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FORUM

Sociocultural frameworks of conceptual change: implications for teaching and learning in museums

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Abstract This article presents a metalogue discussion about the two focus articles and the six associated review essays on the topic of conceptual change as it applies to research, and science teaching and learning in museum settings. Through the lenses of a sociocultural perspectives of learning we examine the applicability of the ideas presented in the forum for museums and museum educators. First we reflect on the role that emotions can play in concept development; second, we reflect on the role of language, talk, and gestures to concept development and conceptual change in the short-lived nature of experiences and conversations in museums; and third, we consider the nature of objects as representations of science content in museum settings.

Keywords Museums · Museum educators · Conceptual change · Dialogue · Emotions

Introduction

For their proposed cultural framework, Roth, Lee, and Hwang claim that, at the most basic level, the coordination of talk and gestures in real-time is the most significant and reliable means of determining how an individual understands and makes sense of an idea, concept, or notion. They ground their proposal in two arguments. First, they contend that, at best, mental models represent only one concrete realization of an idea (concept, notion), which

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individuals may possess; that individuals do not have fully formed mental models; and that we (researchers and educators) can never really know with certainty the mental models inside someone's head. Furthermore, mental models do not predate thought because we can talk about topics that we have not thought about before. Consequently, research and teaching (in science education) that depend on determining individuals' mental models to represent what individuals know, and to ascertain whether they have learned, are unreliable. In fact, they propose, it is more appropriate to assume that these models are created and developed during the course of conversations. Second, the authors argue, talk is a cultural activity where the rules of engagement are predetermined and learned socially. Moreover, the language used in talk events, such as interviews, conversations, and discussion, possess meaning independent of the speakers; that is, the words, phrases, and forms of talk—the symbols and artifacts of language—are borrowed from the cultural context, and are not owned individually. As a result, Roth et al. maintain that "communicative resources"—the words and gestures—are produced situationally, and can be a reliable means to establish the speakers' meaning and sense. From this position, they argue that conceptual change research and teaching to eradicate individuals' mental models is inappropriate at best, and borders on conceptual violence at worst.

Treagust and Duit contend that conceptual change perspectives are a valid way of improving science teaching and learning; however, there is a gap between the research and what teachers know about teaching for conceptual change. They propose that a multidimensional perspective of conceptual change—that considers the epistemological, ontological, and affective—needs to be utilized for effective teaching and evaluation of learning for conceptual change. Describing conceptual change as an evolutionary process, they suggest that conceptual change instruction needs to consider "the role of specific, usually small scale insights within the long-lasting gradual process of conceptual change." In addition to approaching conceptual change from multiple perspectives, they presented two additional challenges for researchers and educators: to determine sufficient evidence for identifying conceptual change, and bring successful conceptual change approaches to regular teaching and learning situations. These challenges, they argue, are even more pertinent given the "ambitious" Programme for International Student Assessment (PISA) definition of science literacy, "the capacity to identify questions and to draw evidence-based conclusions in order to understand and help to make decisions about the natural world and the changes made to it through human activity."

It is appealing to adopt the proposed cultural framework (Roth, Lee, and Hwang) and multiple perspectives of conceptual change (Treagust and Duit) to science education research and teaching in learning environments such as museums.[1] Museums today are places in which socio-historical, scientific, and artistic knowledge and objects are preserved, studied, and displayed. Also, they are social places where people gather to experience, explore, and extend their understanding and appreciation of this knowledge. Whilst multiple experiences occur in museums—"for each museum experience there are multiple influences and multiple outcomes" (Leinhardt and Crowley 1998, p. 4)—visitors' conversations are a naturally occurring process that researchers are finding to be a useful indicator of the meaning, and hence the learning, that people may gain from their visits to museums. It is from this position and within a cultural perspective that we examine the practicality and applicability of the ideas proposed by Roth et al. and Treagust and Duit,

[1] We use the International Council of Museums' definition of "museum" (ICOM 2001), though we focus specifically on museums within the domain of science, such as natural history museums, nature centers, science centers, and botanical gardens.

along with comments from the authors of the six review essays. More specifically, first, we reflect on the role that emotions can play in concept development; second, we reflect on the role of language, talk, and gestures to concept development and conceptual change in the short-lived nature of experiences and conversations in museums; and third, we consider the nature of objects as representations of science content in museum settings.

One of the theoretical frameworks that currently underlie the work on learning in museums is Falk and Dierking's (1992) Contextual Model of Learning (CML). This model is based on the premise that, "learning is always a complex phenomena situated within a series of contexts" (Falk and Storksdieck 2005, p. 745). Learning is viewed as a life-long process, "a never-ending dialogue between the individual and his or her physical and cultural environment"; it is the "process/product of the interactions between an individual's personal, cultural, and physical contexts over time" (Falk and Storksdieck 2005, p. 745). We find evidence of this framework in both the Roth et al. and Treagust and Duit articles and corresponding critiques. In agreement with the sociocultural context, both of the article sets emphasize the role of social mediation in the form of dialogue in, and as evidence of, conceptual change. Recognizing the evolutionary process with punctuated insights of conceptual change, Treagust and Duit are in accordance with the personal context, that prior knowledge and experiences influence learning. Critiques to the Treagust and Duit, notably by Regina Smardon, discuss the role of emotions, which also speak to the motivation, choice and control aspects of the personal context. In this metalogue, we discuss the implications of the articles adding the third dimension—the physical context of museums.

