hadenfeldt et al. 2014). Much like with the energy concept, there is a particular consensus that four ideas are involved in students' progression in developing understanding of matter: (1) structure and composition, (2) chemical properties and change, (3) physical properties and change, and (4) conservation. In case of matter concept, however, students' increasingly integrated knowledge about (or understanding of) matter is thought to be characterized by an increasingly integrated knowledge about each of the above ideas (Liu and Lesniak 2005). We utilized OMC tasks to assess students' level of knowledge integration about an idea in the context of a single scenario.

In principle, OMC tasks work like regular multiple-choice tasks. A problem is presented and several response options given. One response option represents the correct answer (i.e., a scientifically appropriate understanding). All other options are incorrect (i.e., represent a scientifically inappropriate understanding). The correct option corresponds to the highest level of knowledge integration that can be assessed with this task. All other response options correspond to lower levels, usually reflecting typical misconceptions that arise from a less integrated knowledge. In case of the example shown in Fig. 6.4, the first option (option a) represents the highest level of knowledge integration (i.e., Level 2 – hybrid particle concept) that involves linking the (scientifically) normative ideas of water being in the air and water condensating on cold(er) surfaces. The remaining options mark lower levels of knowledge integration (Level 1 – naïve particle concept) reflecting non-normative ideas developed from everyday experiences. Even if a student falls short in choosing the right answer, he or she can be assigned a level of knowledge integration. That is, where a regular multiple-choice task provides us only with the information of

It's summer time and Nina takes a drink can out of the fridge. She puts it aside in order to get a glass. When she comes back, she finds some drops of liquid on the outside of the can. Where does the liquid come from?

a)The liquid comes from the air. (2)

b) The liquid comes from the inside of the can. (1)

c) The liquid comes from the cold. (1)

d) The liquid comes from the heat. (1)

e) The liquid comes from the fridge and was not visible at first. (1)

Fig. 6.4 Sample ordered multiple-choice (OMC) task

whether a student has mastered a particular level of knowledge integration in the context of a particular scenario, OMC tasks can provide us with information about which level of knowledge integration a student can achieve in the context of a particular scenario.

As part of our study, we developed a total of 44 OMC tasks following a rigorous procedure similar to the one described above (Hadenfeldt et al. 2016). Again, we selected scenarios and identified a problem within this scenario. Then we created the correct response option and subsequently incorrect response options based on a review of typical student alternative conceptions. Using the data collected from 1368 students from grade 6 to grade 12 of German middle and high schools, for the purpose of this chapter, we investigated the effect of the scenario in comparison with the effect of the level of knowledge integration for each of the four ideas about matter. We analyzed measures of task difficulty obtained from the analysis reported in Hadenfeldt et al. (2016). In this analysis we utilized a Partial Credit Rasch Model to obtain for each task, the difficulty measures for each level of knowledge integration represented in this task. That is, for each level of knowledge integration (other than the lowest level) represented in a task, we obtained a measure of how difficult it is for a student to master this level of knowledge integration. In the task shown in Fig. 6.1, for example, it should be more difficult for students to choose option (a) over the other options because this option requires a higher level of knowledge integration (in this case simply the knowledge of a scientifically normative idea instead of a non-normative idea developed from everyday experiences).

The results of our analysis of the difficulty measures as a function of scenario and complexity for each of the four ideas about matter are shown in Table 6.2. Overall, we do not find an effect of the scenario, whereas we can identify a significant effect of the level of knowledge integration. More specifically we find that for the big ideas *structure and composition* and *physical properties and change*, we find a clear effect of knowledge integration and no effect of the scenario. For the big idea *chemical properties and change*, we do not find an effect at all (which is well in line with the findings reported in Hadenfeldt et al. (2016) that the items assessing

Table 6.2 The effect of context and complexity of students' understanding of matter on the item's difficulty for each of the four big ideas about matter

	Scenario			Complexity		
Big idea	F	p	η^2	F	p	η^2
Structure and composition	2.02	= 0.12	0.48	16.70	< 0.001	0.69
Chemical properties and change	0.75	= 0.58	0.25	2.68	=0.14	0.29
Physical properties and change	7.78	= 0.52	0.34	3.84	< 0.05	0.41
Conservation	3.66	< 0.05	0.68	7.65	< 0.05	0.51

chemical properties and change did not work as intended). For the big idea *conservation*, we found an effect of both the scenario and the complexity. This suggests that as students progress toward a more integrated knowledge about conservation, they may be able to correctly apply their knowledge to one scenario but not necessarily to another.

We can conclude that OMC tasks can be used to reduce the effect of the scenario, effectively offering the opportunity to measure the extent to which students are able to connect relational networks between science ideas to real-world problem solving. In some cases (like the idea of conservation), there may still be an interaction effect suggesting that integrated knowledge (or understanding) about a concept is not simply the ability to apply relational networks to a given problem (requiring understanding of the concept in question), but that the scenario in which the problem is situated may play a major role in how students perform. That we found this to be the case for the idea of conservation of matter together with the extensive literature on the persistence of everyday conceptions around the conservation of matter seems to confirm once more the role of students' mental models and their contextualization (Bransford et al. 2000; DiSessa and Sherin 1998).

In summary, our analyses reveal that the role of the scenario must not be ignored in the design and analyses of contextualized tasks. For one, the range of scenarios students can consistently apply their knowledge to is a measure of the extent to which students' knowledge is actually integrated, that is, how firmly students have established the relationships between the science ideas in question. However, the range of scenarios is also a measure of how well students' knowledge is decontextualized (Bransford et al. 2000), that is, how well students can connect their knowledge about the relationships between science ideas. Our analyses also showed that while many multiple-choice tasks are needed to assess students' integrated knowledge, using OMC tasks can help reduce the number of tasks needed considerably. This raises the question of how the response format affects the assessment of students' integrated knowledge. For example, do open-ended tasks require the same integrated knowledge or understanding of a concept as multiple-choice tasks? And what about other, more innovative formats of assessments such as performance assessments? If controlling for the scenario, will such formats yield the same results?

4 The Role of the Response Format

In order to explore the role of the response format, we are drawing on data from two more studies. One study was specifically designed to investigate the role of the response format when controlling the scenario in the context of assessing students' understanding of the concept of force (Härtig 2014). The other one was carried out as part of a research project on the influence of different ways of teaching students about the control of variable strategy on students' ability to use their knowledge to solve problems across different scenarios (Schwichow et al. 2016c).

4.1 How the Response Format Affects the Assessment of Integrated Knowledge

Concept inventories have been built around contextualized multiple-choice tasks for a considerable amount of time now. One such inventory is the Force Concept Inventory. This concept inventory has been designed to assess students' understanding of the force concept and students' progression in developing understanding of the force concept. In its published version, the FCI includes 29 multiple-choice tasks in which students are supposed to apply their integrated knowledge of Newtonian physics across different scenarios (Hestenes et al. 1992). The FCI has been used without modifications for more than 20 years now in many different countries and languages to prove students' conceptual understanding and the effect of specific curricula. As it is a standardized instrument, the scenarios as well as the response format are usually not varied across different studies. However as argued above, the scenarios as well as the response format might influence students' performance within an assessment. In the past it could be shown that within a re-submission of the FCI, students switch back and forth between different distractors when the same question is shown more than once (Lasry et al. 2011). Also a relevant proportion of students who perform very well in the FCI were found to be unable to reproduce their results in interviews (Savinainen and Viiri 2008). Additionally, in a comparison of four tasks of the FCI presented in both multiple-choice and open-response formats, students who received the open-ended tasks offered more false solutions than offered by the distractors in the multiple-choice version (Rebello and Zollman 2004).

In order to further examine these results, we designed a study to find out whether the systematic variation of the response format within the FCI may affect students' performance. The goal was comparing results from the same students between constructed response and multiple-choice format tasks – while keeping the scenario(s) identical. To meet this criterion, the study was limited to a subset of FCI tasks. More specifically, we selected those tasks that represent the same aspect of Newtonian physics. In all tasks, students had to describe whether and which forces were acting.

Additionally, in some of the tasks, students were asked to describe in detail how the (gravitational) force might change during the movement. Seven tasks have been selected in total from the FCI. Since we hypothesized – in line with the findings presented in the previous section – that the scenario may influence student performance, we added several more items: We took one original item (e.g., golf; see Fig. 6.5) and embedded the same task in a different scenario (e.g., a soccer ball is kicked). The multiple-choice version of the instrument consisted of 13 tasks. All tasks were then administered additionally as constructed response questions to be answered. Each student received all 26 (13 MC, 13 CR) tasks. To avoid a bias, the constructed response tasks were always presented before the MC items. Otherwise a student could be influenced by the offered answers within the MC item when answering the constructed response version.

The main purpose of this study was to compare the results from the open-ended answers with the results from multiple-choice questions. The assumption would be that students choose or write down the same ideas regardless of the response format. For our analysis, students' answers were dichotomized (coded into correct or incorrect). We then constructed and compared a set of three structural equation models (SEM). SEM is a statistical technique in which one tries to explain a data pattern using a hypothesized model (Maruyama 1997). We explained the patterns using one dataset and comparing three possible hypothesized models.

Baseline model: All 26 tasks defining only one latent variable. This model assumes that the students' ability of expressing their understanding is neither related to the scenarios nor to task format.

Format model: Instead of 1 general variable, there are 2 independent latent variables differentiating the 13 open-ended tasks and 13 closed-response tasks. This model takes into account that differences between multiple-choice and open-response formats have been found for other concept inventories. It is hypothesized that just deciding (multiple-choice) and writing (open-ended) are completely distinct, yet somehow related.

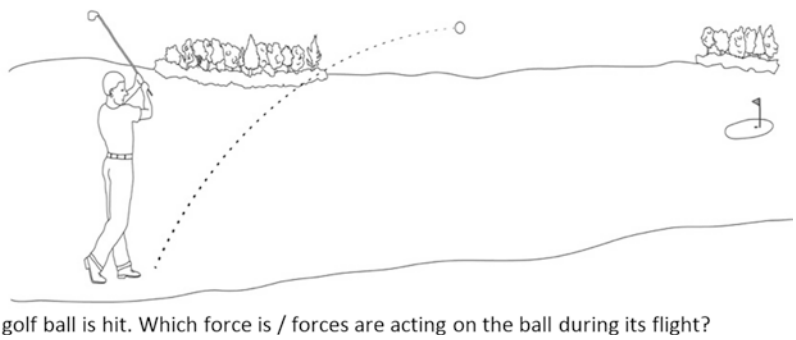


Fig. 6.5 Example of a constructed response item: Students have to write down an answer without offering multiple-choice options

Nested format model: Besides a general latent variable, two nested factors differentiate between the response formats. Within this model, both aspects are taken into account, since a general latent variable measured by all 26 tasks describes the force concept understanding, while two integrated (nested) latent variables account for additional components of the model. The first variable is based on the 13 open-ended tasks; the second one consists of the 13 multiple-choice tasks.

The sequence of different hypothesized models is crucial. This is mostly due to the fact that, by comparing the fit indices of the three different models, we become able to identify the model that explains the data patterns best. We hypothesized that the third model fits the data best. In other words, even if understanding the force concept is the main focus, the response format still matters.

A total of 610 university students were surveyed in two cohorts. A subset of $n = 412$ was pursuing a physics major. The described models were fit to the data using the software Mplus (Muthén and Muthén 2007). Since not all tasks were used in both cohorts, the robust maximum likelihood estimator (MLR) was applied. To test which model fit the data the best, we utilized the Satorra-Bentler Scaled Chi-Square. The results show that the nested format model (response format as nested latent variable additional to force concept understanding) fits the data significantly better than the other two models. This suggests that in addition to the integrated knowledge (or understanding) of the force concept, two other factors predict students' performance on the tasks. These two factors are the ability to produce an answer within a constructed response item (i.e., writing a response) and the ability to identify the correct answer in a multiple-choice task (i.e., choosing a response). While these abilities are highly correlated ($r = 0.84$), they are not identical (note that correlations in structural equation models are corrected for measurement error and typically higher than manifest correlations). Our results obviously suggest that students' performance on a particular set of problems does not only depend on their integrated knowledge but also other abilities – depending on the format of the tasks. Students who are less familiar with multiple-choice tasks, for example, may be disadvantaged when required to answer multiple-choice tasks only. This suggests that in addition to the scenario in the context of which students are expected to apply their knowledge, the format in which students are expected to demonstrate their knowledge needs to be considered as well when designing assessments.

