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The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree. [A]nd in the ash is the small remnant of the part which did not come from air, that came from the solid earth, instead. These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others.

…Richard Feynman (as cited in National Academy of Science, 1995)

We believe understanding is <u>not</u> most often driven by practical or instrumental purposes. The desire for understanding is driven by something more human. It is peoples' nature to seek connections - connections to others, to the earth, and to ideas. This sense of connectedness is not only at the level of individual cognition, it comes from a desire to know with one's heart <u>and</u> mind, emotions <u>and</u> cognitions, imagination <u>and</u> reason. People pursue understanding to feel connected in ways that tell them they are human. As Feynman suggests, people strive to understand for aesthetic reasons.

Many views of learning science are driven by the goal of conceptual understanding. Teachers want their students to have accurate mental models of the way the world operates - to "get it," if you will. Recently, another goal for science education has become to help students learn to "talk science." Such discourse-based perspectives argue that science educators should strive to teach students how to inquire, formulate, and argue in ways true to the nature of science.

Both of these are worthy goals. However, we will argue that both fall short of another important criterion of success in science learning. Ultimately, education should influence not only how students understand and talk about the world but how they experience (i.e., think, feel, act) it. The arts can educate people in ways few other disciplines can. We believe science can be taught in ways that borrow from aesthetic and artistic pedagogy to tap the power of aesthetic experience. These experiences can be the basis for a powerful, different kind of understanding - aesthetic understanding.

To some readers, using the arts as inspiration for science education may seem misguided. Jackson (1998, p. 124), referring to Dewey's "Art as Experience," explains what one can learn from experiences with art, "The arts, above all, teach us something about what it means to undergo an experience. Successful encounters with art objects and performances offer a set of standards by which to judge ordinary experiences."

We articulate one possible solution to the following question: How can one construe learning in ways that appeal to aesthetic ways of knowing while fostering value in important and powerful curricular ideas? We compare and contrast our perspective to two other popular views of understanding in science education research: learning as change in conceptual understanding (as exemplified in conceptual change theory) and learning as change in discourse and participation with others. Because our theoretical framework is relatively new and, in some ways, radically different from other current science education frameworks, we take the time to develop it more completely than perhaps most research studies.

Three Conceptions of Understanding in Science Learning

Two common and popular views of understanding in science education are conceptual change learning made popular by Posner, Strike, Hewson, & Gertzog's (1982) widely cited paper,

"Accommodation of a scientific conception: Toward a theory of conceptual change," and a discourse-based view of understanding as characterized in Jay Lemke's (1990) influential book Talking Science. We realize that no one work represents the theoretical preference of all researchers in a single paradigm, but we chose these works because they lie at the heart of these two perspectives. Each of these views has garnered much support in the science education research community and has led to considerable research. In order to better understand what we mean by aesthetic understanding and to make a case for its importance, we compare and contrast it to these two important perspectives on learning science. To better understand how these perspectives relate to each other, we organize our discussion around six main questions.

- To what epistemological tenets does the theory subscribe?
- What is the role of the learner?
- What motivates learning?
- What is learned?
- What would be the central curricular organizer in the theory?
- What's the role of the teacher?

We believe these questions address the most substantive issues in a theory of understanding and allow us to highlight the similarities and differences between theories. We first characterize each perspective and then offer a critique through a Deweyan lens.

Conceptual Understanding and Conceptual Change Theory

Conceptual understanding and conceptual change theory, at least as we characterize them here, are rooted in Cartesian rationalism and individual cognitive psychology. Research on the power of misconceptions has been taking place for 60 years. It originated in the early work of Piaget, but only in the 1980s did the science education community appropriate misconceptions

and conceptual change research. Posner et al. (1982; p. 212) give the best description of the underlying philosophy and intentions of conceptual change theory:

> Our central commitment in this study is that learning is a rational activity. That is learning is fundamentally coming to comprehend and accept ideas because they are seen as intelligible and rational. Learning is thus a kind of inquiry. The student must make judgments on the basis of available evidence. It does not, of course, follow that motivational or affective variables are unimportant to the learning process. The claim that learning is a rational activity is meant to focus attention on what learning is, not what learning depends on. Learning is concerned with ideas, their structure and the evidence for them. It is not simply the acquisition of a set of correct responses, a verbal repertoire or a set of behaviors.

