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Putting the Cart Before the Horse: The Creation of Essences out of Processes in Science Education Research

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ABSTRACT: This article addresses the problem of treating generalizations of human activity as entities and structures that ultimately explain the activities from which they were initially drawn. This is problematic because it involves a circular reasoning leading to unwarranted claims explaining the originally studied activities of science teaching and learning. Unlike other fields within social science research, this problem has not been appreciated and discussed in the science education literature and the field thus needs to be reminded of it. A heuristic specifically developed for the purposes of this article is applied to two examples taken from a much-cited research in the field. Through the examples it is argued that the practice of creating entities out of generalizations of science classroom activities leads to a number of unintended consequences. It is further argued that the stated purposes in the two example articles would actually have been better served by investigating the entire processes through which the activities develop, as well as how the activities may change through teaching. The article concludes that through the search for explanations caused by underlying entities, science education research runs a risk of alienating its results from the activities from which it initially wanted to meliorate. © 2013 Wiley Periodicals, Inc. *Sci Ed* **98:**127–142, 2014

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INTRODUCTION

This article is intended as a reminder to the field of science education of the problems associated with the search for behind-the-scene structures (Pickering, 1995) that can explain what occurs in activities in science classrooms. In particular, we are concerned with the practice of creating mental and social structures out of generalizations of observed human activity.[1] We argue that this practice often involves circular reasoning, because the legitimately construed generalizations are, nonlegitimately, turned into objects that acquire an ontological status instead of a purely analytic one. Consequently, the generalizations tend to be treated as entities that underlie, and thus ultimately cause, the activities from which they were generated in the first place.

Historically, the phenomenon of first creating entities from processes and then describing these entities as the causes for the processes has been discussed on several occasions. One of the central educational philosophers of the twentieth century, John Dewey, often addressed this problem through the metaphor "putting the cart before the horse." This allusion is found in 24 different places in his collected works (cf. Hickman, 1992). One of the examples that Dewey used to show how easily activities might be converted into entities is the capability of *imitation* from the psychology of learning. Dewey demonstrated that the concept of imitation originates from our day-to-day experience of a common process, that is, people do similar things in similar fashion. But within certain research traditions, it has been argued that these behavioral patterns arise because the human mind possesses an inherited, instinctive, and underlying driving force that causes imitation to occur. According to the advocates of this view, then, the behavior of mimicking each other's behaviors is directed by this mental entity. However, as Dewey states,

> "Imitation" throws no light upon why they so act; it repeats the fact as an explanation of itself. (Dewey, 1916/1996, p. 39)

Thereafter, he calls up the famous metaphor that Nietzsche (1886/1997) had used to elucidate the same thing: "It is an explanation of the same order as the famous saying that opium puts men to sleep because of its dormitive power" (Dewey, 1916/1996, p. 39).

A recent critique along the same lines is given by Pleasants (1999). He succinctly formulates the issue, which is central to the argument of the present article, in the following way: "The basic form of this type of reasoning involves the postulation of various mechanisms, powers, structures, etc. . . . . These transcendental entities are then taken to be, in a sense, more "real" than the reality which can be and is known; the former is understood to generate the latter" (p. 182). Unlike many other fields within the social sciences (see Adams & Markus, 2001; Goodwin, 1993; Heinz & Beck, 2011; Hyman, 2010; Pickering, 1995; Säljö, 2002 for examples from psychology and sociology), the issue of first creating entities out of processes and then invoking them as causes lying behind these processes has not received much attention in the science education literature. One exception is Bailin's (2002) critique of the treatment of critical thinking as a skill residing within individuals. Or Wickman (2012), who warned against the unreflective mapping of "conceptual schemes." On a more general level, a number of science education researchers, especially from sociocultural and pragmatic traditions, have claimed that the entities of cognitive psychology, as well as other kinds of allegedly underlying structures, have comparatively little to offer

[1]The conversion of processes to things is referred to in the literature as reification or hypostatization. However, we have chosen not to use either of these two words since reification, in particular, constitutes a technical term in several fields, for instance within Marxist (e.g., Honneth, 2008) and Sociocultural (Wenger, 1998) theory.

in terms of understanding what occurs in the science classroom (Garrison, 1995; Lidar, Lundqvist, & Östman, 2006; Lundegård & Wickman, 2012; Roth, 1998, 2013; Schoultz, Säljö, & Wyndhamn, 2001; Wickman, 2006; Wong & Pugh, 2001). Finally, it should also be acknowledged that there are examples of studies which take a process and dynamic approach while not explicitly arguing for the approach as such (cf. Hamza & Wickman, 2009; Hwang & Roth, 2007; Nemirovsky, Tierney, & Wright, 1998; Orlander Arvola & Lundegård, 2012).