4.2 *How to Account for the Effects of the Response Format in the Assessment of Integrated Knowledge*

A recent meta-analysis on the effects of teaching students in the use of the control-of-variables strategy (CVS) confirms this finding. One surprising finding from this meta-analysis was that the effect of teaching students the CVS is closely linked with how student learning was assessed (Schwichow et al. 2016b). Studies using performance assessments exhibited significantly larger effect sizes than studies using either virtual performance tests or paper-and-pencil tests. In order to further examine this interaction between students' learning and the assessment format (i.e., paper-and-pencil vs. performance assessments), we conducted an intervention study on CVS in which the connection between training format (hands-on vs. paper-pencil) and the test-format (performance vs. paper-pencil) was investigated (Schwichow et al. 2016c).

In this study students were instructed on the idea of CVS (i.e., on what dependent and independent variables are and how to develop a non-confounded experiment). Then students were randomly distributed across two training conditions: One group was trained in the use of CVS by means of hands-on experiments, while the other group designed experiments on paper and interpreted the results of experiments presented to them as photographs. In both cases, students designed experiments in the context of scenarios from the topic of electromagnetism. A paper-pencil instrument on CVS has been constructed and validated in a prior study (Schwichow et al. 2016a). Furthermore, a performance test was developed, in which CVS has to be applied in two different scenarios, of which one was more familiar with the training material than the other one. The paper-pencil test on CVS was designed to measure the success of increasing students' understanding of CVS. The students had to answer it in advance of the study, after the first and again after the second part to assess how large the gain is and whether it differs between parts of training and conditions (see Fig. 6.6).

The participants of this study were 161 eighth graders from two comprehensive schools; they were academically diverse, including students with special educational needs as well as students approaching a university entrance exam. The students were assigned to two different training conditions based on pre-test scores regarding their CVS skills. The results indicate that students indeed learned through

Training condition	Pretest	Direct Instruction	Intermediate Test	Training	Posttest
Hands-on (n = 82)	Multiple-Choice CVS	Cognitive conflict	Multiple-Choice CVS	Hands-on	Multiple-Choice CVS Hands-on CVS: Elec.magnets Light bulb
Paper-and-pencil (n = 79)				Paper-and-pencil	

Fig. 6.6 Study design. CVS instructional phases are marked gray. The two training conditions differed only on the nature of the activity during the *Training Phase*

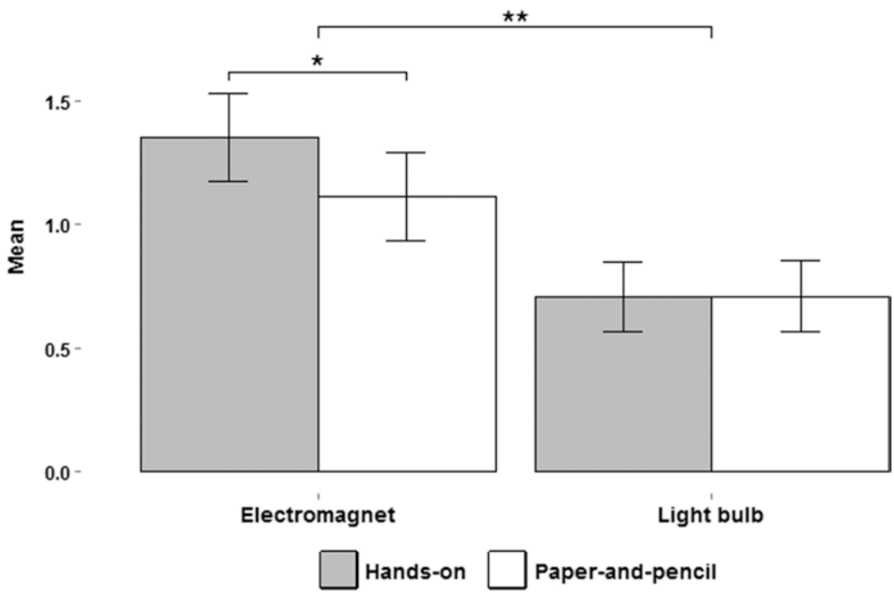


Fig. 6.7 Results from the performance post assessment in the CVS intervention study

the introductory part, but neither group made further advances throughout the training when measuring the intervention success only by the paper-pencil CVS instrument (Schwichow et al. 2016c). No difference could be found for the multiple-choice test between groups. In comparison, the performance test generated group differences for the posttest. The training phase had an impact on the results of the experimental hands-on posttest after the intervention (see Fig. 6.7).

Obviously, training for the CVS using hands-on experiments helps students develop some knowledge about the CVS. Students from the hands-on training condition perform better in the first experiment of the posttest. However, this improved performance can only be observed when the experimental material (the scenario) is exactly the same. As soon as either the topic of the scenario or the assessment format changed, students were found to perform significantly worse. It seems that the training was not successful in helping students develop a sufficiently integrated knowledge of the CVS. These findings demonstrate that the term “context” does not only apply to the scenario presented in a task but also the format of the task. This suggests that in assessing students’ integrated knowledge, a broader approach to the contextualization of assessment is necessary, in that the tasks as a whole need to be considered to represent the context. Task features that are considered relevant to the assessment of students’ integrated knowledge need to be systematically varied, task features that are not needed to be kept constant (Harris et al. 2016).

5 Summary and Conclusions

In order to prepare students for the challenges of a world increasingly permeated by science and technology, students are expected to develop an integrated knowledge about science – knowledge about the relationships between science ideas together with the ability to use this knowledge to solve real-world problems. In line with this development, the contextualization of science education and the assessment of the outcomes of science education have become increasingly important. Too often in science education we find contextualization reduced to the use of real-world contexts as a motivation to make students learn about science. Similarly, we find that in order to contextualize (assessment) tasks, they are often simply embedded in a real-world scenario. This is not enough in order to assess the extent to which students have developed integrated knowledge.

In this chapter, we aimed to develop two major points about the contextualization of assessments: (1) that in the contextualization of assessments the choice of the scenario(s) plays an important role and (2) that the contextualization of assessment requires attending to more features of the tasks than just the scenarios. In the assessment of students' learning about science, the tasks as a whole represent the context in which students demonstrate the extent to which they have developed an integrated knowledge about science. As a result, a valid assessment of students' learning about science should include a broad range of tasks designed to systematically vary in their characteristics.

With respect to the role of the scenario in the assessment of students' knowledge, we have presented evidence that the assessment of students' level of knowledge integration is affected by the choice of scenarios. In addition to choosing scenarios that are relevant to students and meaningful in the sense that the problem naturally emerges from the scenario, assessment designers need to ensure that the scenarios are presented in ways that are both as complex as necessary and as simple as possible. Scenarios that are lacking important information (as it could be in the case of an urban scenario presented to a student from a rural area without further explanation) and scenarios that are presenting too much information can have an unwanted effect on students' performance. Carefully chosen (and presented) scenarios are more likely to activate the knowledge about science ideas that the tasks are intended to address.

However, the choice of scenarios is not just an issue of bias, but more fundamental (Ahmed and Pollitt 2007). While we know from (our) research that the number of scenarios across which students are able to solve a problem is a meaningful proxy for how integrated students' knowledge is, we also know that some scenarios are more difficult for students than others. This may be related to familiarity, but the findings presented in this chapter also suggest that even when scenarios are carefully chosen and presented to students to attend to familiarity, some scenarios are still more difficult than others. These scenarios may trigger more persistent alternative conceptions (or non-normative ideas, respectively). In line with DiSessa and Sherin's (1998) idea of decontextualization, we assume that students develop science ideas or relational networks of science ideas by learning about them across a wide range of contexts. In teaching we typically develop careful sequences of learning activities to guide students in developing such ideas in a particular order – from ideas that are easier to understand to ideas more difficult to understand. In a similar notion, we envision that in the future contextualized assessments will include a sequence of scenarios (and problems emerging from these scenarios) that represent an increasingly integrated knowledge. However, more research is needed in order to understand why and how some scenarios are more difficult than others.

In this chapter, we also demonstrated that the scenario of a task is not the only feature affecting its difficulty. The response format – from multiple-choice to constructed-response to performance-based – has a major effect on students' performance (in the context of a given scenario). Similar to the role of the scenario, we showed that the choice of the task format is important. This does not only refer to the number of different formats included in an assessment. It also includes the alignment of the assessment with the context of student learning. Again, we envision future assessments to systematically vary the format of assessments between formats closer to the contexts in which students developed the respective knowledge (e.g., performance assessments) and formats further away from the contexts in which students developed the respective knowledge (e.g., paper-and-pencil tests). This should allow us to measure an increasingly integrated knowledge or increasing abstraction of knowledge, respectively. These issues will require more research.

In summary, we suggest a more comprehensive approach to conceptualizing the contextualization of assessments or assessment tasks – in which the task as a whole is understood as the context. We are aware that more research is needed to understand the role of the tasks as context, but we envision that in future assessments, the choice of tasks will not only relate to the science ideas or relational networks of tasks addressed in the tasks but will also include a systematic variation of task features such as the scenario or the format.

Appendix A: Sample Assessment Task

This performance assessment task is designed to assess upper elementary (or middle school) students' knowledge-in-use about heat transfer in the context of designing a test to evaluate different methods for keeping a hot drink hot. The context was carefully chosen and presented such that the task was not overtly about "heat transfer"; rather, students' attention was directed toward a vivid, relevant problem that requires students to blend ideas about heat transfer with scientific practices.

To present the context of the performance assessment, students are first introduced to a related problem that is especially relevant in the warm climate where the task was developed and administered: keeping a cold drink cold. The hot drink challenge is a natural extension of this problem. Because the introduction to the problem is text-intensive, the introductory passage is read aloud with all students in order to reduce the effect of individual reading ability on task performance.

After the problem introduction, students think individually about how they can use the materials listed (and shown by the teacher) to design a test to find out whether a "double cup" or a lid works for keeping a hot drink hot. After individual thinking, students work in pre-assigned groups and share their thinking in order to decide upon a procedure for their test. Groups are given a tray of materials only after they have agreed on a procedure; this helps to minimize student distraction. Groups then work together to gather data, record their observations, and discuss what they find. In a subsequent individual portion, students are asked to construct a scientific argument for whether a double cup or a lid is a good way to insulate a hot drink and to reflect on ways they might have improved their investigation. Throughout their involvement in the context-based problem, students are prompted to engage in investigation design, using tools to make measurements, organizing data, and constructing arguments based on their data. As a final task, students are presented with a related problem and associated data, and they are asked to construct an argument individually based on these data. This individual task with standard data provides additional information regarding individual student performance.

Importantly, this task is designed not to feel like an assessment. Rather, this task more closely resembles a classroom learning activity while providing ample opportunities for gauging how students use their knowledge in conjunction with science practices to investigate and construct arguments relating to a real-world problem that may even inform their decision-making outside of school.

Science Challenge

Part One: Group work

My name is:________________________________

My teacher's name is:____________________________

My group number is (you're teacher will tell you this):________________________

A cold drink on a hot day

Have you ever wanted to keep a drink cold even though the weather outside is hot? You might have used an insulated cup to do it. An “insulator” is a material that prevents heat from passing through it.

