The Science Curriculum at the Elementary Level:
What are the basics and are we teaching them?

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The Science Curriculum at the Elementary Level: What Are the Basics and Are We Teaching Them?

Christina Siry

When I was asked to contribute to this book by addressing the question of what the basics are for teaching science at the elementary school level, and whether or not these are being taught, I began by first taking a step back to consider why science as a discipline is (or should be) taught at the elementary level. I write this from the standpoint of a former elementary school 'science specialist', grounded in critical sociocultural theoretical frameworks. I begin with this question of 'why' because it is one that I am often confronted with in my own research, and it is a question that I argue all science education researchers should engage with reflectively. In particular, I contend that as a field we ought to consider: what are the needs and purposes of teaching science at the elementary level? Is it to create scientists? Is it to support an informed citizenry? Or perhaps it is to facilitate scientific literacy for either of these viewpoints? The answers to these questions are of course complex, especially as they have been asked by science educators for generations, and also given that the answers have changed as what is valued by society has shifted over time. With that in mind, in the sections that follow, I reflect on the purpose and potential foci for elementary school science teaching, guided by international research findings, critical theoretical perspectives, and my own experiences working in the field of elementary science education for the past 20+ years.

Why Teach Science in Elementary School?

> There are many who do not believe it amounts to much one way or the other what children do in science in the elementary school. I do not agree, for upon the whole, I believe the attitude toward the study of science is, and should be, fixed during the early years of life. (Dewey, 1910, p. 123)

There has been much written in the field of science education about teaching children positive attitudes toward science at an early age, and young children have been situated in the literature as being "natural scientists" (e.g., Head Start, 2010, p.18), "scientific learners" (e.g., Gopnik, 2012, p. 1625), and "emergent inquirers" (e.g., Hedges, 2014, p. 39). Undoubtedly, interacting with young children often reveals curiosity and fascination with new discoveries, especially when engaging with science questions. Science itself is a human endeavor, one that is particular to inquiring into phenomena of the natural world. In curricular debates regarding science at the elementary levels, there tends to be a split between those who emphasize primarily science content and those who emphasize primarily the processes of science, but in both of these perspectives, positive attitudes towards science are often held as a central underpinning, as also emphasized by John Dewey in the above quote.

Science as a specific focus for a school discipline typically lacks the clarification of what, specifically, is meant by the term "science" in thinking of school science – many have preconceived notions of textbooks, magnifying lenses, and lab experiments – all of which come from clearly confined cultural contexts and expectations. Recently, the Science Council in the UK (2015) took a step back and defined the word *science*, which they contend is the first time this has been done by scientists for clarification of the term. Their perspective is that "science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence" (http://www.sciencecouncil.org/definition). Related to this is the Next Generation Science Standards ([NGSS]; NGSS Lead States, 2013) in the US which have clarified that "in the K –

12 context, 'science' is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences" (p. 103), and further that science is "both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge" (NGSS Three Dimensions, 2013)

Taking these perspectives together, science can be perceived as an approach to investigating the known, and the unknown, and to an understanding of a body of knowledge that evolves over time. Further, science can be situated as being central to engaging in processes of knowledge construction – of the known and the unknown – which certainly extends far beyond the realm of science in and of itself, in order to support learning, reflecting, and understanding of the social and natural worlds in which we participate. Yet we find in many schools that the primary focus in elementary grades is on literacy and numeracy (Appleton, 2007), and that science is not consistently taught at the elementary level. When science is taught, it is common to be in a fragmented, reduced manner, focusing almost exclusively on developing vocabulary (e.g., Newton & Newton, 2000) and/or descriptive regurgitation of information. This is unfortunately not restricted to particular isolated regions of the world as there is a globalized focus in elementary school of accountability. The pressures of such accountability position teachers to teach only that which will be tested and relies on rote memorization of facts, which marginalizes a subject such as science (Berg & Mensah, 2015). As a former researcher and teacher in the United States, I was confronted with this situation time and time again. Currently I live in the European country of Luxembourg, and continue to be confronted with the same types of experiences regarding the de-valued role of science at the primary school level. As an example, my own daughter recently came home from her first day of sixth grade with a note to parents from her teacher, which stated that:

> Due to the standardized tests later this year [in French, German and math] the following subjects will not be taught during the first two trimesters: art, music, history, geography, science, and Luxembourgish.