However, despite these various efforts, there have been no continuous in-depth discussions within our field more broadly. Thus, although the practice of creating entities out of processes is indeed a potential problem for social research generally, it is particularly important to raise this problem within the field of science education, since we have no history of dealing with it explicitly. This article is an attempt to begin such a discussion. To achieve this, we develop our argument with the aid of two empirical examples and a heuristic developed for our purpose. We show what the problem may look like in science education research, what consequences it may have, and suggest possible ways out of it. First, however, we deepen the background of our argument a little more by showing how the problem has been treated in philosophy.

THE PHILOSOPHICAL ANGLE

The tendency of constructing abstract entities, structures, and mechanisms from observed activities or processes and, subsequently, assigning an underlying power to these entities, has been a subject for discussion in different philosophical schools. Ancient philosophy created a distinction between phenomena and the eternal ideas that are supposed to lie behind them (Dewey, 1929/1996; Rorty, 1979). The platonic philosophy, in particular, transformed preceding cultures' animism and pantheism into an ontological division between things and their underlying, inherent ideas. In that way, the human body came to be seen as separated from its soul, and nature became separated from culture. The early teleological sciences made a habit of postulating underlying structures and essences out of processes and observed patterns in nature. Later, certain biological currents of ideas, such as vitalism, as well as more recent ones, such as organicism and the Gaia hypotheses, were all built around the idea of emergent entities working as hidden, transcendent, or even mysterious driving forces behind observable phenomena in nature (Worster, 1987). As Dewey pointed out over and over again, this habit has the consequence that some aspects of existence are denied the possibility of empirical scrutiny (Dewey, 1929/1996; 1933/1996):

> In the history of the progress of human knowledge, out and out myths accompany the first stage of empiricism; while "hidden essences" and "occult forces" mark its second stage. By their very nature, these "causes" escape observation, so that their explanatory value can be neither confirmed nor refuted by further observation or experience. (Dewey, 1933/1996, p. 271)

In the 19th century, Nietzsche (1886/2000) brought attention to the illusion of ideal states. It was the tragedy that followed upon man's insight into the unpredictability and contingency of life that made him create idealized states in which he could rest (Deleuze, 1983). Later, pragmatically oriented philosophers such as C. S. Peirce observed that western philosophy for a long time has been occupied by a Cartesian anxiety from which arises a desire to overcome that which is otherwise experienced as a quagmire of complete doubt (Bernstein, 2010; Peirce, Kloesel, & Houser, 1998). Dewey described how mankind, reflecting on our place in life historically, has successively turned phenomena in the world and within itself into abstract entities, and located these abstractions outside the normal course of events in the material world: "All the spooks, fairies, essences, and entities that once had inhabited portions of matter now took flight to new homes, mostly in or at the human body, and particularly in the human brain" (Dewey & Bentley, 1949/1996, p. 123).

In mid-20th century European philosophy, the coming into being of metaphysics as a consequence of our language usage was a central theme (Rorty, 1992; Russell, 1946). Ludwig Wittgenstein in particular described how difficult it is for man to move away from the search for the ideal and the transcendental. He wrote, "The ideal, as we think of it, is unshakable. You can never get outside it; you must always turn back. There is no outside; outside you cannot breathe. –Where does this idea come from? It is like a pair of glasses on our nose through which we see whatever we look at. It never occurs to us to take them off" (Wittgenstein, 1953/1997, p. 45).

The clarity that Wittgenstein brings to philosophy consists of reminding us of the fact that our language constantly refers to behind-the-scene structures, and that this is a trap from which it is impossible to escape. Instead, he suggests that we should remind ourselves how language works in our everyday ways of talking about things for a variety of purposes. Through such reminders, Wittgenstein tries to dissolve some of the purported problems that have occupied philosophers for centuries.

Of particular interest for our present argument is the fact that Wittgenstein reminds us over and over again how easy it is to get caught in the trap in which we refer to rationally created abstractions as if they rested on empirical grounds. This habit of talking about material processes in terms of abstract states, confusing grammatical peculiarities of language with empirical facts, is labeled a "conjuring trick" by Wittgenstein (1953/1997, p. 102). For instance, Wittgenstein shows us how one single term such as "understanding" is used in a large variety of ways. Thus, just because the word "understanding" exists in our language, it does not follow that there exists some entity within the brain that corresponds to all the different ways the word understanding is used (Wittgenstein, 1974, p. 12 § 36–44). This does not mean that understanding is not associated with cognitive as well as neurological processes. But this is a trivial statement. On the other hand, what Wittgenstein as well as several contemporary students of psychology argue is that there is little reason to assume that in every possible situation in which we would be inclined to say "I understand," this would be represented by a certain neurological state (Bennett & Hacker, 2003; Moyal-Sharrock, 2009; Standish, 2012; Stern, 1991). Here, we are simply trapped by our language use, in which it may seem as if we were doing the same thing every time we say we "understand" something.