Restaurants sometimes use insulated cups to serve your drinks. If you’ve ever gotten a cold drink from Sonic, they probably gave you a Styrofoam cup, and you might have noticed that the cup doesn’t feel cold even though there’s an icy drink inside. If you’ve gotten a cold drink from McDonalds, they probably gave you a paper cup, and you might have noticed that the cup felt cold when you held it.

A cold drink in a paper cup will feel colder in your hand than a cold drink in a Styrofoam cup because Styrofoam is a better insulator than paper.

A cold drink will stay cold for longer if you put it in a Styrofoam cup instead of a paper cup, because Styrofoam is a better insulator than paper. That is, Styrofoam does a better job than paper at keeping heat from getting to your cold drink!

Insulators are also useful for hot drinks. If you’ve ever gotten a hot chocolate in a paper cup, you might have noticed the cup gets very hot. But, a hot chocolate in a Styrofoam cup doesn’t feel as hot in your hand.

Putting a drink in a Styrofoam cup is not the only way to insulate it. When some people get a hot drink, they put it in a double cup (two cups stacked together) to insulate it. Other people think that the best way insulate a hot drink is to use a lid. Today, you will investigate whether using a double cup or a lid is a good way to insulate a hot drink.

Thinking Ahead:

Soon, your teacher will give you a tray with the materials listed below:

Six paper cups with lids
Beaker
Three thermometers
Stopwatch
Ruler
Thermos filled with hot water
Paper Towels

On your own, think about how you can find out whether a double cup or a lid is a good way to insulate a hot drink. Write your ideas here:

When you finish writing your ideas, put down your pencil and wait for your teacher to tell you what to do next.

In your groups, follow the directions below:

1. Talk with your group members about how you will test whether a double cup or a lid is a good way to insulate a hot drink. After you agree on a method to use, carefully describe what you will do:

2. Once your group has decided upon a plan to investigate whether a double cup or a lid is a good way to insulate a hot drink, start doing your investigation. Use the box below to record any observations or measurements you make during your investigation.

Observations and measurements

3. After you have completed your observations and measurements, talk with your group about whether a double cup or a lid is a good way to insulate a hot drink.

Science Challenge

Part Two: Individual thinking

My name is:________________________________

My teacher's name is:________________________

Thinking about your group's investigation

In part one, your group investigated whether a double cup or a lid is a good way to insulate a hot drink.

On the lines below, write whether a double cup or a lid is a good way to insulate a hot drink, and explain why you think so.

If your group were to try your investigation again, how could you improve upon what you did today?

A Chef's Puzzle

A chef wants to figure out the best way to serve soup to her customers and keep it hot. She wants to find out whether a plastic bowl, a clay bowl, or a metal bowl is the best insulator.

To investigate which type of bowl is the best insulator, she measures the temperature of the soup at different times: first when she pours it into the bowl, then 5 minutes after pouring, and again 10 minutes after pouring. She records the results of her investigation in a table below.

	Plastic Bowl	**Clay Bowl**	**Metal Bowl**
Soup temperature when it is poured	150 °F	150 °F	150 °F
Soup temperature after 5 minutes	140 °F	145 °F	135 °F
Soup temperature after 10 minutes	132 °F	142 °F	125 °F

Which type of bowl is the best insulator? Explain why you think so.

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Part II
Reflections from Practice, Policy and Research

Chapter 7
Reflections from a Science Teacher Educator: Supporting Pre-service Teachers to Teach Science in a Contextualized Manner

Vanashri Nargund-Joshi

The purpose of this chapter is to reflect on the promise and challenges to translate the research findings, presented in the empirical chapters, into the preparation of future science teachers, through the lens of a science teacher educator. In doing so, I will draw some themes about how some of these ideas can be implemented in training pre-service teachers and in shaping teacher education programs. I am an Associate Professor at public, urban, diverse, Minority Serving Institution (MSI) and Hispanic Serving Institution (HSI) in the Northeast area of the United States with a student population displaying a high level of linguistic and cultural diversity. Our university population consists of 39% Hispanic, 22% African-American, 21% Caucasian, and 9% Asian/Pacific Islander. As a teacher educator, I work closely with elementary and secondary science pre-service teachers to prepare them to teach science effectively so that they can address needs of ALL students, as aimed by Next Generation Science Standards (NGSS). NGSS is the latest science education reform in the United States. In order to make students scientifically literate, ready to ask questions, find problems, investigate, analyze data, construct explanations, and design solutions, the Next Generation Science Standards (NGSS) provide an opportunity to improve science education for all students across K-12 grade levels, reflecting a new vision for science education in the United States. NGSS has created a context for comprehending the core knowledge and ideas and engaging in scientific and engineering practices to prepare students for broader and deeper understanding of scientific and engineering investigations.

Today, more than 20% of school-age children speak a language other than English at home. English language learners[1] have more than doubled from 5% in 1993 to 11% in 2007 (National Center for Education Statistics 2011). While the

[1] Limited English Proficient (LEP) students is the official government category for this group of students in the United States of America.

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student population in the United States is increasing more racially, ethnically, and linguistically diverse, science achievement gaps have persisted by race, socioeconomic status, and language (National Center for Education Statistics 2011). As student population in the classroom continues to diversify, prospective teachers should be made aware of the changing trends and how to embrace this diversity; and they should provide equitable learning opportunities for *ALL* students to become scientifically literate. Literature indicates that majority of language minority students do not have access to rigorous subject matter instruction or the opportunity to develop academic language—the specialized, cognitively demanding language functions and structures that are needed to understand and conceptualize, about topics in academic subjects (Lacelle-Peterson and Rivera 1994; McGroaty 1992; Pease-Alvarez and Hakuta 1992). The academic progress of language minority students is significantly behind that of their native English-speaking peers. Hence, in my methods class, we explicitly focus on addressing needs of diverse students but more specifically one group of student population that is identified as English learners (ELs). We discuss ways and strategies to address needs of English learners (ELs) while teaching science. Most of my pre-service teachers end up serving in nearby urban areas where school classrooms are very diverse. For example, the county where most of our pre-service teachers go for clinical experience and clinical practice or end up taking employment has student demographics of Latino (38%), African-American (27%), Asian-American (18%), Caucasian (14%), and Pacific Islander (0.81%). My pre-service teachers and their students come from urban environment, and most of them identify themselves as English learners/bilinguals at some point in their life. These pre-service teachers and students are either immigrant themselves or have parents who immigrated with them when they were relatively young. This background of my pre-service teachers and students makes discussions about contextualization in a science classroom especially relevant. My students' bilingual background not only equips them to serve English learners but also empowers them to contextualize science content within meaningful language context. Stoddard et al. (2002) explains the context of language as the degree to which language provides learners with meaningful cues that help them interpret the content being communicated—visual cues, concrete objects, and hands-on activities. Most of the school language is "context-reduced"; English learners often find themselves in a world of meaningless words.

Learning about contextualization allows my pre-service teachers understand how their own learning experiences about science content and language are often representative of their students' learning experiences. The focus of my methods class is to allow pre-service teachers to understand *why* do we observe gaps in students' understanding of science concepts and *how* these gaps can be addressed especially for students who come from similar background as theirs and can be identified as ELs. The theoretical lens of contextualization allows me to present science teaching as *process*. This approach provides cornerstones for pre-service teachers to think critically about: *How are students learning and how meaningful for their lives is what they are learning?* This lens allows me to unfold the intertwined relationship between individuals and context while learning science.

Throughout this book, authors highlight different aspects of contextualization to make science learning more effective, current, and relevant for students. In the following section of the chapter, I will discuss what I find promising for my pre-service teachers to apply in their classrooms from the ideas presented by different authors in this book.

1 Tensions Between National Curricula and Contextualized Science Teaching

During classroom discussion I explicitly discuss about what it means to make science accessible to students and how can we achieve it. My pre-service teachers struggle to achieve balance between creating contextualized lesson and addressing NGSS. Román, del Rosal, Rahim, Rossi, and Gates (Chap. 3) provide insight into teachers' efforts to contextualize the national curriculum to the unique lives and natural environment of students in the Galapagos Islands. This kind of struggle is shared by pre-service teachers as well, especially while they are attempting to figure out multiple aspects of teaching and trying to connect with students to make content more relatable. For instance, during one of the classroom discussions about developing contextualized lesson around a concept of carbohydrates, pre-service teachers came up with different food items familiar to the Latino culture in the United States that have high carbohydrate content. Pre-service teachers felt such need because of their own Latino background and the school districts where they would eventually serve with large Hispanic population. Pre-service teachers believed that analyzing Latino food choices would help break a misconception about Latino food being oily and unhealthy. Pre-service teachers felt the need of educating their students and students' families about their own food practices since a lot of students and parents held deficit view about Latino food culture. Pre-service teachers hoped to develop the lesson around food to empower their students, families, and communities around by explicitly and empirically discussing about food. Pre-service teachers also wanted to address the chemistry concepts of micro- and macro-level molecules in carbohydrate structure. However, while developing the lesson plan, pre-service teachers struggled with identifying appropriate NGSS and how to contextualize the lesson that addresses issues such as what kinds of food are available around the area, quality of the food, and the carbohydrate content (simple vs. complex) of the food. Roman et al. share a tension that Ecuadorian teachers perceived between their role as preparing the student to succeed in college based on national science curriculum and how to adapt the national curriculum to reflect issues important to the Galapagos archipelago. I found my pre-service teachers struggling since the new science standards in the form of NGSS are too open-ended yet too narrow to address such contextualized issues while teaching science concepts.

Roman et al. provide a suggestion of making the national science curriculum more contextualized to address the needs of the local environment. This recommendation is very apt and timely in the context of US science educational system since many in-service and pre-service teachers find interpretation of NGSS too complex and without in rooting to their context. Hence, it is essential that teacher educators like myself develop concrete examples that are contextualized to help teachers translate national standards (curriculum) successfully in a classroom. To be able to appropriately contextualize curriculum, teachers need in-depth understanding of the local issues to adapt existing curriculum to meet their students' needs (Giamellaro 2014). Only, local teachers can have such in-depth understanding and authority over such issues to be able to contextualize the curriculum. However, similar to my pre-service teachers, the teachers may feel constrained in their freedom to make their instruction locally meaningful since the curriculum and national standards are not open enough for interpretation. During lesson plan development assignment, I always encourage my pre-service teachers to find NGSS core concepts that can be contextualized. I also explicitly provide opportunities for my pre-service teachers to reflect on their strengths as a local teacher and how can they use this knowledge base to contextualize their instruction. I try to explain the term 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 2014, Wilson et al. 2015). This explanation allows my pre-service teachers to understand their position in developing contextualized instruction. I envision building a contextualized lesson plan library for my course, so that future pre-service teachers will be more supported and will be able to develop effective lesson plans that are contextualized yet are based on national standards/curriculum as per Roman et al.'s suggestion.

2 Contextualization as Place-Based Science Education

I have often used place-based education as one of the tools to introduce contextualization for my pre-service teachers (Chinn 2006, Semken and Butler Freeman 2008). In this sense, I find a framework presented by Brocos and Jimenez-Aleixandre most practical. It makes contextualization accessible for pre-service teachers. Place-based education and socioscientific issues allow pre-service teachers to analyze students' background and local setting. By doing so, pre-service teachers can design lesson plans that are more relevant to their students' life. In recent years, one of my secondary science methods cohorts developed a unit for ninth graders about how their city has been polluted in the last century. The unit allowed ninth graders to analyze their local zip codes and learn about which part of the city is more polluted than the others. It also allowed students to learn about stakeholders and their positionality in decision-making. In the final stage of this unit, students generated various artifacts such as brochures explaining various types of pollutant in the city, interactive maps, and Internet-based videos explaining their findings. I found the framework of place-based education most effective with my pre-service teachers in order to discuss and implement contextualization in a classroom. This framework also allowed my pre-service teachers to focus on strengths of their students and make science content more accessible and relevant (Semken and Butler Freeman 2008). Brocos and Jimenez-Aleixandre share a specific example of diet planning task with pre-service teachers. During this task, pre-service teachers were required to consider cultural-personal, ecological, ethic, nutritional, and socioeconomic dimensions. I found these dimensions intriguing since, with little modification, these can be utilized in designing several lesson plans that can revolve around many science concepts such as solid waste management, pollution, water conservation, healthy food habits, etc., yet can fit with place-based framework, making science learning relevant. Another strength of this dimensional framework is its *scope*. Authors have categorized it at three levels: global, regionally place-based, and locally place-based. Although authors have made the categories, implementing it as a continuum would prove as a powerful tool.