Issues of power, emotions, and learning

Helen: I am a border-crosser in my museum research group. As a teacher who has coordinated many trips to museums and other informal learning centers, I see the parallel between classroom lab activities and museum exhibits. At times the students must interact independently with the exhibit/lab materials, at other times this interaction is mediated by an explainer or the teacher. School-based lab activities and museum settings allow students more choice in activities. This choice empowers students by increasing their agency, which also results in a more positive emotional landscape. In the museum setting this is further enhanced by the absence of power structure and history of power struggles with the staff to color the emotional climate. Museum explainers do not grade students, or give negative feedback. Learning is by necessity positive or students can walk away. This landscape of increased emotional valence contributes greatly to the student popularity and enthusiasm for field trips and the increased learning opportunities afforded by such experiences.

Preeti: I would disagree, Helen, that power struggles and structures are absent. They are there, but they are different. But yes, in the relationship between teacher and learner, there are less obvious power structures. Also, some teachers force their kids to use certain exhibits and fill out worksheets, and it is clear when you walk the halls of a museum when this is happening, because kids are hurrying through it to finish it so they can get to the "fun stuff." Often, teachers can inadvertently make a free-choice learning environment, not free-choice.

Jen: Helen, I will have to disagree with you here too. Each museum has its history of both internal and external power struggles. While a teacher visiting a museum with a class may not be aware of its power struggles, those struggles are a part of the structure of the institution that will subsequently shape the resources available and the learning that happens. It is those power issues that determine what is displayed, how it is displayed, what

educational programs are associated with which exhibits, and the nature of the associated printed material. Additionally, there is a hierarchy of (scientific) knowledge that is inscribed by teachers and students on museums (Adams 2007), therefore there is a power structure that exists between schools and museums.

Preeti: Museum environments, exhibits and staff can create very affective climates for learning. This affect in the form of play, joy and exploration opens the door for positive emotional flow.

Interactions between staff and students, while short-lived, are relationships that are created on the spot and fade away when the interaction ends. When an Explainer at a science center approaches a student in a fun, excited manner with words like, "Can I show you something cool?" or "Try this!" he or she is setting the stage for a positive experience. Talk and gestures in this interaction have the potential to build a relationship between that student and Explainer, one of museum expert who is giving personal attention and learner. If that Explainer happens to be the same ethnicity, gender or physically looks similar to the student, there is an unspoken, intrinsic relationship that exists as well.

Lynn: Moreover, due to the ephemeral nature of these relationships with their learners that Preeti describes, educators in museums do not usually have the opportunity to follow up or extend the learning experiences. Consequently, while cognitive gains are welcomed and appreciated, educators in museums more readily strive towards affective gains. They ground their practice on two underlying premises: (1) irrespective of age, if a learner has a positive and fun experience, she or he will come back for more (because the learning is fun); and (2) museums are supposed to be available to people throughout their lifetime, whether through repeat visits to the same museum or visiting many different museums. As a result, over time and after many short but positive experiences, their learners develop an understanding of the scientific phenomena. The contemporary view of conceptual change is in accordance with this position.

The emotional aspect of conceptual change

Helen: "Theories of learning that do not acknowledge the emotional drain associated with power struggles do not address the lived experience of teachers" spoke to me as a classroom teacher (Smardon, this issue). I've known the joys and exhaustion of full-time teaching. The chasm between educational research and practice is wide. The power of the emotional climate to motivate and influence learning cannot be underestimated in my experience as a teacher/researcher.

Preeti: I would also add that conceptual change implies shifting from a familiar concept to a new or enhanced way of envisioning that concept, or possibly creating a new conceptual model altogether. A range of emotions accompanies this shift and growth such as self-doubt, discomfort, confusion, excitement, enthusiasm, confidence and zeal. Therefore, emotions are intricately tied to learning (Alsop and Watts 2003).

Helen: While Treagust and Duit cite Zembylas proposing that emotions have equal status in moderating cognitive outcomes, I would argue this one step further, and say that a positive emotional landscape is essential for learning and teaching to happen. Without positive emotional valence, classroom interactions are mired in power struggles, posturing, and rhetoric where the academic material is at best a tool for the power struggle, not a topic of study. Positive emotions allow increased confidence in learning where students and teachers feel safe, honored, respected and validated. Negative emotions cause defensive mechanisms to be enacted to protect emotional valence, at the expense of learning.

Jen: While negative emotions can cause defensive mechanisms that could impede learning, I also believe that certain negative emotions might facilitate learning. In the classical conceptual change literature, displeasure or dissatisfaction with original misconceptions is cited as one of the conditions for conceptual change to occur. Treagust and Duit state, "when a competing conception does not generate dissatisfaction, the new conception may be assimilated alongside the old." Frustration is also a negative emotion that can facilitate learning, but this depends on how the student personally deals with frustration. From my experience both as a classroom and museum educator, I saw where the frustration that would cause one student to shut down/give up, caused another student to become more determined to solve the "problem" that was causing the frustration.