Moreover, Wittgenstein systematically opposes any attempt to take recourse to concepts such as praxis, rule following, or the nature and structure of language to find a higher order in existence. But where Wittgenstein pointed the way out, others, when they have used some of the concepts that Wittgenstein had to employ in his investigations, have gotten caught in precisely the trap that he warned about. For instance, Pleasants (1999) provided ample illustrations that several critical social theorists still adhere, in their actions if not in their theories, to an ontological picture of language as consisting of hidden structures. He gives us several examples of concepts such as "forms of life," "language game," and "rule following," which Wittgenstein, ironically, invoked precisely to counter such tendencies in philosophy, as well as concepts such as "reason" and "tacit knowledge" (Pleasants, 1999 pp. 16–17, 37, 74).

Other philosophers (Foucault, for instance) have also fought against the risk of being misinterpreted as representationalists or structuralists. Although Foucault's primary purpose was to point out how our habits and customs have led to a circular relationship between knowledge and power, he struggled to avoid being interpreted in terms of simplified explanations when presenting his genealogy (Prado, 2000).

To sum up, the practice of creating entities out of processes was already common in ancient philosophy as well as in the early sciences. It continued through Romanticism to eventually become widespread in large parts of humanities and the social sciences, such as modern psychology, sociology, and philosophy. In 1949, Dewey and Bentley remarked that "Philosophical discourse is the chief wrong-doer in this matter. Either directly or through psychology as an ally it has torn the intellectual, the emotional, and the practical asunder, erecting each into an entity, and thereby creating the artificial problem of getting them back into working terms with one another" (Dewey & Bentley, 1949/1996, p. 187).

We argue that this practice of creating entities out of human activity is still a problem for science education research. The following analysis shows how this is done and how it leads to unintended and unappreciated consequences in our field.

A HEURISTIC FOR ANALYZING THE CONVERSION OF ACTIVITIES TO ENTITIES

For the purpose of this article, we constructed a heuristic, enabling us to develop our argument concerning the potential pitfalls associated with invoking underlying structures to explain human activity in science education research (Figure 1). It is important that Figure 1 be viewed as a heuristic, situated in the problems we intend to address and, therefore, useful primarily for that particular purpose. Moreover, it is not intended as a comprehensive illustration of all kinds of research processes, but serves instead the purpose of focusing attention on certain critical actions on the road toward conversion of activities into entities.

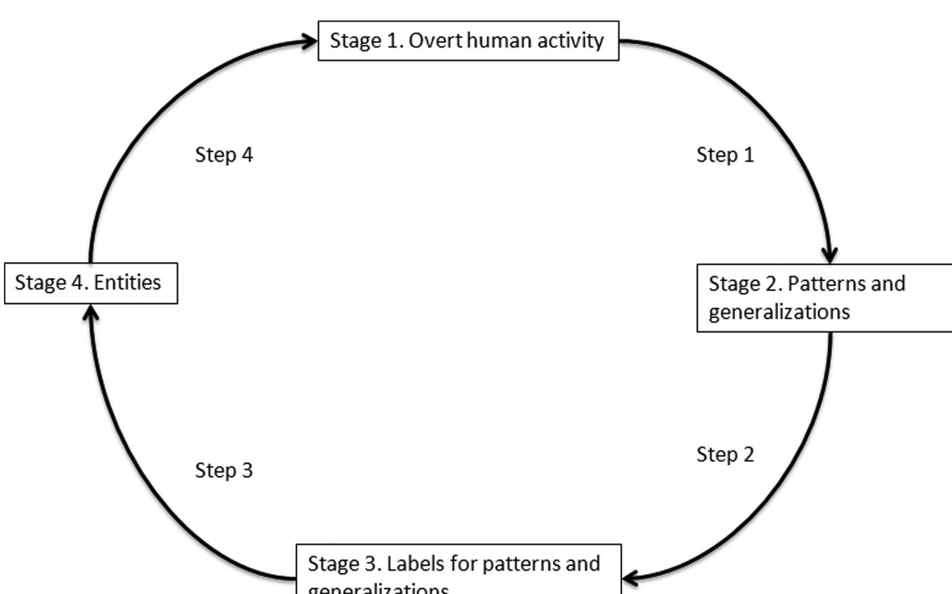

Figure 1. A heuristic for analyzing the conversion of activities to entities.

Stage 1. Observing Overt Human Activity

The point of departure in our heuristic is the study of human activities in some form or another (Figure 1, Stage 1), simply because it is the conversion of human *activity* into underlying structures that ultimately concerns us here. Moreover, our starting point is an *overt* activity because, in the end, the only kind of data available both to educational researchers and to teachers are what people actually do (Säljö, 1999; Wickman, 2006). Thus, the base line in our model is that people do something overtly, and that we as researchers or teachers observe these overt activities. Examples of what people may do in educational settings include the following:

- children playing in the school yard,
- primary students producing drawings of the effects of gravity on the moon (also the actual produced drawings count as overt activities in this sense),
- secondary students answering questions about chemical reactions during interviews,
- undergraduate students answering questions on a written exam (including the final answers),
- boys and girls doing different things in laboratory work in school science.