3 Supporting Pre-service Science Teachers to Address (and Embrace) Their Students' Sociocultural Background

As it is common with pre-service science teachers, my students often find themselves in a difficult situation as they haven't experienced real classrooms yet and also haven't themselves fully immersed in the same context as their students (Agee 2004). In this sense, the experience of in-service Turkish teachers working with refugee students felt relevant to my context. In this particular chapter (Delen, et al.), teachers felt they need more information about refugee students' language, culture, and religion. Many of my pre-service teachers in the past have expressed how they feel inadequate sometimes in a classroom where they cannot speak the same language as their students and do not know details of cultural and social aspects of their students' lives. The discussion of contextualization explicitly during such instances becomes most necessary during our classroom discourse. Constant dialogue about ways to elicit more background knowledge about students' home culture and practices becomes a necessity (Yamauchi 2003). Delen et al.'s chapter sheds light on the experiences of teachers working with refuge students, often feeling unprepared and lacking support to make science learning more contextualized for their changing classrooms.

During one of our classroom sessions, while discussing challenges faced by English learners, my students expressed their views and beliefs about what needs to be done to support students' learning. After a while, my pre-service teachers found themselves in two groups. One group supported the idea of teaching English language while teaching science (or any other) content as the more efficient way of building language along with conceptual understanding, while the second group was in strong support of teaching English language first before students could learn any content area. This was an interesting debate since both groups were partially considering students' background while suggesting potentially effective teaching strategies. As a class, we discussed the ways to learn more about students' background, their family, their beliefs, and how to utilize this information while planning contextualized science lesson for students. For science teachers to be able to contextualize contents and skills for their students, they need to be able to communicate with their students and their families, understand their culture, and support them to communicate their ideas in the language of instruction. This is challenging even for very experienced teachers, as described by Delen et al., but making pre-service teachers aware of this good practice is the first step toward making contextualization more relevant and real in any classroom. Delen et al. highlight that getting to know students' background and culture is an important factor that should be emphasized in teacher training programs. In my science methods class, I make pre-service teachers aware of their students' background in order to build meaningful, relevant, effective, and contextualized lesson plans (Yamauchi 2003). One of the assignments focuses on interviewing a child related to the topic that the pre-service teacher is building a lesson on. This allows pre-service teachers to understand two aspects that Delen et al. emphasize, cultural and linguistic background. The one-on-one interview with a child also allows pre-service teachers to understand student's content knowledge and family background. However, religious views of a student get hardly expressed during this interview process. Delen et al.'s suggestion about learning students' background to build effective contextualized lessons also gets echoed with the newest requirement of teacher training program in the United States in the form of edTPA. The edTPA is a subject-specific teacher performance assessment that pre-service teachers complete during student teaching. edTPA stands for Teacher Performance Assessment Portfolio, an assessment of teacher readiness developed by the Stanford Center for Assessment, Learning and Equity (SCALE) and the American Association of Colleges for Teacher Education (AACTE) but nationally distributed and scored by Pearson Education, Inc. It differs from previous assessments in that it purports to measure "performance" by requiring student teachers to compile a portfolio, including lesson plans, student work samples, a short classroom video (15–20 min), and a lengthy "instructional commentary" of 40 to 60 pages. This new requirement is complex. The edTPA assessment also requires pre-service teachers to understand students' demographic, needs, and linguistic abilities. Most of the teacher educators know the importance of understanding students' background, but Delen's findings can be a map to make the discussion more systematic.

4 Supporting Pre-service Science Teachers to Teach Science and One Way to Explain the World

Sánchez Tapia (Chap. 4) offers a unique lens of border crossing to support contextualized science learning. The author clarifies how this framework allows students to learn Western science yet doesn't silence students' critical voices and living realities. This chapter provides a novel look to contextualization by presenting border-crossing approach to curriculum design and instruction, which has potential for supporting students to understand WSK with deeper understanding and also can facilitate students' success in a multicultural society. While educating pre-service teachers and discussing how to teach science and how to make content accessible to the young students, I often come across fuzzy areas where things are not simply right or wrong. Few such instances that remind me of necessity to learn about are my pre-service teachers' worldview, root cause of their dilemma, and how to attempt to deal with it. A well-documented challenge, teaching theory of evolution and natural selection, is also faced by my secondary pre-service teachers (Borgerding 2017; Sánchez Tapia et al. 2018). Some of my students find themselves struggling with teaching ideas that seem to contradict what they believe in. They are at the crossroads in attempt to find a balance between what their religious views tell them and what scientific explanations present. I consider this as one opportunity for teaching science as "border crossing" where pre-service teachers are attempting to resolve the conflict between their religious views and Western science knowledge. Based on the ideas presented in Chap. 4 (this volume), I am planning to engage students in contextualized discussions about epistemology and the nature of science, so that they can better grasp the idea that science and religion have different goals and we can use them in different aspects of our lives. I will aim to provide multiple opportunities for teachers to discover that a passion for science and trying to explain the world through Western science are not incompatible with having personal spiritual beliefs or exploring the roots of traditional practices that are familiar to them and their students (Bang 2010; Green 2019).

One successful example of a border crossing approach that I have used thus far focused on exploring a traditional practice that is not entirely supported by the scientific and medical community. The case was built around the experience of one of the South Asian pre-service teacher who shared a common practice with babies that is not supported by doctors in the Western culture. According to her culture, babies as old as 10 days are routinely fed some of the herbs and dry fruits to build their immunity and micro gut flora. However, doctors in the West strongly advice against giving any external food to babies until 4–6 months of initial life. After learning about this practice, we as a class examined this practice in the South Asian families at the preliminary level by surveying families within our known friends and acquaintances and also spoke with few families who still live in South Asian countries such as India, Bangladesh, Sri Lanka, and Pakistan. We were positively surprised when we learned about how deeply rooted this practice is and how several families living in the United States and in these South Asian countries follow this practice. Many families shared how their babies weren't affected adversely even after giving external food against medical advices. Also, they believed their babies' immune system boosted because of the herbs and exposing to dry fruits made them less prone to food allergies. This was a start of a discussion that allowed us to learn multiple worldviews. We discussed a research study that concluded how low gut microbiome richness in early infancy is associated with subsequent food sensitization. This study showed that infants with fewer strains of bacteria in their guts had an increased risk of developing food reaction. The literature also indicated that giving breast milk to the infant helped diversify gut flora. We wondered if this could be the reason for the Western medical practitioners to recommend only breast milk. We also contemplated a thought that indigenous people probably were already aware of the need of diversifying baby's gut flora and hence had the practice of using dry fruits and herbs. I consider this as a first step toward border-crossing between indigenous knowledge and Western science knowledge that Sánchez Tapia emphasizes. In order to make science more relevant, it is important that pre-service teachers stand at such crossroads and think about it explicitly. Sánchez Tapia offers two critical points in her chapter: (1) how the framework of border crossing allows to move from one interpretive plane rooted in one culture to a different plane rooted in another culture and (2) how to support and stand for students' critical voices and living realities, so that they don't get silenced. Hence, in my methods class, I encourage such conflicting worldviews from teachers since they offer insights about how knowledge gets built across cultures and how valuable it can be and how it can be interpreted differently in different cultures. This kind of presentation of contextualization demonstrates my pre-service teachers how to acknowledge their students' worldviews and still derive learning gains and clarity. This kind of border crossing also allows students and my pre-service teachers to realize scientific knowledge can be generated with multitude ways (Aikenhead 2001, Bang and Medin 2010).

5 Contextualization of Assessment

Assessment remains integral part of learning process. Many of my pre-service teachers feel uncomfortable when it comes to designing and implementing assessments within a lesson plan to evaluate their teaching and students' understanding. This problem escalates when they are faced with classrooms that are culturally and linguistically diverse. For example, while designing a worksheet for children who have developmental delays or ELs, my pre-service teachers felt stressed. They expressed their concern as feasibility of developing such worksheets on a daily basis once they become full-time teachers. To ease their mind about this daunting task of designing assessment tools, I introduce the concept of contextualized assessment, an idea presented by Hartig and Neumann (Chap. 5). In this context, the approach to assessment items design presented by Hartig and Neumann is promising to equip pre-service teachers with assessment tools better aligned with the culturally relevant pedagogies they learn about in my science methods courses. Since contextualized assessments are more effective to identify the extent to which students have developed knowledge of the relationships between science ideas and their application to solve a wide range of (real-world) problems, this approach emerges as an essential tool I am planning to utilize in my science methods class (Gorin Mislevy 2013).

Authors present *scenarios* as a means to contextualize assessments. The real-world connection is what makes scenarios as strong contextualized assessment, and they can be fictional or nonfictional. Some of these features of scenarios overlap with the case study approach, which I use in my methods class. Case studies also allow assessing students' content knowledge while situating it in real-world context. I find case studies as one of the contextualized assessment methods (similar to scenarios) that has potential to assess students' ideas in a real-world context as mentioned by Hartig and Neumann. During my methods class, we utilize one or two case studies that allow my pre-service teachers to experience assessment first hand as well as analyze it from the teachers' perspective. In my view, case studies share many features and benefits of scenarios, and hence cautions presented by Hartig and Neumann about scenarios might be applicable for use of case studies as well. For example, an influence of familiarity with the scenario sometimes affected students' performance positively or negatively. Some students' performances are also affected because they found the scenarios being too familiar. These insights about scenarios can also be translated while implementing case studies in a classroom. In the future, I feel the need of discussing this cautionary advice by the authors with my pre-service teachers.

Hartig and Neumann also discuss response format as one of the neglected aspects of the contextualized assessment. They discuss a variety of assessment formats that could affect students' performance especially the ones who are attempting the assessment task in non-native language. I plan to share these teachings presented by the authors with my pre-service teachers. In the future, I would like to present different assessment formats with my pre-service teachers and discuss pros and cons of each format. I would also discuss how these assessment formats could affect different student populations differently (DeMars 2000). For example, authors state language learners seem to be disadvantaged by the use of multiple-choice tasks. I would encourage my pre-service teachers to consider a broader view while choosing a response format and how it can be modified to increase contextualization, so that they can gain real understanding of students' understanding.

6 Conclusion

The current educational climate in the United States is defined by how students perform on high-stake exams and what is the overall final outcome (Ryan et al. 2017; Croft et al. 2016; Supovitz 2009). On one hand, we expect *all* our students to be successful in learning science, but on the other hand, we do not provide framework, insights, resources, and freedom to our teachers to implement what is right for their students based on their context, community, and culture. If we equip our pre-service teachers with right tools and understanding with what it means to learn science within context, they can give voice to their students (and their families). By including contextualization as a leveraging practice in teacher education programs, we can hope for better scientifically literate generations of students, fulfilled teachers, and content families. I envision following four aspects as cornerstones of contextualization framework: (1) goals and objectives for science embedded within appropriate culture and context, (2) legitimate participation of students, (3) creating an overlapping space with students' experiences and science learning expectations, and (4) assessment in alignment with students' experiences. Writing this chapter has allowed me to reflect as an educator to make my pre-service teachers feel empowered and prepared to address the needs of their students. Thinking about the variety of contextualized strategies illustrated in this chapter has also indicated me the promises and the challenges that my pre-service science teachers might face while making science more relevant to their students' lives. As I was writing this chapter, different authors who contributed in this book have given me contemporary, real-time understanding of what contextualization means for teachers and students in different parts of world and the importance of accounting for local, political, and geographical context in science teaching and learning. The analyses of these chapters have indicated the need of producing adequate meaning of contextualization and of establishing clear, discrete, and manageable aspects of contextualization that are transferrable to the classroom practice. It also raises questions about the possibility of having a universal view of contextualization for science education itself. However, this leads into questioning the where and how to embed the concept and process of contextualization in teacher education programs. It also shows the need of including different dimensions of contextualization not only during science methods courses but as interwoven elements throughout the whole teacher education program. The discussion on contextualizing science learning will allow pre-service teachers to understand how students' learning is mediated by context (urban setting, culture, etc.), and it will also provide them with a tool that allows them to improve their effectiveness as they develop in their teaching careers.