Imagine for a moment the experiences of children who are in classes all day long, only being instructed in three subjects, every day, all day … one mustn't wonder then why my daughter no longer wants to go to school. While this is perhaps merely one example of one teacher's reaction to standardized testing pressures, those of us working in elementary science education internationally are likely more than aware of this situation in numerous classrooms. An education system that only values the things that are tested will not educate and support children to be able to construct complex understandings of knowledges – instead, what is valued is reduced to what is tested: isolated facts removed from any context, presented as known information to be memorized, or pre-packaged, scripted curricula, created by corporations and designed for teaching to tests (Au, 2011), which is a far cry from the perspective of science as "both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge" (NGSS Three Dimensions, 2013,) and similar explanations of the discipline of science as represented in policy documents.

In considering why science is taught at the elementary level, it is prudent on the one hand to acknowledge the damaging culture of accountability that continues to shape classroom practices and policies, marginalizing and reducing science to something that can be measured and is fact-based; which is far removed from the ideals of why science should even be taught in the first place. On the other hand, it is an opportunity to reflect on the immense possibilities that science as a field can provide at the elementary level for engaging children in enacted, embodied processes of knowledge construction. For example, the work that my research team has been doing examines the ways in which children's interactions around science can serve to facilitate dialogic encounters that support the emergence of complex understandings and questions. This research has revealed that supporting children with extended time for open-ended approaches to investigating can increase children's agency as learners (e.g., Siry, Wilmes & Haus, 2016), and that building science investigations from children's own questions can lead to new conceptual understandings (e.g., Siry & Kremer, 2011). I contend that science education as a *practice* is an entwined mixture of content, process, and attitude, which is deeply contextual, and that none of these can be pulled apart from the other. With a grounding in dialectical theoretical perspectives, science to me is both the *process* as well as the *product* – the act of doing science and the development of conceptual understandings; each of which facilitates the other recursively and together is embedded in the attitudes that are shaped in this. As such, a question such as "why" teach science at the elementary level can be approached with an understanding of working towards the development of content, processes, and critical, positive attitudes towards the discipline. Yet this still leaves the big question of what, specifically, should be taught in elementary school, which I address in the next section.

What Should be Taught in Elementary School Science?

"What" in regards to curriculum is a problematic consideration, as it encompasses not only the intended goals and objectives, but also the specifics of the subject matter, the scope and sequence of these, and the instructional strategies, among other considerations (Gehrke, Knapp, & Sirotnik, 1992). Science as a school subject is impacted in practice by what is valued; valued by policy makers, valued within the curriculum itself, and valued by those who implement these policies – the teachers. Further, the actual implementation of what happens in science classrooms is a complex relationship between the student, the teacher, the curriculum, the context, and the policies (Rodriguez, 2015). Certainly there have been a multitude of policy reforms focusing on the teaching of science in the recent past (e.g., American Association for the Advancement of Science, 1993, 2001; NGSS Lead States, 2013; Rutherford & Ahlgren, 1991), but at the interface between these actual policies and their implementation lies the decision making of the teachers, and this is in essence the curriculum as enacted. In addressing the central question of "what" I attempt to bridge between the printed and the performed curriculum, but it is necessary to acknowledge the possible discrepancies between what exists in teachers' guides and what is lived and practiced in classrooms.