Posner and Strike do not deny that other factors (e.g. emotional, contextual) play an important role in learning but ground their theory in the assumption that learning <u>is</u> a rational activity. As such, learning science is a matter of developing concepts that can be justified as corresponding to the realities of the world. School science is, similarly, a matter of helping students build accurate mental representations of the world based on available evidence.

Conceptual change researchers popularized misconceptions research (Brown and Clement, 1989; Clement, 1982, 1983; McCloskey, 1983; McCloskey, Caramazza, and Green, 1980; Rosnick, 1981) and recognized that students often hold strong yet incorrect ideas about the world. To relinquish these ideas in an attempt to gain more accurate ones is the process of conceptual change and, when successful, the process yields conceptual understanding. In successful conceptual change teaching, students' new conceptions will be "more fruitful" and will more closely resemble the accepted concepts of the discipline. The teacher's job is to

provide opportunities for students to see the weaknesses or the inaccuracies in their current conceptions through demonstrations or activities designed to instill cognitive dissonance. These dissonance-creating demonstrations have been called discrepant events - discrepant because what students think will happen does not because their beliefs are based on incorrect ways of knowing (Liem, 1992). The students' role is to scrutinize and modify their science knowledge. Once criteria for conceptual change have been met, students then work to accommodate this new or discrepant knowledge, with their current conceptions producing, if all has gone well, more canonical conceptual understanding.

Discourse-based Understanding

Discourse-based perspectives, as represented by socio-cultural theory, typically view science as culturally, socially, and contextually situated activity. With an appreciation of the "situatedness" of knowledge comes a concomitant concern about issues of power and equity. Rather than extend the myth that science is for the elite, Gallas (1994) argues that discourse-based pedagogy allows "teachers and children to move purposely together toward an inclusive kind of talk about science where everyone is admitted" (p. 3). Gallas (1994) and Lemke (1990) both suggest that learning to "talk" science is an accurate representation of what the discipline of science is most like: a particular discourse or way of talking. Gallas describes her book in this way, "taken metaphorically, it is about acquiring a discourse" (p. 4), the discourse of science.

Learning in a discourse-based science classroom occurs through joint questioning, rephrasing, defending, hypothesizing, critiquing, theorizing, and imagining about science. Student ideas are taken as central to the class conversation. The direction of conversation is often dictated entirely by students, perhaps only occasionally guided by the teacher. Gradually, students learn how to more easily and appropriately talk about science in ways that use science

words and ideas accurately. Simultaneously, students begin to feel less alienated by science as their own ideas are taken as having worth. An occasional problem in discourse-based classrooms is that ways of talking often take precedence over the acquisition of canonical science knowledge. However, in the hands of a skilled teacher, canonical understandings do develop.

The teacher in such a classroom must be skilled in pedagogy and knowledgeable in subject matter. Beyond establishing a supportive discourse community, the teacher must recognize and subtly guide student talk toward more fruitful paths of inquiry. The student role is to share, defend, and critique science ideas along with the teacher and classmates. Learning in a discourse-based classroom takes a great deal of time and practice. Lemke (1990) offers an entire chapter on changing teaching strategies so that students learn more effectively through discourse. Students feel motivated to learn because their identity and efficacy beliefs about science develop as their ideas are validated and taken seriously. Also, the social qualities of learning are attractive to students.

Successful learning in a discourse-based classroom is challenging. These words from Bakhtin (1990, pp. 293-294) eloquently describe both the idea that to learn is to learn language and the difficulties of learning a new discourse.

> [The word] becomes "one's own" only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. Prior to this moment of appropriation the word…exists in other people's mouths, in other people's contexts, serving other people's intentions: it is from there that one must take the word, and make it one's own. And not all words for just anyone submit equally easily to this appropriation, to this seizure and transformation into private property: many words stubbornly resist, others remain alien, sound foreign in the

> mouth of the one who appropriated them and who now speaks them; they cannot be assimilated into his context and fall out of it; it is as if they put themselves in quotation marks against the will of the speaker. Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated - overpopulated - with the intentions of others. Expropriating it, forcing it to submit to one's own intentions and accents, is a difficult and complicated process.

According to Lemke (1990) and others, discourse-based understanding includes two main components: 1) acquisition of thematic patterns and 2) appropriation of elements of identity as associated with science, science ideas, and scientific community. Thematic patterns can be divided further into two processes. The first involves learning the organizational patterns appropriate to particular science discourses, meaning, the kinds of questions to consider, the evidence that will be persuasive, and something of the logic necessary to make compelling claims from existing warrants. The second consists of learning the particular semantic patterns necessary to string together science words in ways that make sense.