I also think of my experience as an experiential educator, where an important part of pedagogy was getting the learner out of her "comfort zone." That is, to create conditions where a learner may feel low and/or moderate intensity emotions—hesitancy, reluctance, or trepidation, for example (Turner 2002) in order for the learner to move to the next level of engagement or knowledge. Although for this to occur, the learner has to feel safe and trustful, these negative emotions are vital to the learning continuum, so I believe that there has to be a balance between the negative and positive for effective learning to occur.

Lynn: To me, it sounds like the point made here is that it is not exclusively positive or negative emotions, which affects learning. As demonstrated above, arguments, and perhaps even evidence, can be made to support the contributions and impact of both negative and positive emotions on learning. The argument is the need for practitioners and researchers in the educational field to recognize and value the role of the affective domain in learning and teaching. It is not that this argument is new but that in education the more measurable cognitive domain consistently overshadowed it. However, the importance of the affective domain is no surprise since, as humans, we all have feelings (whether we demonstrate or articulate them publicly or not). We know from our own personal experiences that feelings affect our mood, state of mind, and willingness to engage. Furthermore, it is the affective domain, which educators in museums have argued and grounded their practice in for many decades.

Helen: Turner argues that negative emotions are more primitively wired in our brains and outnumber positive emotions 3 to 1 (Turner 2002). Hence, we are more likely to have negative emotions. It takes social work to generate positive emotions and increase the solidarity needed for effective social functioning. This work of increasing positive emotional valence will increase social capital and provide the landscape for learning to take place.

Teachers' emotional drain is reinforced by the isolation of teaching from research and dialogue on improving learning. Teachers' work is intensified by standards and expectations, and enhanced by dialogue and open-ended discussion. Transmissive teaching is an emotional defense mechanism of overwhelmed teachers. Constructivist teaching requires cognitive and emotional energy and strong support.

Jen: I wonder if transmissive teaching is always an emotional defense mechanism? Maybe it is defensive if a teacher knows alternative ways of teaching and does not feel she has the resources or support to teach in a more constructivist, student-centered way. However, it could be other emotions such as fear (not having had the opportunity to practice such methods in a safe environment) or simply not knowing how. I agree with you about the isolation of teachers from research, but I wonder if we can consider it an emotional drain when many teachers are not aware of the research to begin with? Treagust and Duit's conclusions mention teachers' lack of awareness and being informed as an obstacle to more inquiry-oriented, student-centered classrooms.

Lynn: In addition to Jen's point, research on how educators in museums teach science to visitors (primarily schoolchildren) describes their practice and models of the communicative process as transmissionist (Tran 2007). I would argue that, in this case, it is not an emotional defense mechanism, which drives transmissive teaching. The pressures on teaching are extremely different and yet educators in museums commonly, and likely inadvertently, adopt this model. In museums, I believe, part of the reason transmissive teaching is adopted is because there is a lack of an appropriate model of pedagogy specific to museums, as well as lack of professional education to prepare these educators to teach in museums.

Helen: Emotional landscape is the unspoken template upon which academic learning happens. In the traditional classroom with the power in the teachers' field, and students lacking agency, conceptual change and academic learning are secondary to increasing agency, respect and positive emotions of solidarity.

Teachers, who trust and respect their students enough to be seen with them in public, send a strong message of solidarity to the student body, that they and their learning are important.

Jen: This emotional landscape is also important in teacher education. Teachers develop a professional identity as being a certain "kind of teacher" (Gee 2001) based on the resources they access and the structures they create for teaching and learning, which can include using out-of-classroom resources like museums. These are teachers who have had positive learning experiences in museums (from professional education and/or personal visits), and come to associate the museum with these positive emotions, and desire to recreate these experiences for their students (Adams 2007). Leuhmann (2007) discusses the "emotional risk" that teachers take when implementing reform-minded practices and the need for safe places for teachers to practice a reform-minded teaching identity, "one that focuses on student understanding and use of scientific knowledge, ideas, and inquiry processes" (Leuhmann 2007, p. 825). Museums could provide safe places for teachers to practice reform-minded teaching with their students and to experience positive emotions associated with success that would reinforce their professional identities as reform-minded/inquiry-based teachers.

Helen: Over half a century ago, in 1952, Einstein argued that education must work harder to "develop the social side of humans" (Kincheloe et al. 1999). This seems as true today as then. We need conceptual change models to include emotional valence as a key component in learning. When our students, teachers, educators, researchers, and museum participants study emotional valence and its role in learning, we all learn. When we are all more knowledgeable in creating more positive emotional environments, then learning spirals and reinforces itself, increasing science education, on a micro and macro scale.