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Chapter 8
Leveraging National Policy to Generate Awareness and Change Toward Contextualized STEM Educational Practices: The Case of Panama

Nadia De León Sautú and María Heller

1 Introduction

Nadia De León supports educational programs at the National Bureau of Science, Technology and Innovation (SENACYT), the Ministry of Education (MEDUCA), and local nonprofits and directly with public and private schools. She conducts program evaluation and research on the Panamanian national educational system; enacts professional development programs for teachers and principals; and is actively involved in advocacy for educational policy reform, such as the implementation of the 2017 National Commitment for Education, an effort led by the United Nations Development Programme (UNDP) with participation from all Panamanian sectors, including public and private institutions, parents, teacher unions, and universities. Maria Heller is the National Science Learning Director at SENACYT. She has served in this role for two non-consecutive periods of 5 years, under different governments. Maria has worked in science education for over 13 years, designing professional development programs for science teachers at national scales, overseeing the design of materials for science classes, and leading national science assessments. Maria is one of the designers of the national flagship program Let's Do Science,[1] a key program driving science education reform in Panama. Her work involved supporting the introduction of policy changes, such as a 2007 executive order, that allowed for the creation of a teacher-coach figure within MEDUCA.

[1] *HagamosCiencia*.http://www.interacademies.org/42440/Inquiry-Based-Science-Education-Promoting-changes-in-science-teaching-in-the-Americas

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The goal of this chapter is to reflect on the possibility of large-scale implementation of the ideas presented in the empirical chapters of this book within the Panamanian education system. Based on our current knowledge, experience, and roles within the Panamanian public sector, we include references to relevant policy, systemic, or budgetary concerns that may serve as incentives or barriers to such implementation.

2 Contextualization of Science Education in Panama

Panama is a small country with a population just under 4 million people. According to the 2010 census, over 12% of Panama's population is indigenous. A high-income country (World Bank, World Development Indicator, 2017a, b) such as Panama has the economic resources necessary to financially sustain improvement efforts at current rates of investment in education, which is currently between and 3% and 4% of its GDP but could be further increased to over 5% to match the average for Latin American and Caribbean countries (Busso et al. 2017). Many Panamanian K-12 students attend private schools (one in eight students attends a private school, and one in four schools is a private school), particularly within Panama City. The public school system includes slightly over 3000 schools with approximately 50,000 teachers and 700,000 students (MEDUCA Estadística Educativa, 2016; Instituto Nacional de Estadística y Censo 2016). Three public universities provide teacher education, in addition to a few private universities, and a post-secondary institution for teacher education.[2] Panama implements a national curriculum that includes science education at the elementary and secondary levels, followed by both private and public schools, although private schools are free to go beyond the compulsory curriculum by including additional content. Panama is within the top 15 countries globally with the highest income inequality and within the top four in Latin America (World Bank, World Development Indicator 2017a, b). Panama's educational system produces unequal educational results. This inequality is reflected in higher test scores in private versus public schools (OECD 2011) in science and all other subjects, as well as in lower graduation rates and wider gender gaps in provinces with larger indigenous and Afro-Panamanian populations. The Panamanian government has a responsibility to develop and implement national policies that help close the gap that ails schools in the most disadvantaged regions of the country.

As public servants and practitioners, we are convinced that teaching and learning processes must be contextualized to the local reality of students to facilitate and deepen their understanding of curricular contents as well as to make science education relevant to their lives. If science education does not provide opportunities for students to use their traditional knowledge and value their heritage, their motivation to learn science may be negatively affected (Sánchez Tapia et al. 2018). On the other

[2] Instituto Superior Pedagógico Normal Juan Demóstenes Arosemena.

hand, growing evidence shows that culturally responsive teaching and learning improves education outcomes (Aronson and Laughter 2016; Gay 2010; Lee and Buxton 2010; Brown 2007; McKinley and Gan 2014). One-size-fits-all approaches to national curriculum development and teaching strategies are one of the many faults of the aging education system we have inherited from the industrial era. Providing quality science education to all children and adolescents within a country, and particularly one as culturally diverse as Panama, requires policies and practices that allow for local contextualization, particularly in terms of supporting ethnic minority groups in accessing and preserving their traditional knowledge and identities. Panama has engaged in national efforts to improve the quality of education by strengthening STEM education, for example, in a series of programs implemented by SENACYT in partnership with MEDUCA since 2005 to the present, including Let's Do Science, Science and Robotics student clubs at schools, Science Fair and the Young Scientist Program,[3] Khan Academy and local university-led math professional development for teachers, etc. Panama has also conducted efforts to improve equity within the education system. These efforts include providing indigenous communities with intercultural bilingual education (IBE) within the public school system, a policy implemented by MEDUCA and accompanied by an IBE teacher education program at a local public university (the only IBE teacher education program in the country). However, Panama has not yet begun efforts to contextualize science learning as a strategy to help achieve both equity and high-quality STEM education.

Additionally, in a country such as Panama, for which biodiversity is such an important resource, national mandates and government programs that support teachers in the contextualization of education for our children in their local environments are yet to be developed, although collaborations with local nongovernmental institutions, such as the Smithsonian Tropical Research Institute and the Biodiversity Museum, have included professional development for public school teachers that utilize inquiry and place-based learning approaches to science education that could pave the road for such national efforts. Furthermore, whereas some efforts for the contextualization of education, particularly that of intercultural bilingual education for the indigenous populations, have been in place for many years in Panama, no data are publicly available from rigorous evaluations, so evidence-based decisions are difficult to make.

In general, the authors note the lack of national long-term policies within the Panamanian public administration. Many programs that affect science education generally respond to the Strategic Plan for Science, Technology and Innovation (PENCYT) and the Strategic Plan for the Ministry of Education, which span 5 years (MEDUCA 2009, 2014) and respond to government plans by the political party in power. In fact, other relevant policies, such as the National Plan for IBE mentioned previously, have also been developed in 5-year formats and are commonly not available online or accessible to the public. The country would benefit from longer-term

[3] *Feria del Ingenio Juvenil* and *Jóvenes Científicos.*

strategic planning and implementation of educational policies. Despite dozens of modifications in the intervening decades, Panama's educational legislation and policies continue to function within the regulatory basis of the *Organic Law of Education,*[4] which dates from 1946. Many of its premises have become outdated, and the regulations in place often make reform initiatives difficult to implement. For example, the implementation of the *Let's Do Science* program, which established a program for teacher professional development and coaching to support inquiry-based science learning, required a presidential executive order (Ministerio de Educación 2007) to allow for teachers who completed the program to be designated as coaches without losing the privileges of a permanent appointment as a public school teacher, since current law did not permit such a figure as a coach within the existing public school system, nor did it allow for the flexibility within the system to create such new positions.

3 Contextualization of Science Curriculum and Instruction to Achieve Greater Cultural Relevance

Although Panamanian educational policy does not specifically promote the adaptation and contextualization of instructional activities, beyond IBE, it does allow for it. Panamanian national curriculum is a set of required subjects with specific required hours of instruction per subject depending on the grade level. Each subject contains suggested content, but teachers are free to design and implement instructional activities to teach the content as they see fit. However, public schools use standardized textbooks for each subject, which are distributed nationwide and are often utilized as the sole source of instructional activities for the classroom, discouraging individual teacher adaptation and contextualized activities. Additionally, the curriculum and school administration system do not encourage interdisciplinary collaborations across subjects. Fortunately, in 2017, MEDUCA published a set of Fundamental Learning Rights,[5] similar to national standards, for science, as well as math and language. These new standards should allow for the development of contextualized instructional practices and assessment tools and are well-integrated with national programs led by MEDUCA and SENACYT, such as Let's Do Science and *Maximum Learning*, an ongoing national program that responds to current policy aimed at better integrating recurrent classroom assessment and differentiated instruction, which includes a focus on literacy, along with science, mathematics, and other areas.

While IBE policy supports contextualization for indigenous students, other populations are not currently contemplated by existing regulations. For example, the number of foreign children in Panamanian public schools almost doubled between

[4] *Ley Orgánica de Educación.*

[5] *Derechos Fundamentales de Aprendizaje.*

2015 and 2017,[6] reaching nearly 2% of the total student population. Panama has historically received important numbers of immigrants, more recently including asylum seekers from Venezuela and Colombia, and is currently experiencing an increasing flow of transient refugee populations on the Caribbean coast and in provinces such as Darién (which borders Colombia) and Chiriquí (which borders Costa Rica). Currently, no national policies are in place to support schools in serving this population. MEDUCA has yet to prepare appropriate responses from the education sector. As Delen (Chap. 4) indicates, professional development programs aimed at preparing science teachers to support the needs of migrant populations may be needed. Such programs could encourage teachers in their learning of refugee students' cultures and the particular experiences from which their families may be escaping, thereby positively influencing teacher attitudes. Additionally, although most of Panama's population is concentrated in Panama City, nearly half of our student population lives in rural areas. Instructional design, pedagogical practices, and educational programs, stemming from or supporting national policies, rarely consider the contexts of students' communities. For example, the Panama Canal Authority has recently begun transformation of a program intended to teach students about water conservation in rural isolated schools within the Panama Canal watershed. Program facilitators have learned that many participating students have never seen the Panama Canal. Thus, they had a difficult time achieving learning objectives while trying to make sense of references to container ships and locks. The program is now being revised to be more community-based and focused on students' experiences and identities while still connecting them to the topic of water conservation as it relates to the functioning of the Panama Canal.

Facilitating the development of contextualized science curricular materials in Panama, as proposed by many of the authors in the empirical chapters of this volume, will be particularly important, given that our current science textbooks do not necessarily address the contexts of all ethnic and linguistic communities within the country.

Like Román et al. (2020) found in Galapagos, the authors have also encountered Panamanian teachers eager to teach content they feel is relevant to the traditions of the communities in which they live and to the ecosystems their students encounter. In the authors' experience, government agencies such as MEDUCA and SENACYT have supported the implementation of initiatives funded by international organizations, such as UNICEF and the Inter-American Development Bank (IADB), that bring students' home-lives, community values, and areas of lay expertise to the foreground of classroom activities. These initiatives have been regarded by teachers and government officials as having positive results in terms of empowerment, motivation, and learning, as well as reading and writing skills. Teacher and facilitators' comments regarding empowerment often include references to students' changes in attitudes when working with subjects with which they are familiar, especially concepts they have mastered and can teach to their own teachers, who then engage with

[6] From 6487 to 11,457 (Ministerio de Educación 2018).

them in mutual learning processes. However, such initiatives have not focused on science education.