Stage 2. Discerning Patterns and Generalizations

Of course, in many cases, activities such as those in the list are left without further elaboration, in which case we have nothing to do with them for our present purposes. However, researchers often attempt to say something more about such activities which, then, by necessity amounts to a recognition of patterns or constitutes some kind of generalization of them (Figure 1, Step 1 to Stage 2). For instance, we may observe students during school science laboratories and describe their recurrent ways of acting, for instance, "Caren consistently uses appropriate equipment and engages in lab work activities, whereas Billy often uses inappropriate equipment and does not engage at all."

Stage 3. Labeling the Patterns and Generalizations

Possibly, we may also extend these descriptions of student actions into some kind of typification of the patterns of action that are recurrent in the classroom, perhaps labeling these patterns as "Caren's" and "Billy's." In other words, we often need to attach labels to the patterns, especially if we want to communicate our observations of these activities to others (Figure 1, Step 2 to Stage 3). As will be evident as our argument develops, we have basically no quarrel with the process up to Stage 3 in our heuristic. Indeed, professional communication in science education would be utterly difficult, if not entirely impossible, if we did not attempt to locate and name patterns as we try to say something about them.

Stage 4. Creating Concrete or Abstract Entities

However, we will show that it has important consequences if, on the one hand, one stops at Stage 3 (just talking about patterns of action) or, on the other hand, continues to Stage 4 and begins to talk about the patterns and generalizations as underlying entities (Figure 1, Step 3 to Stage 4). This is the first, potentially problematic step on the road to the creation of underlying structures in our heuristic. In our example, it would mean that talk about the patterns "Caren's" and "Billy's" gave way to talk about qualities, such as different competencies, interests, or gender identities (e.g., "girls" and "boys") pertaining to students in the laboratory activity. So, instead of denoting patterns emerging from an analysis of human activities, the labels begin to be used as names for entities that are placed *within* individuals (or, indeed, practices, cultures, or societies). Note that for our argument, whether this move is deliberate and explicit or, rather, simply a question of wording is not important, since we are not concerned with any presumed underlying intentions for ways of talking, but instead with their consequences, (e.g., for future research, teaching practice, or policy).

The last step consists of going all the way and, deliberately or not, invoking *agency* to the entities thus created. So, the patterns drawn from Caren and Billy acting in different ways in the laboratory are converted into personal traits (or, from other theoretical perspectives, gender discourses or power relations) that explain, or even cause, the actions in the first place. The entities are thus used for explaining the same activities from which they were once generated. They are put before the activities as a driving force behind them. In other words, the cart is put before the horse, as Dewey succinctly put it.

In the following section, we will use the heuristic outlined in Figure 1 to track this process in two different examples. Indeed, we are aware that by making use of a picture like the one in Figure 1, we ourselves run the risk of turning the very process we want to warn against into an entity. Yet, as will become evident as our argument develops, our point is not that we may never label a process, nor that we do not need to describe a process through, for instance, a useful picture, but rather that in doing so researchers need to reflect on their responsibility for how these labels and pictures might be used in the future, by themselves or by others.

TWO EXAMPLES FROM SCIENCE EDUCATION RESEARCH

In this section, we present two examples which taken together illustrate how generalizations in current science education research are treated as entities that are related to the activities from which they were initially drawn. Each example is analyzed through our heuristic (Figure 1), and highlights different aspects of what this practice may look like and, more importantly, what consequences it may have.

Example 1: Cognitive Structures as Underlying Entities

From Human Activity to Underlying Entity. Our first example, which may be assigned to a cognitivist and constructivist tradition, is taken from a recent paper by Talanquer (2009). In this paper, a number of *core implicit assumptions* were identified from a meta-analysis of a large number of previous studies of students' understanding of the structure of matter. Because the paper is well written and well argued, it is convenient to use for our purposes, that is, to illustrate how potentially useful generalizations concerning students' understanding of school science content are described as entities preceding and, thereby, explaining the activities from which they were drawn. We will argue that this way of using the generalizations is methodologically unwarranted and, more importantly, that it does not contribute anything significant to the usefulness of Talanquer's framework.

The basis for Talanquer's analysis is overt activity, for instance, drawings and representations or answers to questionnaires and interview questions (Figure 1, Stage 1). Studying such activities is arguably our only way of getting access to students' meaning making in relation to a given science topic. We give an example of one such student activity taken from one of the studies (Samarapungavan & Nakhleh, 1999) cited by Talanquer. The purpose of the interview was to investigate elementary students' understanding of the structure of matter:

Researcher: Now take a look at this sugar cube and say, is this just one big piece of material or is it made up of little bits?
Linda: It's little pieces of sugar.
Researcher: 'Kay, now think about the smallest little pieces of sugar that this cube is made of. Uh, are they all the same or different?
Linda: Different.
Researcher: Okay, can you tell me in what way they're different?
Linda: They're all probably shaped different. . . . I don't know how little they are.

[Linda constructs Play-Doh models, which are very small round and oval objects.]