Objects as representations of science concepts in museums

Jen: In reading the Treagust and Duit article set, I found an overarching theme about the relationship between representations and science conceptions. This, I believe is an important issue for museum educators and researchers to consider since a primary focus of museums is the representation of scientific phenomena. As research institutions, "museums help to mold much of what we know about science" (Vackimes 2003). Whether it is an actual object, a visual representation, or written text (thereafter I will use term "object(s)" to describe the variety of representations in a museum), science museums process scientific research and knowledge in order to create exhibits with the intention of communicating to

the public knowledge about science content, research, and phenomena. Leinhardt and Crowley (2002) describe objects in museums as examples of the evidence of scientific concepts and theories. In other words, objects in a museum are meant to create and/or change conceptions about science.

As with Treagust/Duit and Wells, I would like to start with "considering the nature of conceptions" by extending Wells' notion of knowledge and knowing to the museum context. Wells makes a clear distinction between knowing as contextual and situated, and knowledge as what is "taken to be known" by the scientific community. In the museum context, knowing could be described as what a visitor brings into and takes away from a museum encounter; and knowledge as what is displayed in a museum where objects *are* representations of what the scientific community considers knowledge. Applying Wartofsky's framework, Wells describes representing as a human activity, it is something that we do to help us structure our understanding of the world. Concepts are tools for use; they are embodied notions about science and scientific phenomena that are created and held in the dialectical relationship between an individual and a collective (i.e., individual|collective). Vosniadou (this volume) discusses such a "distributed cognitive system" where these embodied notions (representations or mental models) are generated as a result of one's everyday experiences. These concepts are in the realm of knowing, and I would add being—how one understands and interacts with her natural world. We all have representations of concepts in our minds, but these representations do not become knowledge until they are sanctioned by science (through research, theory, etc.). I believe that this sometimes creates a cultural conflict when people are confronted with representations in museums that are counter to their embodied concepts and corresponding representations of the same phenomena. For example, displays of human evolution and migration as presented in a museum can conflict with some peoples' religious and cultural creation stories.

Lynn: So from this perspective, are you saying that if what people know as representations in their mind is not sanctioned by the scientific community then they do not have knowledge? I like your example of evolution and creation, but as written, are you implying that those with a creationist view do not have knowledge?

Jen: In relation to what is considered knowledge by the scientific community, those with a creationist view would not have knowledge. However, they would have knowledge according to what is sanctioned by their community and this knowledge is not what is generally displayed in museums. Except in the case of a creationist-based museum, interestingly, in such a museum, evolution is not considered knowledge. In essence what is considered knowledge is culturally bound. The Western scientific community is a culture—with its set of ideologies, schemas, and practices (Sewell 1992), therefore the knowledge produced and represented in a Western-oriented science museum is socioculturally constructed and bound (Carter 2007).

I believe that the cultural situatedness of representations are important distinctions to consider as museum educators/researchers because at the basic level, in order for museums to fulfill their goal of engaging the public in science, it is vital to consider: (a) the representations of science concepts that people hold—what is the nature of these concepts? and (b) the representations of similar concepts in museums—taking into consideration the cultural situatedness of the individual (visitor) and institution. This is not to eradicate views that visitors hold in order to replace them with the museum's views, but rather to facilitate a discussion about the object and related science so as not to produce a didactic or dual (right vs. wrong) experience. This type of discussion could, as Vosniadou (this volume) mentions, open up a "conceptual space ... creating the possibility of entertaining different perspectives and different points of view."

Wells urges us to "treat representations as thought contents that are formulated or constructed in the moment according to the perceived demands of the situation rather than as reproductions of some already existing internal objects" (Wells, this volume). To me, this gives the perception of individual internal representations as ephemeral, however I view them as "mutable"—capable of changing but not fleeting. I agree with Vosniadou in that we have the capacity build new mental models on existing ones when we have new experiences, come across new information, learn new language/vocabulary, etc. This is an important consideration given that representations in a museum are at times fixed—sometimes even long after the "knowledge" has moved forward.

Lynn: Museums are not just "presenting science." Aren't they also positioning themselves as places to engage the public in science? More specifically, for scientific literacy so that the general public can be involved in discussions and debates on the ethical and moral issues of scientific work. This position is more commonly found in science communication and STS literature (Lehr 2007). As written, there is a privileging of science and also a sense of authoritarian control over knowledge that museums possess. Perhaps this is the position you hold, which is fine; I just wanted to point out that this is sentiment I am interpreting and that there is literature in museology and science communication that is challenging, or at least exploring, museum's "authority" over knowledge.

Jen: I agree with you Lynn. These conversations are not only happening in museums, but in other scientific institutions as well. However, these science institutions (museums included) still maintain a certain degree of authority over knowledge because of the cultural and symbolic capital that these institutions hold in our society. Although post-colonial perspectives challenge the superiority of Western science, Western science is still judged to be humanity's "most powerful" knowledge system (Carter 2007). Science museums are representative and hold representations of this knowledge system and the corresponding "authority" that comes with it.