One example of a small-scale project including community-based learning units that included science topics is the one led by the local nonprofit Casa Taller from 2011 to 2014 with funding from a private foundation and support from MEDUCA and SENACYT. In the context of this project, it was observed that teachers' perceptions of students who were struggling academically radically changed during the implementation of community-based learning units. For example, during the enactment of a 6th grade unit focused on migratory whales, students felt empowered to have conversations with family members and with teachers about a topic they knew very well and were passionate about, resulting in the engagement of the entire community in the science learning process. Another example was the implementation of a learning unit focused on birds in a forest area near the Panama Canal. The unit was enacted at a multi-grade elementary school where children were expert connoisseurs of the local birds, so they were eager to learn with this unit and to discover new information about birds. However, no such programs have been implemented at a large scale yet, and no systematic evaluation of small-scale science programs has promising results that could facilitate their scaling up.

4 Contextualization of Science Assessments

As we continue to improve the contextualization of science instruction, further contextualization awareness must also be introduced to standardized test development, as suggested by Härtig and Neumman (Chap. 5). Härtig and Neumman warn of the harmful impact of non-contextualized evaluation, because it may bias the measurement of student learning. Given the validity of this concern, we find it imperative to build efforts toward greater contextualization of standardized assessments in Panama. MEDUCA has recently begun efforts to develop national standardized assessments in science, language, and mathematics, with the active involvement of foreign assessment specialists. Assessments are currently being implemented in the 3rd and 6th grades, with developing plans to continue toward the 9th and 12th grades. The development of these assessments and evaluation system is supported by funding from the Inter-American Development Bank (IADB) (PN-T1208), through a large project aimed at improving the efficiency and quality of Panama's education system. Thus, the current momentum and availability of funding would make it possible to add a contextualization component to these initiatives so these assessments become valid for assessing the knowledge of students who are part of indigenous, rural, and/or other communities. The ongoing establishment of a national evaluation system and the consequent analysis of results should provide data to support the need for contextualization and for contextual information to help understand factors that may affect such results.

With regard to international assessments, despite periods of non-participation in the past, national policy is now moving toward continued participation in international standardized assessments, such as PISA conducted by OECD and the learning assessments conducted by UNESCO in Latin America and the Caribbean (UNESCO n.d.). In past applications of such tests, SENACYT witnessed student confusion due to lack of contextualization of the item's text, since some items included references that were irrelevant or even unintelligible for some students. For example, we have witnessed students in indigenous rural communities puzzled at references to a skateboard. In a standardized test, an item asked students to identify "a cube" (cubo in Spanish), without considering that in Panama the same word also refers to a water bucket. Therefore, many of the students selected a cylinder image as the correct answer instead of the correct answer. Another item referred to the experience of seeing fogged mirrors when one comes out of the shower, which rarely happens in Panama's warm weather if one showers with cold water, as most people in low-income communities do. In the past 3 years, MEDUCA and the National Bureau for Science, Innovation and Technology (SENACYT) have been participating in the process of designing international standardized test items to minimize these challenges. The program has included professional development for math, science, language, and elementary school teachers in the area of item development to build the countries' assessment capacity. These efforts to date have included funds to send teachers abroad and to bring foreign specialists to the country to provide training and to facilitate item design processes. These efforts have led to the production and testing of hundreds of standardized test items, the publication of a guidance document, and the cascading of professional development by those teachers who completed the original program. Explicit elements of contextualization can feasibly be included for item design and adaptation in these ongoing initiatives. Doing so would increase the feasibility of implementing contextualized evaluation strategies, as proposed by Härtig and Neumann (Chap. 5), including a comprehensive approach that considers the role of the response format; the importance of congruence between students' experience, learning scenarios, and assessment formats; and the inclusion of a variety of tasks that match students' learning.

One barrier to the contextualization of standardized test items in Panama, as proposed by Härtig and Neumann (Chap. 5), is the limited systematized information about local cultures available to inform such contextualization. For example, the law that established IBE also created an office for the research and revitalization of indigenous languages with a specific budget. However, the law focuses on language and not on culture or traditional knowledge. To generate or adapt locally contextualized items and tasks for Panamanian contexts, we find it promising and imperative to conduct an inventory of local alternative ideas. As all authors in this book note, contextualizing education requires knowing the students' context (background, culture, beliefs, ways of understanding the world, language, and religion).

As Härtig and Neumman identify (Chap. 5), utilizing performance-based evaluations, in which students complete tasks as opposed to answer items on a written tests, and other carefully planned forms of assessment that consider students' cultures and languages may help provide a better understanding of students' abilities in varied contexts despite language and/or cultural barriers. The application of these forms of contextualized assessment beyond summative assessment can only be promising for improving the use of formative evaluation within science instruction. For example, the Maximum Learning[7] program is a national initiative focused on improving learning outcomes and strengthening the education system's assessment capacity. This program involved diagnostic assessments nationwide at the 3rd grade level as well as professional development, coaching, and support for thousands of teachers in the application of standardized diagnostics tests multiple times a year to inform their classroom practices. Including principles of contextualized item design and contextualized science education into a program like Maximum Learning could have positive impacts at the national scale.

5 Including Contextualization of Science Education in Teacher Education and Science Teachers' Professional Development

Across all the proposals presented in the empirical chapters of this book, we find that the biggest challenge for application and scale-up is the need for strengthening the capacity of the Panamanian education system by developing the skills of current science teachers and science educators as well as by increasing their numbers. To develop contextualized curricular materials, such as those proposed by Sánchez Tapia et al. (Chap. 3), we need science curriculum developers and lesson designers to develop knowledge of contextualization principles. Moreover, to implement strategies similar to those used by Roman et al. and Delen et al. (Chaps. 2 and 4), we need to engage curriculum developers with expertise on curricular contextualization so we can provide effective supports for in-service teachers. These areas of specialization often require graduate training, which is scarce in Panama. Only 0.3% of the Panamanian population holds doctoral degrees, as opposed to 1.7% in the USA, and only 2.1% hold master's degrees, as opposed to 9.9% in the USA (UNESCO 2017).

Because the national-scale implementation of any of the proposals in this book would require the support of middle-ground professionals, we must develop policies to support international collaboration and the development of such professionals locally. Furthermore, the feasibility of including contextualization of science education to teacher education programs, as described by Brocos and Jimenez-Aleixandre, is inextricably linked to national efforts to better support our colleges of education. In particular, we need to focus on improving the skills of the current faculty, increasing the number of science education specialists among them, increasing the number of faculty with doctoral degrees and active research agendas, and strengthening science education graduate programs. Present challenges and ongoing research seem to indicate that the current teacher education programs offered in the country are in need of an overhaul if they are to be successful in the quality of

[7] *Aprende al Máximo.*

science education in the country. For example, in 2017, a study funded by SENACYT found that teachers' levels of education were not a variable with significant impact in Panamanian students' scores on a Latin-American learning assessment (Villalba Rey et al. n.d.). As we strengthen our own institutions of postsecondary education, we must continue to deepen a national effort toward identifying and funding science educators who develop specialized knowledge and skills abroad as well as support them in returning to the country to apply their new skills, thereby further building local capacity.

SENACYT has been enacting a program of international scholarships to strengthen national capacity for over a decade. As a way of supporting the improvement of national post-graduate programs, SENACYT offers funding for universities to enact degree-granting programs with a significant number of faculties holding doctoral degrees and having active research agendas. These funds also support collaboration with international researchers and scholars as well as require students to dedicate themselves full time to the program of study and to publish their research. These programs could expand to include science education graduate degrees offered through Panamanian universities.

Additionally, SENACYT has provided funds for approximately a thousand Panamanians to pursue graduate degrees abroad. These programs have often included funding for Panamanians to pursue graduate degrees in education; however, as of 2017, an additional call was made for Panamanians interested in pursuing master's degrees in education fields abroad to increase their numbers. Current policy could include earmarking some of these funds for degrees in science education or for doctoral dissertations focused on the contextualization of science education. Unfortunately, applicants have been difficult to recruit for these scholarships, and available funds are currently underutilized. On the other hand, SENACYT scholarship programs also support national development at the institutional level by providing funds for local institutions to integrate graduates with doctoral degrees. However, thus far, this stipulation only applies to universities and research centers, as well as selected businesses and nonprofits, but not to government agencies themselves. For example, MEDUCA is not currently one of the institutions with a signed agreement with SENACYT to support SENACYT grantees to join MEDUCA after completion of their graduate degrees, thereby missing the opportunity to increase the government's capacity to implement strategies such as those proposed in this book. Additionally, current hiring policies at MEDUCA, based on a point system, would present challenges to the insertion of SENACYT grantees.

Although global consensus indicates that contextualization of curricula, assessment, and instruction should be part of the foundational pedagogical knowledge teachers must develop early, the authors' experience is that teacher education programs in Panama do not currently provide future teachers with sufficient instruction or practice in this area. No national policy is in place that would mandate teacher education programs or professional development for public school teachers to include training for the contextualization of science education. Furthermore, current policy does not clearly dictate any specific minimum subjects to be included in teacher education programs of study, nor does it closely supervise the implementation of such programs. MEDUCA offers week-long teacher development programs nationwide three times per year, but these programs do not include the contextualization of science education.

Making the contextualization of science education a common practice within the education system requires investments in teachers' professional development. Problem-, project-, place-, and inquiry-based learning and other forms of science experiential learning are all pedagogical approaches that need to be better understood and implemented by Panamanian teachers in K-12 schools. To implement contextualized science education, teachers need to routinely gather information about their students' lives and ideas and have high expectations of them. Looking at the study plans for teacher education programs at Panamanian universities, it is unclear whether such content is included to provide teachers with the tools to develop their own skills or to guide others through these processes. In fact, such plans are not easily accessible to the public or to stakeholders in the public education system, thereby further limiting informed policy dialogue. Panama's Organic Law of Education would support required policy changes, because they state that MEDUCA is to coordinate and provide for regular professional development opportunities for in-service teachers; the requirements for teacher education faculty will be regulated through executive order; and teacher education institutions are to be supervised systematically and permanently, including annual evaluation of results.[8] The decision-making related to such policies must be informed by the assessment of current teachers' knowledge, skills, practices, and outcomes. However, access to available data from such evaluations is limited by policies that restrict access to teachers and students' data.

In terms of the availability of funding, policy support, and logistic feasibility, Panama has recently implemented large-scale changes that could be applied to the improvement of science education. For example, Bilingual Panama[9] is a particularly relevant case of ongoing educational policy at the national level. It is an effort initiated by the current government, established through a national law[10] and supported by an investment of over US$80 million. The program features professional development for thousands of language teachers abroad and locally, including coaching; structural changes to the school curriculum; creation of an after-school program; establishment of a national office; and mechanisms for teacher certification, follow-up, and incentives. Although the program has not been without its challenges, it serves as a feasibility model for the large-scale nationwide implementation of reforms, such as those that may emerge from approaches to the contextualization of science education proposed in this book. This is not to suggest that the ideas proposed in this book would require as large an investment as Bilingual Panama but to highlight that Panama has access to the necessary funds for education initiatives considered as priorities, although no comparable investment has been made to improve science education to date.

[8] Organic Law of Education, 1946, Articles 325, 329, 330, 332.

[9] *Panama Bilingüe*.

[10] Law 18 of 2017 (Asamblea Nacional 2017).

6 Models and Opportunities for the Development of Contextualized STEM National Policies and Practices

Panamanian national policy in education has begun a long road toward contextualized instruction and assessment for science education. In general, the Panamanian public education system is not yet teaching or assessing in response to the students' contexts, in science or in any other subjects. Fortunately, national policy on intercultural bilingual education for indigenous populations may provide a helpful starting point. Panama's IBE efforts began in the 1980s and became national policy when a law was ratified in 2010 that required the government to provide K-12 education in all subjects in both Spanish and indigenous languages in schools serving indigenous communities, with a particular focus on the early grades, as requested by indigenous communities. The law also refers to identity, culture, and "the relationship with mother nature," although implementation has so far been mostly focused on language. The law mandates the creation of a national IBE plan to be generated by the IBE staff in collaboration with MEDUCA (units on curriculum and the evaluation).