Researcher: What shapes would these little pieces be, you think they'd be all different shapes?
Linda: Kinda circle and kinda oval.
Researcher: Okay. [pause] You think there would be any other shapes, like squares, or triangles, or things like that?
Linda: Yeah [long pause].
Researcher: You know, this tiny little piece of sugar, uh, what would they taste like?
Linda: Sweet.
Researcher: Sweet. What color would they be?
Linda: White. White and [pause] I dunno. White.

On the basis of this and numerous similar activities, a large number of generalizations concerning the ways in which students understand a certain science topic were generated (Figure 1, Step 1 to Stage 2). For instance, the above example constitutes an instance of the generalization that *students often equate microscopic and macroscopic properties of substances* as they talk about them in interviews (Samarapungavan & Nakhleh, 1999). Of course, the generalizations may be further refined in steps of increasingly general scope. For instance, one important contribution of Talanquer's analysis is that it subsumes the virtually ungraspable plethora of generalizations of students' understanding of the structure of matter into a smaller set of more manageable and potentially more useful generalizations. (cf. Talanquer, 2009)

Closely tied to the process of generalization is almost always another process, namely that of assigning labels to the generalizations made from the studied activities (Figure 1, Step 2 to Stage 3). For instance, Samarapungavan and Nakhleh (1999) labeled the generalization that students equate microscopic and macroscopic properties *macroparticulate*. In Talanquer's scheme, this way of talking about matter was further subsumed under a more inclusive generalization (viz., a core implicit assumption) with the label *inheritance*, implying that students often explain the characteristics of submicroscopic particles through the macroscopic characteristics of a substance. Thus, the submicroscopic particles tend to "inherit" the macroscopic characteristics.

However, after having presented this overview and condensation of the various ways in which students cope with issues of the structure of matter, Talanquer, deliberately or not, begins to talk about the core implicit assumptions not only as labels for generalized ways of action, but as entities that have some kind of relation to these actions (that is, apart from being drawn from the generalizations) (Figure 1, Step 3 to Stage 4). This is evident when Talanquer talks about the core implicit assumptions as "*underlying implicit assumptions* that constrain student thinking" (Talanquer, 2009, p. 2133, emphasis added). Next, the purported entities (i.e., the core implicit assumptions) are described as actually influencing the ways in which students act as they talk about the structure of matter, thus closing the circle (Figure 1, Step 4 to Stage 1). For instance, Talanquer claims that the core implicit assumptions that he has described "*guide and restrict* student thinking" about the structure of matter (Talanquer, 2009, p. 2133) and that their ways of reasoning in interviews "may indeed be explained by *the presence of* implicit assumptions" (Talanquer, 2009, p. 2127, emphasis added).

The methodological mistake here is to separate "implicit assumptions" and "student thinking" as two different entities having a relationship with each other, whereas empirically speaking, the former are simply the labels given to generalizations of the latter. The problem may also be pinpointed through the following quotation (Talanquer, 2009, emphasis added): "The present work was guided by the assumption that student thinking at different learning stages may be thought of as *constrained by implicit assumptions* that can be *inferred from the analysis of students' descriptions and representations* of different types of substances and their changes" (p. 2126).

But here dwells circularity. From where does Talanquer get the implicit assumptions? The answer is that they are "inferred from the analysis of students' descriptions and representations of different kinds of substances." And what is it that the implicit assumptions constrain? It turns out to be precisely the "descriptions and representations of different types of substances" from which they were inferred. The result of this circularity is that less generalized ways of talking about matter are purportedly explained as being constrained by more generalized ways of talking about matter. This, we argue, is to put the cart before the horse.

What Difference Do Entities Make? Even more important than this methodological critique, however, is to examine the actual and potential consequences of the practice outlined above. To begin with, let us look at how Talanquer (2009) motivates his work of subsuming previous generalizations of students' talk about matter into broader categories:

> The identification of students' implicit assumptions and reasoning strategies can help us *better define learning progressions* that describe how students gain expertise in a given domain.... These learning progressions are *useful tools in the design of educational materials and experiences* that foster meaningful learning, as well as in the development of assessment practices that set clear standards of performance, properly track student progress, and provide formative feedback.... (Talanquer, 2009, p. 2125. Emphasis added)

Thus, the point is to make the "tool" (*learning progressions*) better suited to do what it is intended to do, namely to aid in the planning and assessment of science teaching in school. To that end, Talanquer (2009) presents a framework consisting of a set of generalizations of students' ways of talking about matter. The framework lays out, in a more comprehensive and manageable way than before, what kind of reasoning one may expect from students as they learn about the structure of matter. It is explicitly pointed out that the framework does not imply simple linear trajectories through these different ways of talking, nor that at any given moment it would be possible to know in advance how a student will reason in response to a particular task. Instead, the framework provides a resource for teachers and researchers to better recognize certain aspects of students' thinking about matter, and even to know what to expect in general from this. The framework thus constitutes a guideline for producing learning progressions about the teaching of matter on various levels of generality, from statewide syllabi through entire courses to particular lessons. With the help of the different labels given within the framework, teachers or policymakers can more easily communicate about what they want to accomplish with a certain educational effort and what to expect from it.