Objects mediate learning

Lynn: I would like to continue discussing the role of objects in museums and how museum educators use objects to mediate learning, and thus examine how experiences in museums contribute to a person's conceptual development. "Museums are repositories for objects, which are displayed for their authenticity, immediacy, interactivity, and cultural capital" (Tran 2007, p. 140). In this case, I use "objects" to mean the things in museums that people go to see, touch, and experience, and these objects are the central means of representation of the knowledge of the discipline in a museum. Using Wartofsky's framework (Wartofsky 1979), these objects are primary artifacts, while their complementary labels and signage are secondary artifacts. Leinhardt and Crowley (2002) explain that objects in museums offer a level of information unavailable in two-dimensional image or text. For instance, there is the opportunity to experience a sense of scale (the smallness or largeness of an object) and realness (its connection to real events or people), which makes the museum experience truly memorable. Thus, objects in museums are no longer only "visual proof" of scientific knowledge (Conn 1998), but also provoke affective and sensory connections to the social, political, scientific, cultural, and historical knowledge that they represent. And in this technological age, wherein virtual experiences are ubiquitous, opportunities for experiences with tangible objects may have special significance (Tran 2007).

Helen: Most of us are visual processors, some auditory, and some kinesthetic, though all of us can learn from all these sources of information. While research on the different

learning styles is mixed, as a practitioner I believe engaging students in as many ways as possible reinforces learning (Coffield et al. 2004). Museums are great places for this to happen. Museums do not only engage the visual and sometimes the auditory senses, but the kinesthetic sense, as visitors move through the space(s) and interact with different objects and exhibits. As a teacher, another value of the museum trip is to remove me from the position of sole proprietor of knowledge. The museum trip exposes students to generally accepted science information that supplements texts and other teaching methods. It is an opportunity for us (my students and me) to process and analyze information together. To me, this is one of the more powerful benefits of the museum visit—the museum trip "clears the cob-webs from their minds." The trip allows students to be more physically engaged, more energetic, in a different environment and open to different stimuli on scientific topics. This clears the way for different thoughts and interpretations of the information to happen. Clearing the cobwebs means removing the rigidity of former thought processes and allowing a fertile ground for conceptual change to occur.

Lynn: Educators in science museums acknowledge the central role of objects as they engage with visitors, which they do through organized and casual interactions (Tran 2007, p. 447). Organized interactions are scheduled, pre-planned, in special rooms (such as auditorium or classroom) and sometimes scripted, and thus tend to be prescriptive and educator-directed; these include shows, demonstrations, and classroom-based lessons. Casual interactions are unscheduled, unscripted, and tend to occur on the exhibit floor; these interactions are more likely to be learner-directed, and refer to object handling carts and educators facilitating experiences at exhibits. In both types of interactions, the objects are at the center of the engagement, and the educators use the objects to teach (communicate) the knowledge that they represent.

Whilst for the visitors/learners, their engagement with the objects offers them tangible examples (primary artifact) of scientific concepts (tertiary artifact), and their interactions with educators, which include both verbal and non-verbal actions, serve as the "motor" (to borrow from Mercer, this issue) for conceptual development. What is significant here is the complementary contribution of both objects and social interactions in learning experiences (and conceptual development) in museums. Interestingly, the authors in these two paper sets overlook this position, though Wells touches on this idea peripherally.

Preeti: I am reminded of the statements made by Wolff-Michael Roth in his collection of key works of research (Roth 2007a, b) where he describes his phenomenological study of a physics classroom and discovers that while the teacher was demonstrating a certain principle, different students made different meaning out of it and it was related to their lifeworlds or their experiences. In a museum, when visitors experience an exhibit or watch a demonstration, there is no real way to know about the mental models being developed in their minds. When a museum educator interacts with one of those visitors, that is when the structure is in place for those mental models to surface and possibly become known to the educator. Informal conversations, utterances, and gestures between all those involved in the interaction often allow for those individual mental models to form and re-form. So an exhibition or demonstration might be static in many ways, but through interactions with each other and staff, the different concepts in different people's minds might materialize.

The nature of talk in museums

Lynn: In the cultural approach proposed by Roth et al. museum educators would be able to make assumptions about their learners' understanding, with confidence, solely based on

what is said at the time, and not rely on inferences of mental models that are gathered superficially. Similarly, researchers would be able draw on the talk and gestures exclusively to make conjectures about the learning that takes place and visitors' sense making from their experiences without complications from conditions external to the talk event. Indeed their framework is convenient, but is it plausible and practical for science education in museums? Let me begin with a brief description of visits to museums to demonstrate the complexity of learning experiences in them.

Visits to museums can range from one-off occurrences to return visits over a lifetime, though individual interactions—the experiences and the conversations about them—are measurable in minutes. While there is evidence to suggest that visitors talk about their experiences at museums well after their visits (Stevenson 1991) the experiences themselves tend to be ephemeral and unique. On average, visitors tend to remain at an exhibit between a few seconds and 2–5 min, though stay time depends strongly on the nature of the exhibit and how much it can engage visitors, and the personal needs of the visitor (Serrell 1998), while educational programs rarely extend beyond 60 min. Given the short-lived nature of such experiences, for educators and researchers interested in learning and teaching science in museums, a framework grounded in talk and gestures in real-time can be of value.

Preeti: Additionally, talk in museums does not take place exclusively between and among visitors. Museums place great value on the need for human mediation in the form of museum educators in the exhibition galleries (Zana 2005), such that the educators are equally as important to the museum experience as the exhibit design, labels, and signage.