IBE law also mandates that MEDUCA provide resources for teacher education and professional development in IBE, approve related degree programs, and provide special incentives to IBE teachers "when they sufficiently master the indigenous language and know the customs and traditions of indigenous peoples, and have obtained a certification of language and cultural proficiency expedited by the National IBE Office." Current policy dictates that teachers who speak the local indigenous language have priority in regard to placement in indigenous regions. Finally, the law created a special fund for indigenous peoples' education with the goal of improving their access to education, which could be utilized to develop bilingual and/or bicultural materials, as has already been done in Panama, utilizing funds from international nongovernmental organizations. The law also mandated the creation of an IBE curriculum that should include the study of the "language, traditions, spirituality, worldview, culture, identity, history and customs" of each indigenous group. This curriculum was to be built as a product of research and collaboration with indigenous authorities (Asamblea Nacional 2010).

The IBE national policy can be leveraged to support the inclusion of science education in efforts of curricular contextualization related to intercultural teaching and learning, including initial teacher education. All the approaches to the contextualization of science education presented in this volume seem like promising tools to improve teacher education and the teaching effectiveness of Panamanian educators, particularly IBE teachers. Given that the overall spirit of the IBE law is based on "the value of cultural diversity" and the rights of students to an education that responds to their cultural identity, when extended beyond indigenous groups exclusively, this law could serve as a basis to support the implementation of contextualized science education for all Panamanian students.

Another example of existing program that could be leveraged to support the implementation of contextualized science education is the program Maximum

Learning. This program included nationwide census testing, teacher training for all 1st through 3rd grade teachers over a period of 2 years, and ongoing coaching for approximately one-third of participating teachers (those in schools with the most needs). Funding for *Maximum Learning* has been a mixture of local revenues and technical cooperation funds from IADB. Its application demonstrates the feasibility of implementing nationwide professional development efforts, which may be required for the national scaling of any of the initiatives proposed in this book. Maximum Learning also pioneered large-scale teacher coaching, a key aspect for teacher success that was absent from previous teacher professional development policies. Other past programs, such as Get Connected[11] and Amongst Peers,[12] involved investments surpassing $US30 million, successfully reaching thousands of Panamanian public school teachers and students, providing public schools with laptops and computer literacy training for up to 5 years. Although Amongst Peers reached most teachers nationwide, the program's long-term impact has not been assessed.

Panamanian national policy on education includes stable funding for ongoing professional development for teachers. The strategies for the regulation and implementation of professional development for teachers are the subject of ongoing policy reviews, including a 2017 resolution that clarified certification processes for entities approved to provide such training (Ministerio de Educación 2017). Nonetheless, educational reform should be implemented through nationwide professional development of in-service teachers along with modifications to include contextualized science education within teacher education programs and to develop congruent policies regarding certification requirements.

Recent policy changes and the development of national standardized assessment practices have allowed for decisions regarding professional development needs to emerge from evaluation results. Additionally, a new integrated System for the Improvement of Educational Quality was established through an executive order in 2016 (Ministerio de Educación 2016). The approval of the program was associated with increases in the standard pay for teachers within the public school system, and it includes reporting and follow-up processes for academic and administrative improvement plans for each school. These changes have motivated efforts toward better integration between the offices currently responsible for evaluation, professional development, and curriculum, which would favor the implementation of contextualized science instruction at the multiple levels proposed in this book. An associated Program for the Improvement of Educational Quality has been rolled out across the country since 2017, which includes the expectation that education in general, including science education, should be better contextualized to the lives of Panamanian students.[13]

11 *Conéctate.*

12 *Entre Pares.*

13 Estandar 18, Programa Integrado de Mejoramiento de la Calidad Educativa.

7 Further Challenges and Priorities for the Implementation of Contextualized STEM National Policies and Practices

Ultimately, the feasibility of the application of many of the models proposed in the chapters of this book depends on the teachers' capacity to contextualize science education within each classroom and the facilitation of processes where teachers and students are learning from each other's experiences. This paradigm requires particular pedagogical content knowledge which must be supported by national teacher education strategies, professional development policies, a flexible curriculum, and structural policies. Additionally, given Panama's educational system's current limitations, compared to other countries in the region,[14] Panamanian educational policy should continue to build national learning standards, policies, and evaluation systems for science education while fostering and supporting contextualized instruction and assessment. At the same time, we need to inform our efforts with ongoing program and impact evaluations as well as classroom support and public progress reports.

Panama is currently experiencing a political moment in which increased public awareness of the critical situation of our education system has generated pressure for considerable reforms, thereby making them more politically viable. An important first outcome of this situation has been the approval in 2017 of a National Commitment for Education. This document was generated through a dialogue led by UNDP, which included parents, students, teacher and worker unions, the private sector, education NGOs, universities, and MEDUCA. It contains agreed-upon objectives, which include topics that would indirectly facilitate the implementation of the ideas presented in this book. In reference to the possibility of implementing the ideas proposed in Sánchez Tapia (Chap. 3), Delen (Chap. 4), and Brocos and Jimenez-Aleixandre's (Chap. 1) work, the National Commitment for Education includes the creation of new requirements for teacher education programs, a national system for teacher professional development, and the updating of the national curriculum (including its relevance). In reference to the possibility of applying Härtig and Neumman's ideas (Chap. 5), the National Commitment for Education also includes the creation of learning standards and the regular assessment of student achievement utilizing national and international parameters.

None of the aspirations described in these pages will be achieved without building awareness of the importance of contextualizing STEM education. Additionally, more needs to be done in terms of strengthening the capacity of the education system. MEDUCA should support teachers who are willing and able to utilize their local resources and their students' socioculturally based knowledge and who con-

[14] PISA 2009 results ranked Panama as 8th out of 9 participating Latin-American countries (outperformed by Chile, Uruguay, Mexico, Colombia, Brazil, and Argentina). TERCE 2013 results ranked Panama 11th out of 15 participating Latin-American Countries (outperformed by Chile, Costa Rica, Uruguay, Mexico, Colombia, Brazil, Argentina, Peru, Ecuador, and Guatemala) and performing at or below regional average across all grades and subjects. UNESCO.

textualize their teaching accordingly. Additionally, curricular reform of teacher education programs must be advocated for to include these elements. This goal can only be achieved through national policies that embed support for contextualization of science education across teacher education and professional development, curriculum development, and assessment. Moreover, contextualization of science education at the national level requires administrative decentralization, as well as decentralization of knowledge. For example, along with national policies, we should invest in local diagnostics and specific regional solutions. In time, if we strengthen our national universities, as well as their regional branches and counterparts, they will continue to grow in their role as key players in the unceasing improvement of science education in the country.

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Chapter 9
Supporting Contextualization: Lessons Learned from Throughout the Globe

David Fortus and Joseph Krajcik

Our global world faces innumerable environmental, scientific, and health challenges. To solve these challenges, individuals throughout the globe will need to have the STEM knowledge and collaborative capabilities to solve such complex problems. As such, all learners throughout the globe need to experience science education in which they will develop usable knowledge of science. From making personal decisions about daily life issues to working in rewarding scientific careers, knowledge-in-use of science (Pellegrino and Hilton 2012) is essential. We define knowledge-in-use as knowledge that learners can apply to make decisions, solve problems, innovate, and learn more when needed.

Today's children can only meet the future challenges they will face as citizens of a global world if their science education prepares them to have knowledge-in-use that they can apply in a wide range of situations and draw upon to be able to learn more when needed. The importance of context in science education cannot be stressed enough when constructing this knowledge-in-use. Context plays a major role in providing meaning and significance to what is learned. If students don't see the value of what they are learning, they will not engage and expend the cognitive effort needed to learn challenging ideas and construct knowledge-in-use. As Sánchez Tapia states in the introduction to this book, there are limited opportunities for cognitive engagement in STEM for girls, marginalized ethnic groups, children and adolescents living in poverty, and communities that see their belief systems at odds with traditional Western science education. Yet context plays a major role in determining what we learn, how we learn, what we remember, and how well we are able to use

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what we've learned in new scenarios. As a community of science educators and policy makers, we need to know more about how to make science education relevant for all learners so that they can obtain a high-quality science education. The various chapters in this book provide insights in how we might go about creating learning environments that can better engage all students in learning challenging but indispensable science ideas.

In our own work in developing teaching and learning materials, we stress the importance of contextualizing science learning by using phenomena and meaningful questions that we refer to as driving questions (Fortus and Krajcik 2012; Shwartz et al. 2008). Driving questions not only provide a reason for exploring challenging phenomena and studying complex scientific ideas, but they also provide an anchor to which students can attach these complex scientific ideas. One of the challenges in using driving questions to promote contextualization is that the driving questions need to link to important learning goals (Krajcik and Blumenfeld 2006). The driving question is just one way to provide contextualization. Sánchez Tapia et al. (2018) have discussed several ways in which instructional designers can adapt curriculum materials to local contexts to support learners from indigenous communities, including using traditional local knowledge as contexts to explore Western science knowledge.

The chapters in this book bring examples of the value offered and challenges involved in contextualizing science education from pre-service teacher education in Galicia, Spain; practicing science teachers from the Galapagos Islands, a small town of Nahua people in the highlands of the Gulf of Mexico; Syrian refugees and their science teachers in Turkey; students in Germany; a science teacher educator at a public, urban, diverse, minority-serving institution (MSI) in New Jersey; and policy makers in Panama. This diversity of contributions highlights the relevance of contextualization for all students and teachers of science.

1 What We Learn from the Various Chapters

In Chap. 2 (this volume), Brocos and Jiménez-Aleixandre provide a compelling example of the power of Place-Based Education (PBE) in contextualizing pre-service teachers' learning. The teachers in this study investigated the relationships between their personal diets and the local, regional, and global environments. In doing so, the teachers learned that "no man is an island" (Donne 1624) and raised, on their own initiative, the need to consider changes to their personal actions and social habits related to their diets. This is one of the potentially powerful outcomes of learning that is contextualized in a personally meaningful manner – it can lead to a recognition that things do not need to be the way they are, that social norms and personal behavior are not set in stone. This recognition can become the first step in changing one's perspective and from this to a personal call to action. When striving to rectify a social or personal issue, one must first recognize that the issue exists and that it need not be permanent, that it can be changed. As the example in this chapter shows, personally contextualized learning has the power to lead to this recognition. Teachers recognized that their diets were largely driven by local traditions but that other diets were possible, feasible, and perhaps even preferable when seen from a more global perspective. A following step could involve taking action aimed at changing their present diets. But for such an action to occur, it is not enough for the teachers to recognize the importance of the issue and the need to change; they must be agentic and feel efficacious about their abilities to make a change in their own behavior. This raises the question whether contextualized science education can also support the development of personal agency, how it can go beyond the construction of knowledge to helping students feel empowered to steer their lives in the direction they wish to be heading. This is not something that schools traditionally view as part of their charter. Other than in democratic schools, we have never encountered schools where students are regularly encouraged to generate opportunities for change, at school and away from it (Vedder-Weiss and Fortus 2012).

Román and his colleagues (Chap. 3, this volume) discuss the tensions between the desire of *Galapagueño* science teachers to locally contextualize curriculum to address issues that are relevant to the Galapagos, the expectations of the national standards which do not address local Galapagos needs, and what is best for their students in the long-term perspective, since any who wish to continue to post-secondary education will have to leave the Galapagos. To be able to appropriately contextualize curriculum, teachers need intimate knowledge of the local issues facing their students and a degree of professional freedom to adapt existing curriculum to meet their students' needs (Giamellaro 2014). While intimate knowledge of the students and the locale is available only to local teachers and officially they may have a degree of autonomy in adapting the curriculum, the teachers feel constrained in their freedom to make their instruction locally meaningful since the curriculum and the national evaluations are centrally standardized, away from the Galapagos. The Galapagos teachers are also missing expertise on how to adapt the national curriculum to meet local needs, and they feel the need for external support in this endeavor.