But we claim that for the purpose of improving learning progressions in the way intended by Talanquer, it is quite enough to have his framework of the generalized ways in which students talk about the structure of matter. We simply fail to see how talk of *implicit assumptions* and *constraints* that are purported to influence students' ways of talking adds anything useful to Talanquer's stated purposes. We will illustrate our point by taking another quotation from the paper and then rephrase it in terms of student overt activity, that is, in terms of what both researchers and teachers are faced with in real encounters with students in class. Relating to how students move from talking about matter as *continuous* to talking about it as *particulate*, Talanquer states,

> Novice learners seem to presuppose the existence of some sort of material support in which the granules or particles are immersed; commonly air or the substance itself (*embedding* supposition). Research results indicate that the embedding assumption constrains learners thinking even after they develop more advanced ideas about the structure of matter.... This suggests that this presupposition may evolve independently of students' assumptions about the nature of the particles that comprise a substance. It is not until relatively advanced learning stages that students assume that the particles in a substance are separated by empty space (*vacuum* assumption). (Talanquer, 2009, p. 2130. Emphasis in original, underlining added)

Now take a look at the same quotation, but this time, rephrased without invoking the purported underlying assumptions. By rephrasing these statements, we want to show that talking about assumptions and suppositions lying behind and constraining student talk is not necessary for the purpose of improving a learning progression:

> Novice learners often talk in terms of some sort of material support in which the granules or particles are immersed; commonly air or the substance itself (embedding talk). Research results indicate that this is a quite persistent way to talk about the structure of matter .... This suggests that this way of talking about the structure of matter may remain the same independently of students' ways of talking about the nature of the particles that comprise a substance. It is not until relatively advanced learning stages that students say that the particles in a substance are separated by empty space (vacuum talk). (modified from Talanquer, 2009, changes underlined)

Here we have substituted reference to students' ways of talking with reference to entities (i.e., assumptions) underlying their ways of talking. It should be obvious that with regard to how the framework might aid in the planning and assessment of teaching about matter, nothing is lost by this substitution. That is, we can still do the same things with the framework when referring directly to the ways students talk as when referring to *assumptions which constrain* the ways students talk. Reference to students possessing assumptions, or constraints, or whatever causative agents one wishes to invoke, is simply not needed. The entities purported to lie behind the overt activities cancel out from the equation, as it were.

Superficially it may seem as if this amounts to nothing more than a question of wording. In a way, it is. However, we claim that it is an important one, because it directs attention differently, either to assumptions that constrain students' thinking (as it is seen through talk and action) or directly to their talk and action. Invoking entities that cause students to talk in certain ways may be taken as an indication that the primary focus for teaching should be precisely on these entities. On the other hand, if we would instead retain Talanquer's framework for how students are talking about matter, but leave aside the inferred causes in the form of assumptions, there is nothing to suggest beforehand exactly what in a teaching situation about matter should be the target of instruction. From the framework, we know that students often display, in general, certain ways of talking about these things. This is crucial knowledge to think about how to support the progression of students' learning, but additionally, detailed and meticulous empirical work on the processes of student–teacher interactions is needed concerning how changes in ways of talking may actually be accomplished through teaching.

It is important to understand that our argument is not that "there is no such thing as student thinking, but only student talk." Of course, students' ways of talking can also be related to their ways of thinking. But this is beside the point. Our argument is that it is methodologically problematic to infer causes for human action on the basis of observations of human action and that, therefore, communicative action should not be described as caused by learning stages or more or less advanced ideas (see the quotation above).

Example 2: Cultures and Subcultures as Underlying Entities

From Human Activity to Underlying Entity. The next example that we will use to illustrate the conversion of human activity to underlying entities takes its departure from studies (Aikenhead, 1996, 1998, 2001; Jegede & Aikenhead, 1999) conducted within a social anthropological and sociocultural tradition (cf. Geertz, 1973; Lemke, 1990), in which cultural identity is a central concept. We will show how these studies make use of previous research results and develop these into underlying structures, entities, and causes in new contexts. The studies deal with group-level analyses and are situated in an ongoing discussion concerning the importance of students' cultural identity as it shapes their ability to take part in and become active members of science.

In his article "Science Education: Border Crossing into the Subculture of Science"—which has the laudable goal of creating equal opportunities for all students in science irrespective of gender, class, or ethnicity—Aikenhead (1996) describes science as a specific subculture. In accordance with other colleagues in the field, he demonstrates that students coming from other so called subcultures, such as family groups or peer groups of Native American, African-American, Hispanic-American, Asian-American, and European-American origin, have unequal opportunities for learning a school science emanating from a Western European tradition. Analogous with our first example, we show that what people do and say is initially categorized, then labeled, and subsequently treated as entities (viz., subcultures). Finally, the essential state of belonging to a certain subculture becomes the underlying cause for the fact that students have unequal possibilities of crossing the border into the subculture of science.