Lynn: Museum educators have a longstanding presence in, and value to, museums (e.g., Hein 2006). In fact, I perceive museum educators as the interface between the museums' collections, the knowledge and culture that are represented, and the visiting public; thus educators have growing importance for contributing directly to educating (or communicating with) the public—a public that includes school children, families, and adults.

Typically, as described earlier, an educator engages with thousands of visitors every year during casual interactions at exhibits and in gallery spaces for a few minutes at a time, or within organized interactions of pre-planned programs that usually do not last more than 60 min. There are rarely opportunities for the educator to determine her/his learners' prior conceptions or mental models with precision, or to extend the interactions in order to assess conceptual change. Instead, the educator relies on the volume of visitors with whom she/he engages and the repetition of these pre-planned programs as a means to form a general sense of how different people (such as adults and children, novices and experts) tend to understand or know scientific phenomena, and then individualize as needed in order to accommodate the diversity of interests, knowledge, and abilities (Tran 2007). Likewise, for researchers, an ongoing challenge is to determine what visitors learn in an environment where lifelong learning is emphasized, there is no curriculum, and no one fails.

Preeti: I would also add that visitors to museums are different in nature, age, gender, ethnicity, socio-economic status, and interest and motivation for visiting the museum. A museum educator has to structure each talk experience or interaction accordingly.

The exact role for these educators is a great point of debate and discussion for the museum field. There are many approaches to the exact job description and even the job titles. Some places call them Explainers, others Facilitators, Enablers, Guides, Hosts and the lists continues. There is research and associated dialogue underway internationally to investigate the differences and similarities across the models as well as the diversity that exists in the training models for the museum educators. While the role and training models

for human mediating experiences is diverse, it is clear that museums value the idea that talk and gestures help people construct or reconstruct mental models on different concepts.

Cultural approach to conceptual change in museums

Lynn: So, given these complexities, to what extent is the cultural approach that Roth et al. propose usable for science education in museums?

A significant point of contention that I hold builds on Hewson's critique that Roth et al. "largely ignore the external context." From a sociocultural perspective on learning, the unit of analysis is the social group engaged in a shared activity that is mediated by the tools, signs, languages, and symbols of the culture and context, as well as the actions of individuals (Rogoff 1995). Thus the context in which conversation takes place is just as important as what is said in conversation. For instance, families tend to spend more time at individual exhibits than non-family groups visiting a science museum, though time spent at exhibits also varies according to day of the week–weekend visitors, when the museum is more crowded, spend less time at exhibits than weekday visitors (Sandifer 1997). Thus these external conditions, which the proposed cultural approach overlooks, would likely affect the quality and extent of the same people's conversations.

Preeti: I agree. Hewson points out that the social relationship of the people engaged in talk is also an important part of that context. In a museum setting, the visitor–educator relationship can take many shapes. Specifically, during a school group visit, a teacher may view an educator as a helper to teach their children. During a family visit, the members of the family might view the museum educator as a science expert (even a high school student–educator, just by virtue of the uniform). Visitors' identities may also change within the visit. While an adult may have come as a chaperone for her child, she may take on the role of a learner in the midst of an interaction. Additionally the different identities of the museum educator, as defined by Thomas Gee (2001), may play a role in the type of talk. Is the educator a retired schoolteacher, a college student with a science major, a college student with a communications major, or a parent from the local community? Similarly, what does the educator have in common with the visitor from a gender, ethnic, or socio-economic perspective? Do they happen to come from the same neighborhoods? These factors influence which words or phrases might be in the talk, the utterances used in the exchange and, of course, the nature of the gestures.

Jen: Preeti, it is interesting that you discussed identity as an important factor in mediating the interactions, conversations, etc. that happen at an exhibit. Both Rounds (2006) and Falk (2006) have presented compelling arguments for looking at identity as a way of studying how people learn in museums. For example, Falk (2006) presented several museum-going identities that influence peoples' motivation and learning; he mentioned the "professional/hobbyists" as closely mirroring museum professional's museum-going identities. According to Falk (2006), this identity expresses strong interest in the content of the exhibit and how the exhibit is presented—the representations used to convey certain concepts. This brings up a very important layer to add to the discussion about the nature of science conceptions because the ones underlying identity in different contexts will influence how they are motivated to learn, and learn and develop science conceptions during a museum interaction. Wells (this volume) discusses this immediacy of constructing representations to solve problems (from, as I understand it, a continuum of fluid representations)—in this case the problem would not only be a science query or curiosity, but a "problem" of maintaining an identity. For example, the professional/hobbyist may look to

maintain a science teacher identity by getting current information as well as seeing how the content is presented and how other professionals (museum educators) may present the information. Thus, the conceptions developed go beyond just an acquisition of science content and processes, but also a corresponding pedagogy of presenting the content to others. An environmentalist may visit the same exhibit about, let's say, climate change to not only learn more about the processes and latest research about climate change, but perhaps to learn about actions around the world aimed at curtailing global warming. Both are enacting a professional/hobbyist identity, however each are coming away with a different set of conceptions based on their identities and corresponding goals and motivations for visiting the museum. Falk (2006) sums this up with a nice quote, "learning expresses identity," (p. 154), but I would also add that teaching expresses identity as in the case of the museum educator or facilitator.