The debate over what, specifically, should be in elementary curricula to be taught in science has focused on content of science and the process of science for over 100 years (e.g., Dewey, 1910). Visions for science curriculum have included a variety of perspectives on what should be taught in the elementary school level, but quite consistent over the past several decades has been a discourse with foci on considering scientific content as thematic and focused on "big ideas" (e.g., Harlen, 2015), and scientific skills as process-based and focused on "habits of mind" (e.g., Gehrke, Knapp & Sirotnik, 1992). In short, we have learned from international research findings that there is a benefit for working towards emphasizing knowledge, skills, and values of science with children at the elementary level. What is often missing, however, is the focus on the contextualized ways in which children and teachers can learn together, in order to emerge with culturally and socially relevant understandings of the known, and the unknown.

What are the basics of a well-conceived science education is a controversial question in many ways–is it that the basics are an objective body of facts? Turning to the NGSS illustration mentioned above of science as the traditional natural sciences: physics, chemistry, biology, as well as the earth, space, and environmental sciences, once could perceive of this as a focus on knowing a specific canon of knowledge, even if the NGSS clarifies that the focus ought to be on a small number of core ideas in the sciences. In times of immense knowledge literally at our fingertips, the memorization of specific facts is in many ways superfluous, yet this is often the focus of elementary school science teaching practices, as students are to be prepared to memorize information that will be evaluated with tests. I contend that instead our focus should be on working to support students in creating knowledge and valuing the knowledges that they have and that evolve over time. Students ought to be supported in creating their own conceptual frameworks for understanding science phenomena and connections, and make meanings that connect with their own experiences and perspectives. If we consider such meanings as not things that are static, but rather as constructs that "come-to-be" in relations (Vagle, 2015, p. 9), then it is critical that we focus on these contextualized relations; between students, students and teachers, students and subject matter.

Above I asked if the "basics" are an objective body of facts. Perhaps one can also ask if the basics include a generalized approach for engaging in science as well. Turning again to the NGSS as an example of a standards-based conception of a discipline, once could conceive of science as a "theory building enterprise", which turns attention to the action of engaging in science and the "doing" of science (e.g., Siry, Ziegler, & Max, 2012). The doing of science in a classroom situation is a relational one (Cavicchi, 2014), as participants engage collectively in approaching science phenomena as something that is done. This relational aspect of science education turns the attention to the value of the process of science as a central basic grounding for science education. The argument for integrating content and process is certainly not new – it is one that has been in the literature on elementary science education for over 100 years (e.g., Dewey, 1910), and had been persistently argued for generations. David Hawkins (the director of the "elementary science study" in the early 1960s) emphasized the necessity of bridging what he coined "messing about" in science (1965) as he illustrated the value of balancing open-ended investigation time with more structured discussion opportunities. The connections between doing science, talking science, and learning science are deeply integrated and inseparable. Why then do we continually find that classroom practices return to knowledge acquisition alone? This persistent focus on knowledge acquisition in science has been suggested to be damaging to those concerned (Bryce, 2010), and it is far removed from any relational, contextualized meaning-making that students are more than capable of creating at the elementary level. This relational meaning-making was recognized in a review of the curriculum materials in science education from almost 50 years ago: "… the student is constantly making discoveries and organizing the processes and content which he is learning into some sort of fabric meaningful to him" (O'Hearn, 1966, p. 1). If we flip the focus from concrete certainty to be recast as a focus on uncertainty, there emerges a simple focus on valuing difference (Osborne, 1997), and an emphasis also on the focus on the unknown.