Thus we see that even though just about everybody recognizes the value of locally contextualized science materials, there is no simple path for teachers to follow when they want to adapt their materials. Additional studies are needed to identify the key players and the roles they can and should play in the process of locally contextualizing centrally created curriculum materials. Should curriculum experts be "imported" and work together with local teachers to make the required adaptations? Or should the local teachers be provided with professional development and then continue by making the adaptations on their own? What roles do school administrators need to play in this process? How long does such a process typically take? Which material resources are needed?

Sánchez Tapia highlights in Chap. 4 (this volume) another central issue in contextualizing science instruction, that of border-crossing (Aikenhead 2001). Contextualizing instruction can make science ideas accessible and meaningful to students, but not necessarily plausible, as many students bring with them a wealth of knowledge and experiences entrenched in their local cultures that may contrast and contradict with science ideas. Some students succeed in crossing the border between local epistemologies and Western science, in taking multiple perspectives to analyze natural phenomena, in seeing the value of the different perspectives. Other students do not. The same student will successfully border-cross in some situations but not in others. Why does border-crossing sometimes occur and in other times not? Additional research is needed to identify the conditions that need to exist for students to be able to successfully cross the borders between science and their local cultures, back and forth, recognizing the value of scientific perspectives without having to reject their other epistemologies.

Just as standardized tests create tensions for science teachers in deciding whether to contextualize their curriculum with local issues, standardized tests do a disservice to the challenging process of border-crossing because they value only one type of knowledge and do not recognize the social value of other perspectives on natural phenomena, thus encouraging students to play the school game, where at school they express one type of knowledge, canonical knowledge that is valued by the tests and school system, but away from school students fall back on their more traditional sources of knowledge. It would be interesting to see if tests could be designed that provide legitimate opportunities for students to express different sources of knowledge, contrast and compare them, without penalizing students for expressing non-canonical ideas and without losing the psychometric characteristics required of high quality tests.

Can any scientific idea be introduced through appropriate contextualizations, regardless of the external conditions? How does one introduce the concept of electricity to students who live in a place where there is no electricity and little to no battery-powered equipment? How does one contextualize the particle nature of matter to students who don't know where their next meal will come from, indeed, when they will eat again? Is it realistic to expect students to be able to devote attention to the learning of abstract scientific concepts and engage in scientific practices when they are facing other much more pressing personal issues?

In Chap. 5, Delen, Aktuğ, and Helvacı discuss some of the issues facing Turkish science teachers of refugee students. In *The Need for Contextualized STEM Learning Environments for Refugee Students In Turkey*, Delen, Aktuğ, and Helvacı (this volume) stress that knowing how to contextualize STEM education for refugee students is essential to promote equal opportunities to learn and succeed as any other student. Although this issue is critical for Turkish science, technology, and mathematics educators as the number of Syrian refuges has escalated in Turkey, it is an urgent issue that needs to be addressed by the STEM education global community. As they state: "Failing to provide contextualized STEM education for refugee students may lead to inequality of opportunities for these students to pursue their interest in STEM." Such a result would prevent refugee students from having access to equal opportunities as they grow into adults. Unfortunately, as Delen and colleagues show in their research, only a small percentage of Turkish STEM teachers attempt to contextualize learning in meaningful contexts for refugee children. This unfortunate situation most likely results from three reasons: (1) teachers not understanding the importance of contextualization to promote usable knowledge, (2) teachers recognizing the importance of contextualization but not knowing how to contextualize in the lived experiences of children, and (3) pressure to cover required materials to meet national standards. This situation points to the need for continuous professional learning where teachers learn about the importance of contextualization but also share and discuss how they try to contextualize and describe their challenges and successes. Moreover, given the multitude of life-changing challenges these students are facing and their limited knowledge of the Turkish language, we wonder whether even wonderfully contextualized materials have any chance of succeeding in reaching a significant number of these students. This chapter helped us realize that contextualization is not a magic bullet, that it too has its limitations.

The chapter by Härtig, Nordine, and Neumann (Chap. 6, this volume) about the importance of contextualization in assessments reminded us of the Wason selection task (Wason 1968), where participants are shown four cards placed on a table, each which is colored on one side and has a number on the other side. The visible sides of the cards show 25, 16, red, and blue. The participants are asked which card(s) they must turn over to test the truth of the statement: "If a card has an even number on one side then its other side is red." In Wason's study, less than 10% of the participants gave the correct answer (the 16 and the blue cards must be turned over). This is an abstract, academic task. Cosmides and Tooby (1992) showed that performance on this task completely changed when it was contextualized in the following manner: the numbers represented people's ages and instead of having colors on the back sides of the cards there was a picture of a soft drink or a beer. The statement participants were asked to test was now: "If you drink alcohol you must be at least 20." Once contextualized, 75%(!) of the participants gave the correct answer.

Thus, we need to remember that, while contexts are critical in providing an anchor for new knowledge, they also provide access to existing stores of knowledge that might otherwise remain untapped. However, inappropriate contextualization can also block access to existing knowledge or bias different students' access to their knowledge because some contexts may be less familiar, unfamiliar, or even absurd to some students, depending on their experiential background. Just because a contextualized item works well with one population does not guarantee that it will work equally well with other populations. Using different contexts to assessing the same ideas can lead to dramatically different results. We need to recognize that students' performance on assessments is dependent on multiple factors, not just the understanding of the ideas underlying a specific assessment item.

In Chap. 7, Nargund-Joshi highlights the tensions that can exist between national standards and the desire to contextualize learning to meet local needs. This issue was also raised by Roman and colleagues in Chap. 3. National standards are abstract statements and are not contextualized. Mapping between them and locally meaningful contexts is not trivial and requires education, deep understanding of the science, and experience. When choosing a local context that is meaningful to students as a focus of instruction, such as local pollution or the nutritional value of different Latino dishes, one needs to map between the standards and the context to make sure that instruction will focus on learning important learning goals that have been identified in the standards document. However, not all standards will be able to be mapped onto meaningful local contexts. How should these standards be addressed? Do some formats of standards provide greater affordances for mapping the standards onto contexts than other formats? In other words, do some standards support the development of contextualized instruction better than others? Perhaps standards should come with lists of possible contextualizations that have been shown to support the learning of these standards. This might help teachers adapt materials to local needs. These are open questions that require further research to answer.

De León and Heller discuss, in Chap. 8, of the importance for long-term national policy and legislation for supporting and maintaining contextualized instruction. We liked their distinction between government policy and national policy. Government policy looks for quick and visible changes which may not necessarily be valid long-term improvements; national policy looks for improvements that are sustainable, even though they may take time to become visible. Education is an incredibly high-inertia enterprise. Any shift in course requires multiple joint and coordinated efforts over extended periods of time. For this shift to remain on target and be properly guided, it needs to be accompanied by ongoing research. We believe there is a need, now more than ever before, to support the creation of international collaborations that focus the challenges related to the contextualization of instruction, since so many of these challenges are similar across the world, many which were raised in this volume.

2 Concluding Comment: The Value of Contextualization and the Importance of Supporting Teachers in Selecting and Using Appropriate Contextualization

As argued in the *Introduction* by Sánchez Tapia, contextualization plays a crucial role in developing students' knowledge. Without appropriate contextualization, most knowledge remains inert. Although contextualization can provide meaning to an otherwise abstract science topic, unfortunately, inappropriate contextualization can also distract, confuse, and activate irrelevant knowledge that is, in a student's mind, associated with the same context. Bjork and Richardson-Klavhen (1989) distinguished between integrated, influential, and incidental contexts. When learning new ideas, the contexts in which the ideas are presented can become explicitly associated with the new ideas (integrated), they can influence the learning of the new ideas without necessarily becoming explicitly associated with them (influential), or they can be incidental in the sense that they do not influence the student's learning of the new ideas. Bjork and Richardson-Klavhen also demonstrated that ideas are much easier to retrieve and use when they are triggered in contexts that are similar to those in which the ideas were initially learned.

Contextualization is key to developing usable knowledge, but there are also challenges. One challenge we mentioned above is that the context that is selected needs to relate to the learning goals that the teachers or the instructional materials hope that students learn. If not, then we have a situation like that described by Bjork and Richardson-Klavhen in which the context can get in the way of developing usable knowledge.

A second challenge that we have observed in many classrooms is that, even if an extremely motivating context is described and selected, the teacher needs to make use of the context. Often an engaging context can carry and motivate students across several weeks of inquiry, but if the teacher never refers back to the context, then we are back to a situation where instruction is not explicitly related to an engaging phenomenon and to students' lives. Meaningful contexts provide a reason and motivation for students to cognitively engage in learning challenging science ideas. For instance, learning ideas related to the transfer of energy between and within systems is challenging for many middle school students, but when it is situated within a context that is meaningful for the students, the students will engage cognitively to master the material. For instance, in our work, we used the driving question *Why do some things stop but other things keep going?* (Fortus et al. 2015). This question along with associated phenomena that serve as puzzles to figure how they work provides the meaningful context for a range of leaners.

When new ideas are encountered for the first time in a contextualized manner, they tend to be integrated with the context in which they were originally learned. This presents a third challenge because if only one context is focused on, it makes it difficult for students to apply their learning to new scenarios. Fortus (2003) suggested that when these new ideas are relearned by applying them in new contexts, the link between the ideas and the contexts tends to be weaker, influential but not integrated. Finally, after enough reapplying (and, each time, relearning) of the ideas, the links between the ideas and the contexts become incidental, so that the ideas are no longer associated in the students' minds with any particular context. At this stage, after the ideas have been relearned and "decontextualized," they are readily available to be transferred to new scenarios (Cognition and Technology Group at Vanderbilt 1992; Gick and Holyoak 1983). Thus, while contextualization improves and motivates initial learning, a potential danger of contextualized instruction is that if the ideas that are learned are not applied to new contexts, and thereby relearned and decontextualized, there is a possibility that the ideas will remain inert and difficult to be used outside of the original context of learning. How severe this restriction is and how many relearning opportunities are needed to decontextualize ideas are an issue for further research.

A fourth and final challenge is knowing which contexts are meaningful to learners at different age ranges and from different backgrounds. Knowing how to select appropriate contexts is one of the most critical aspects in promoting the construction of usable knowledge. Not all phenomena and contexts will be equally meaningful to all learners. For example, as Brocos and Jiménez-Aleixandre (Chap. 2, this volume) indicated, selecting contexts that are place-based can be meaningful to learners. The curriculum designer and teacher need to become aware of what is motivating and engaging to learners. In our work, we have found it valuable to interview students to find out what is meaningful to them and what is mundane. Have students experience an anchoring phenomenon helps in creating a meaningful context. For instance, as adult learners, we are all interested in the quality of our drinking water, but many students don't care. It is critical to help them realize that our rivers, streams, and lakes not only provide drinking water for us but also opportunities for recreation and for supporting local wildlife (Novak and Krajcik 2019).

These challenges point to need for pre-service and in-service professional learning opportunities that extend across time and engage teachers to talk about solutions for contextualization. Long-term professional learning is key to supporting teachers in creating and using rich contextual examples in their STEM teaching. This professional learning needs to start with pre-service experiences and continue throughout a STEM teacher's professional life.

A necessary design principal in supporting students in developing usable knowledge is to contextualize the learning experience. Schneider and colleagues (Schneider et al. 2019) presented convincing evidence that developing learning environments that present meaningful phenomena to students that are linked to driving questions fosters innovative thinking and the learning of challenging science ideas in high school chemistry and physics for students in both the USA and Finland. Although creating learning environments that are rich and meaningful can be challenging for designers and teachers, and while such environments require teachers to use new teaching practices and many of the environments will need to be adapted to local contexts, such contextualized environments can propel learners of various ages and backgrounds to engage in challenging science ideas, supporting them to develop knowledge they can use to solve real-world problem, make decisions, innovate, and learn more when needed.

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