To make our point concerning the conversion of student activities into underlying entities in the articles by Aikenhead and colleagues, we need to know what kind of empirical basis they build on. Going back in time, we can see that Aikenhead explicitly builds his argument on empirical studies made by Costa (1995). In her article "When Science Is 'Another World': Relationships between Worlds of Family, Friends, School, and Science" Costa presents a sociocultural basis for her studies and cites Lemke (1990), according to whom "science does not stand outside the system of social values.... It depends on socially shared habits, practices, and resources that each individual [has] because she is a member of a community with a history and a system of basic values" (Costa, 1995, p. 331–332).

In the article, Costa examines the relationship between the attitudes toward science in a number of students and their social background or, as she puts it, between students' "worlds of family, peers, and school and the world of science and the scientific community" (p. 315). Costa interviewed 43 high-school students about their family conditions and friends as well as about their perceptions and attitudes of science. She writes, "all [interviews] began with me asking students to describe a 'typical day in school' and included questions about their science class, future goals, and feelings about and definitions of science, technology, and scientists. Several interviews, however, shifted focus rather quickly, as students provided their own categories" (Costa, 1995, p. 316).

Moreover, Costa made classroom observations, which also contributed to the final categories emanating from the study. Thus, the point of departure for Costa's study is human activity, that is, what the students were saying and doing as they took part in two particular practices, namely interviews and classroom work (Figure 1, Stage 1).

Next, Costa finds patterns in these activities (Figure 1, Step 1 to Stage 2) and divides them into five categories (Figure 1, Step 2 to Stage 3). Her final student categories are as follows:

- Potential Scientists: Worlds of family and friends are congruent with worlds of both school and science.
- "Other Smart Kids": Worlds of family and friends are congruent with world of school but inconsistent with world of science.
- "I Don't Know" Students: Worlds of family and friends are inconsistent with worlds of both school and science.
- Outsiders: Worlds of family and friends are discordant with worlds of both school and science.
- Inside Outsiders: Worlds of family and friends are irreconcilable with world of school, but are potentially compatible with world of science.

Aikenhead picks up these categories and argues that the students' narratives emanate from the specific "subcultures of their peers and family" (Aikenhead, 1996) to which they belong and, thus, from within which they are talking. In that way, Costa's categories of student activity are turned into cultural entities, subcultures (Figure 1, Step 3 to Stage 4). This step may be exemplified through the following quotation from Aikenhead: "If students are going to cross the border between everyday subcultures and the subculture of science, border crossings must be explicit and students need some way of signifying to themselves and others which subculture they are talking in" (p. 26).

Finally, the differences between these subcultures and the scientific culture are inferred to explain why students vary concerning their difficulties in being socialized into the latter (Figure 1, Step 4 to Stage 1). We can see this from Aikenhead in 1996: "Science seems foreign to the vast majority of students in school science, whether they live in Western or non-Western communities," and then in 2001: "This foreignness *arises from* differences between students' life-world cultures and the culture generally embraced by the scientific community" (emphasis added).

Consequently, the problem here is neither the passion nor the care with which Aikenhead and his colleagues plead the underprivileged's cause. Aikenhead (and others) have listened carefully to students' personal narratives. They have observed that they talk about, for instance, nature in different ways. Native Americans' narratives are characterized by accommodating, intuitive, and spiritual wisdom, while science is described as aggressive, manipulative, mechanistic, and analytical (Aikenhead, 1998; Peat, 1994). In every culture, they claim, there also exist subcultures in terms of, for instance, social class, gender, or religion, each having different norms, values, and expectations constituting barriers that need to be overcome to access the scientific subculture. We do not even see any real problems with employing the metaphor of *culture* for talking about what students do and say. But we do find it problematic that, just as in our first example, Aikenhead and his colleagues are "put[ting] the cart before the horse" is that concepts, such as subcultures that were created from an analysis of human activities (e.g., students' narratives), are inferred as the causes for students' difficulties in school in the first place. Aikenhead explains "learning becomes culture acquisition which requires students to cross cultural borders from *their* life—world subcultures (associated with, for example, family, peers, school, and media) to the subcultures of science and school science" (p. 37. Emphasis added).

What Difference Do These Entities Make? Aikenhead's and his colleagues' purpose is, thus, to create increased awareness of the necessity of creating a special kind of crosscultural science education (Aikenhead & Jegede, 1999; Jegede & Aikenhead, 1999). Thus, Aikenhead can, legitimately, claim that "if only we could understand how students make sense of their natural world, we could design a science curriculum so that science makes sense to all students" (1996, p. 2). Once again, we want to stress that we wholeheartedly acknowledge Aikenhead's and his colleagues' purposes and the care they devote to the problem. But the additional level of explanation invoked by Aikenhead and his colleagues is simply not needed to accomplish these purposes. Instead of imposing an intermediate in the shape of a culture or subculture purported to constitute a barrier which needs to be crossed, their findings can be used for asking the pragmatic question about how certain activities may be developed further to support students' meaning making in the science classroom. Then, a reasonable question may be: *what additional resources are possible to invoke if the purpose is to help students establish relations and continuity between their everyday narratives and those of school science?* Just as in our previous example, we claim that by making the move back from underlying causes to overt activity, we avoid the risk of establishing the cultural entity that we once created as the target of instruction.