Today we are stuck in a pre-internet paradigm in elementary school science, where facts needed to be easily recalled to be useful. Simple facts are easy to find online, but the relationships between these are more difficult. The Internet gives students the ability to retrieve simple facts and thus the starting point to analyze these facts, their contexts, and their relationship to children's contexts. While those simpler facts may be easy to test, and thus measure, the purpose of the potential next step is missing–the development of scientific understandings in a relational manner. However, such contextualized understandings and foundations for an appreciation of uncertainty and the unknown is quite difficult to measure. If we work more on facilitating students' abilities to investigate the unknown, we are supporting them to create their own knowledges. In not teaching students to think and apply knowledge, we also limit the scope of who is reached, as there is a need to embed notions of engagement, equity, and diversity, to make science learning accessible to a wide range of students (Rodriguez, 2015). Further, we need to consider policy and curriculum as a lived text (Vagle, 2015) – to consider curriculum as it might be lived, not as it has been designed and planned, in order to emerge with a more contextual, relational view of science, and a school population supported in thinking, learning and being able to discover the unknown. In doing so, we can move towards the "re-imagining" of science education in order to move away from the "authoritarian knowledge structures" (Tytler, 2007, p. 67) to incorporate approaches to classroom investigations that lead to more diverse approaches to thinking about knowledge as well as about learning.

How Should Science be Taught in Elementary School?

> Scientific knowledge is not a universal "metanarrative" from which one might eventually expect to be able to deduce a reliable answer to every meaningful question about the world. It is not objective but reflexive: The interaction between the knower and what is to be known is an essential element of the knowledge. And like any other human product, it is not value-free, but permeated with social interests. (Ziman, 2000, p. 327)

There has been significant research regarding the low confidence of elementary teachers to teach science (e.g., Appleton, 2007), suggested to emerge in part from teachers' own perceived lack of content knowledge (e.g., Keys & Bryan, 2001). Additionally, it has been elaborated that teachers' past experiences in science education have a strong impact on teachers' thinking about science education as a discipline (e.g., Bryan & Abell, 1999). The low confidence in teachers is not surprising if we think of teaching science as requiring an understanding of curricular objectives, pedagogical approaches for teaching in a "hands-on" manner, and the entire body of knowledge that is science. But, if we reframe what these basics are we can restructure teachers' roles as well as the purposes of the curriculum. In doing so, teachers can be supported to deconstruct their own notions of science with an emphasis on reconstructing to have an understanding of uncertainty, which is the heart of the scientific endeavor. If teachers begin to understand science as a search for meaning in essence, then this meaning making can be framed as locally bounded, and as individual and collective – content and process. Science is a set of cultural practices and discursive relationships focused on "constructing explanations, defending and challenging claims, interpreting evidence, using and developing models, transforming observations into findings, and arguing theories" (Kaartinen and Kumpulainen, 2002, p. 190). Reframing the focus of science as a school content area to move away from discreet, isolated facts, and instead to be on the discursive and cultural processes at play in the act of science, can ideally support a contextualized, relational teaching of science at the elementary level. As such, the interactive nature of learning – between the knower and the known as John Ziman (2000) elaborates – can be moved to the foreground of science teaching and learning.

As Madeleine Grumet noted in the original *Thirteen Questions* book over 2 decades ago, the notion of relation is one that is basic to education writ large (Grumet, 1995), yet it is often what is left out of the conversation of what "the basics" actually are. Relationships between the students and the material, and also human relationships, can become central as "the relational processes that negotiate trust are inseparable from the intellectual processes that initiate experimenting" (Cavicchi, 2014, p. 188). Relational, contextual approaches can connect science to students' lifeworlds, and there is sufficient evidence from research of the value of reframing science education as participation in communities (e.g., Roth & Lee, 2004) and as a cultural way of knowing (e.g., Meyer & Crawford, 2011), so that cultural practices of science can be woven together with the cultural experiences of students.

Returning to the opening quote from John Dewey from over 100 years ago, attitudes are a critical part of science education, and I suggest that positive attitudes for children as well as their teachers can emerge if science is framed as something that is close to participants' lives. In supporting teachers to find contextualized approaches to engage in science with their students can lead to a contextualized science based on diversity and difference, one that is not only focused on memorizing and regurgitating information, but one that is focused on teaching and learning science as a complex, contextualized experience.

> When our schools truly become laboratories of knowledge-making, not mills fitted out with information-hoppers, there will no longer be a need to discuss the place of science in education. (Dewey, 1910, p. 127)

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