Preeti: Hewson agrees with Roth et al. that a person can join a conversation that she does not know much about, however Hewson contends that the person can do so only to a certain degree. Visitors to a museum often may not have any context for a given exhibition and be uncomfortable to participate in social conversations about it. The museum field places great effort in creating structures to afford those visitors agency to enjoy and learn from the exhibition. The role of a well-trained museum educator becomes that much more important. The challenge for the museum educator is to help link the context of the exhibit to some aspect of the visitor's everyday life so that a shared vocabulary and a link between those mental models and then ones being put forth by the exhibit can begin to establish.

Jen: As you (Lynn and Preeti) mention above, one of the main themes in the Roth paper set is the use of dialogue to make the mental models or representations of science concepts discernible. The museum educator (knowingly and unknowingly) has this task of making obvious what is not immediately obvious in the relatively short time a visitor spends at an exhibit. The museum educator potentially helps the visitor to create a salient science conceptual representation to add to her lifelong representation continuum to be used in future problem-solving events. In order for this to occur, museum educators have to acquire a fluency of reading gestures, body language, and verbal cues to determine what people may already know and how to best engage them in the topics—content and processes—presented in the exhibit. Even, as you mention, when visitors use words, such as science terms like force and energy, the museum educator has to know what questions to ask and/or how to engage them in the exhibit in such a way that allows them to demonstrate understandings or "misconceptions" they may hold.

There is an immediacy of interactions between the visitor and the museum educator/facilitator, and in these interactions/conversations, representations are elicited and re-created to fit the problem-solving needs of the moment. However, I wonder about the self-directed learner—those without the benefit of a museum educator, teacher, or knowledgeable other; or if, in other words, the "knowledgeable other" is the museum/exhibit. Falk (2006) describes the visitor in the museum as using the provided "raw material" to construct a new experience, which could be described as constructing new representations, or altering existing ones. He also warned a museum to be "cognizant of its own culturally and physically imposed identity..." In anthropomorphizing the museum, Falk recognizes that a museum as a cultural institution plays a central role in the interactions with visitors—mediated and unmediated—therefore there is a conversation that happens, and within this conversation, representations are created. This also creates a certain degree of passivity in the visitor—which could be related to what Roth (2007a, b) theorizes as coming to learn something that one did not know previously existed therefore,

the museum's representation may be the only representation the visitor has of the novel thing she has come to learn (at least for the moment).

Museums as environments supporting conceptual change

Jen: Treagust and Duit propose, "conceptual change strategies may only be efficient if they are embedded in a conceptual change supporting learning environment." This leads me to ask the following questions: (1) do museum environments support conceptual change? and (2) do museum educators teach for conceptual change?

Lynn: I would say given the contemporary understanding of conceptual change that is discussed by Treagust and Duit, Hewson, and Smardon, museums can be learning environments that support conceptual change. As they describe, conceptual change and development occur over time and in small increments, and their occurrences do not rely on cognitive conflict. Unlike in schools, where experiences occur and then are likely not revisited given the curriculum by which teachers are bound, museums are supposed to be places where people can visit (and revisit) over their lifetime. Consequently, visitors have many opportunities to learn over different stages of their lives, and as they acquire life experiences, to develop or change their conceptual understandings. Thus, while individual interactions may be ephemeral, where cognitive conflict may or may not be made or resolved, there are numerous occasions to stimulate and develop cognitive dissonance and development.

As for the museum educators, your question is difficult to answer for two reasons. First, whether educators in museums "teach" is a point of contention among practitioners in the field (Tran in press). Many purposely distance themselves from the term and the idea because they associate "teaching" to be the work of schoolteachers, while they communicate, facilitate, and perhaps educate. Second, the professional preparation for museum educators to "teach" in museums is inconsistent at best, though it is more commonly non-existent. Individual institutions offer training for staff that directly engages with the public. However, the quality of their training is inconsistent across institutions, specific to their individual institutions, and thus, do not compare with professional education that teachers pursue. Consequently, is it appropriate or fair to ask, and perhaps criticize, whether educators in museums teach for conceptual change when they are not educated about what it is and how it is applied in the museum settings?

Preeti: Lynn, as someone who is intimately involved in issues in floor staff training, both from a logistics and theoretical standpoint, it seems to me that the field is young in thinking about what preparation is necessary and even possible for floor staff. It is true that there is great diversity across museums when we prepare staff to interact with visitors. Some of us are interested in conceptual change, but as you say, we haven't given ourselves opportunities to really understand the current literature in conceptual change. However, as a former floor staff member and as a supervisor of current staff, I often find that floor educators are in many ways, aiming for conceptual change, whether we are supposed to or not. Without having enough background on conceptual change, this attitude often makes our job difficult and dissatisfying. Massey (1994) argues that museum educators particularly face a big challenge when they are trying to teach a concept because as we have mentioned earlier, they don't know what prior knowledge visitors bring. She encourages

museum educators to take time to listen carefully to visitors to find out what they already know (or think they know) and how they think about the concept being discussed.