DISCUSSION

In this article, we used two empirical examples from current science education research to point at a problem which we, inspired by John Dewey, labeled "putting the cart before the horse." This problem consists of talking about generalizations generated from studies of human activity as entities, as well as inferring these entities as driving forces behind the activities from which they were initially generated. Our argument has been (1) that this practice leads to a problematic circularity and (2) that the original observations and generalizations of human activities are enough to accomplish the stated purposes in the example articles. These generalizations would be more valuable if they continue to inform further empirical study concerning their consequences in new practices.

Although the article concerns a well-known mistake that has been treated by various authors in fields such as philosophy (Dewey & Bentley, 1949/1996), psychology (Säljö, 2002), sociology (Pleasants, 1999), medicine (Adams & Markus, 2001), and science (Mayr, 1982), it has been largely neglected in the science education research literature. This article, therefore, constitutes a reminder to our own field of this old discussion, while at the same time contributing with two original analyses of common practice in science education, thereby giving the reminder an empirical justification. Below, we put our empirical results back into the theoretical context from the introduction.

A Category Mistake

The search for essences or universal structures that may explain phenomena around us is what Ryle (1949) referred to as "the source of the double-life theory" and a "category mistake" (p. 18). Dewey (1929/1996) explicitly contrasted this "quest for certainty" within philosophy, social sciences, and the humanities with the success of science at the time. The reference to a "quest for certainty" does not imply that these fields of research pursue a positivist agenda. Instead, according to Dewey, science had done away with the old search for universal structures and underlying fundaments once and for all through the introduction of the experimental method. He argued that the scientific concepts of modern science signify operations (relations between actions, e.g., in an experiment) and their consequences. It was this relational character which made the new concepts of science fundamentally different from those still being generated in humanities and the social sciences (Dewey, 1929/1996; Dewey & Bentley, 1949/1996):

> It required over two centuries for the experimental method to reach a point where men were forced to realize that progress in science depends upon *choice of operations performed* and not upon the *properties of objects which were alleged to be so antecedently certain and fixed that all detailed phenomena might be reduced to them*. This conception of knowledge still dominates thinking in social and moral matters. (Dewey, 1929/1996, p. 148)

Our two empirical examples demonstrate that the critique that Dewey and Dewey and Bentley raised at the time is still valid today in science education research. In both our examples, the analyses eventually end up pointing to underlying entities explaining and causing student action, irrespective of whether they concern students' talk about the nature of matter or their feelings about and definitions of science.

From Everyday Speech to Scientific Claims. Wittgenstein draws similar conclusions when he describes how our observations of everyday actions have led to our talking about underlying entities. He does this by reminding us that how we use words springs from how we act in our daily lives. In these day-to-day contexts, where we talk and act in relation to purposes to which we ascribe certain values, without any ambition to explain how the world around us works, the conversion of our actions into entities is both a natural and an inevitable part (see also Wenger, 1998). For instance, when we want to describe that somebody is successful in an activity, we can choose to express that as "she has demonstrated that she was able to . . . " over "she is able to" to "she has the ability to . . . " and, finally, the almost entirely frozen ascription of a quality or essence in "she possesses this competency." What was initially described (by a verb) as an activity has, thus, been converted (through a noun) to an entity. When researchers step out of these day-to-day contexts, with the purpose of analyzing the content of our speech, they are tricked by their own language use. Thus, Wittgenstein's point is that certain peculiarities of our language lead us to the search for entities, structures, or rules that are thought to regulate our actions. The linguistic abstractions take form, as it were, and begin to have a life of their own. This is in many ways similar to our two examples, in which generalizations have been named, for example, as "core implicit assumptions," "subcultures," and "borders," and subsequently raised to entities, thereby creating a risk of them acquiring a life of their own outside the relatively limited contexts in which they were generated.

The tendency of language toward reification and institutionalization has long been recognized in Marxist theory. Berger and Luckmann (1967), for instance, point out that the subdivision of people into classes, identities, and roles, or the subdivision of society into institutions risks producing unwanted exclusion and increased alienation between people. Through this institutionalization, social phenomena, previously perceived as multifaceted processes open to conflict, are turned into frozen cultural norms or structures in which people lose contact with themselves and with others (Berger & Luckmann, 1967).

We argue that research in science education needs to be much more restrictive in invoking such structures and entities. The search for entities such as "implicit assumptions" and "subcultures," as well as others, might divert attention from the burning issues concerning the apparent relations between overt actions and their consequences. By instead bringing the objectified concepts back to the activities from which they came, we are forced to remind ourselves of the activities and problems that they originally arose out of and were designed to solve (cf. Wittgenstein, 1953/1997). In that way, we, as a field, may begin to appreciate and discern the contingent, multifaceted and conflict-filled tensions that are always present in school science classrooms, and remember what it was that we originally wished to care for.

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