Areas of research that need further exploration include visitor understandings of concepts and conceptual change based on interactions with floor staff. This research would allow us to delve deeper into the role of talk, gestures, utterances and emotions through the interactions between floor educators and museum visitors. The object or exhibit in the museum as the subject for the conversation will play a key factor in this research agenda. Conversations in zoos, science centers, natural history museums or history museums, art museums and so on will take a very different shape simply because of the object and associated concept being discussed. Having said that, this research may be difficult to design because of limitations in methods and tools, the transient nature of the visitor and complexity in measuring conceptual change.

References

Adams, J. (2007). The historical context of science and education at the American Museum of Natural History. *Cultural Studies in Science Education, 2*, 393–440.

Alsop, S., & Watts, M. (2003). Science education and affect. *International Journal of Science Education, 25*, 1043–1047.

Carter, L. (2007). Sociocultural influences on science education: Innovation for contemporary times. *Science Education, 92*, 165–181.

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. London: Learning and Skills Research Centre.

Conn, S. (1998). *Museums and the American intellectual life, 1876–1926*. Chicago: Chicago University Press.

Falk, J. (2006). Impact of visit motivation on learning: Using identity as a construct to understand the visitor experience. *Curator, 49*, 151–166.

Falk, J. H., & Dierking, L. D. (1992). *The museum experience*. Washington, DC: Whalesback Books.

Falk, J. H., & Storksdieck, M. (2005). Using the contextual model of learning to understand visitor learning from a science center exhibition. *Science Education, 89*, 744–778.

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99–125.

Hein, G. (2006). Progessive education and museum education. *Journal of Museum Education, 31*, 161–174.

International Council of Museums (2001). *Development of the museum definition according to ICOM statutes: 1946–2001*. Retrieved Feburary 18, 2008 from http://icom.museum/statutes.html.

Kincheloe, J. L., Steinberg, S., & Tippins, D. (1999). *The stigma of genius: Einstein, consciousness, and education*. New York: Peter Lang.

Lehr, J., McCallie, E., Davies, S. R., Caron, B. R., Gammon, B., & Duensing, S. (2007). The value of "dialogue events" as sites of learning: An exploration of research and evaluation frameworks. *International Journal of Science Education, 29*, 1467–1487.

Leinhardt, G., & Crowley, K. (1998). *Museum learning as conversational elaboration: A proposal to capture, code and analyze museum talk*. (Museum Learning Collaborative Technical Report MLC-01). Retrieved Feburary 18, 2008, from http://museumlearning.com/paperresearch.html.

Leinhardt, G., & Crowley K. (2002). Objects of learning, objects of talk: Changing minds in museums. In S. G. Paris (Ed.), *Perspectives on object-centered learning in museums* (pp. 301–324). Mahwah: Lawrence Erlbaum.

Leuhmann, A. (2007). Identity development as a lens to science teacher preparation. *Science Education, 91*, 822–839.

Massey, C. (1994). *How cognitive scientists view learning. What research says about learning in science museums: Volume 2*. Washington, DC: Association of Science Technology Centers.

Rogoff, B. (1995). Observing sociocultural activity on three planes: Participatory appropriation, guided participation, and apprenticeship. In J. V. Wertsch, P. Del Rio, & A. Alvarez (Eds.), *A sociocultural studies of mind* (pp. 139–164). Cambridge: Cambridge University Press.

Roth, W.-M. (2007a). *In search of meaning and coherence: A life in research*. Rotterdam: Sense Publishers.

Roth, W.-M. (2007b). Theorizing passivity. *Cultural Studies of Science Education, 2*, 1–8.

Rounds, J. (2006). Doing identity work in museums. *Curator, 49*, 133–150.

Sandifer, C. (1997). Time-based behaviors at an interactive science museum: Exploring the differences between weekday/weekend and family/nonfamily visitors. *Science Education, 81*, 689–701.
Serrell, B. (1998). Paying attention: Visitors and museum exhibitions. In R. Adams (Ed.), *Professional practice series*. Washington, DC: American Association of Museums.
Sewell, W. (1992). A theory of structure: Duality, agency, and transformation. *The American Journal of Sociology, 98*, 1–29.
Stevenson, J. (1991). The long-term impact of interactive exhibits. *International Journal of Science Education, 13*, 521–531.
Tran, L. U. (2007). Teaching science in museums: The pedagogy and goals of museum educators. *Science Education, 91*, 278–297.
Tran, L. U. (in press). The work of science museum educators. *Museum Management and Curatorship, 23*.
Turner, J. H. (2002). *Face to face: Toward a sociological theory of interpersonal behavior*. Stanford: Stanford University Press.
Vackimes, S. (2003). Of science in museums. *Museum Anthropology, 26*, 3–10.
Wartofsky, M. W. (1979). *Models: Representations and the scientific understanding*. Boston, MA: Reidel.
Zana, B. (2005). History of the museums, the mediators and scientific education. *Journal of Science Communication, 4*, 5.

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