Identity acquisition includes imagining possible "future selves" (Markus & Nurius, 1986) and appropriation of a "science self" into one's "identity kit" (Gee, 1991). Students who learn science for a discourse-based understanding develop positive conceptions of themselves as science learners, do-ers, and inquirers. Students take on the identity of participants in a particular science discourse community.

Dewey's View of Learning

Dewey's ideas about knowledge and learning, particularly his more mature views developed in Experience and nature (1929) and Art as experience (1934), are the foundation for

this analysis and the development of our perspective on aesthetic understanding. Dewey would probably acknowledge that learning science's concepts and appropriating its discourse are important features of effective science education. However, he would go on to emphasize that these elements are subsumed in the broader goal of education - to help students lead lives rich in worthwhile experiences. The task of school is to provide students with transformative experiences: experiences that are valuable in themselves and in their potential to lead to other worthwhile experiences.

Dewey's emphasis on experience needs elaboration, for he gives the term important, but easily overlooked, nuance. What does Dewey mean by experience, particularly educative experience? The potential for educative experience often arises in the course of living. However, the experience frequently ends without ever developing. The "inchoate" experience remains embryonic and never comes to mean anything because one is distracted, tired, or lazy. Thus, although there is activity – that is, things happening over time, there is no coherence, development, or flow to these things. Such is the nature of ordinary experience. Dewey (1934, p. 35) contrasts ordinary experience with what he alternately calls educative experience, aesthetic experience, or simply, an experience:

> In contrast with such experience, we have an experience when the material experienced runs its course to fulfillment. Then and then only is it integrated within and demarcated in the general stream of experience from other experiences. A piece of work is finished in a way that is satisfactory; a problem receives its solution; a game is played through; a situation, whether that of eating a meal, playing a game of chess, carrying on a conversation, writing a book, or taking part in a political campaign, is so rounded out that

its close is a consummation and not a cessation. Such an experience is a whole and carries with it its own individualizing quality and self-sufficiency. It is an experience.

When material experienced "runs its course to fulfillment," Dewey emphasizes that educative experiences become more than events that merely happen. Instead, the forward movement of an experience has a unity among its elements: "every successive part flows freely, without seam and without unfilled blanks, into what ensues" (Dewey, 1934, p. 36). Furthermore, in these experiences there is a sense of what could be, an anticipation of how things might come together. As an experience becomes imbued with qualities such as anticipation, development, and unity, it also becomes an act of thinking and meaning. Dewey describes educative experiences as having a plot or history, and pervading dramatic quality. Given how Dewey has characterized the structure, flow, and energy of an experience, we propose that educative experiences can be thought of, indeed they are, dramatic events.

Drama and anticipation: The motivation for learning. An important issue to consider when comparing perspectives on learning is what motivates learning. In the discourse-based perspective, the construct of participation is crucial as both the product and motivation for learning. The product of learning, the goal of instruction, is the development of new forms of participation and acquiring the language of a new community. Motivation for learning is characterized by how students respond to their evolving participation – the degree to which they feel able or willing to take on new roles and identities. Dewey would likely applaud the discourse perspective's attention to identity and participation because it pushes understanding out from inside the head and reconnects it more directly with action and activity. He would likely remark, however, that the discourse perspective's emphasis on language is an overly narrow interpretation of activity. Language is principally a social phenomenon, an activity between

people. Although the study of language is an effective way to appreciate the socially contextualized nature of meaning, it underestimates the importance of interaction with the world of objects and nature. This is a critical shortcoming when the domain of interest is science. For Dewey, an account about what motivates student learning must take into account the interaction of person and world. Indeed, science learning is often a discourse between learner and idea, objects, and experiences in science.

In mainstream cognitive perspectives, such as conceptual change theory, learning is motivated by a desire to reduce perturbations in one's various representations of the world. Thinking is prompted by disequillibrium or problems. To think is to solve problems (Posner et al., 1982). Dewey's response to this image of the learner is interesting. Many educators, particularly in the science education community, associate Dewey with inquiry learning, that is, problem driven learning. Although his earlier work tends to support this view, he modifies his position in his later writing. (The two versions [1910 & 1933] of his How we think illustrate this development). Dewey maintains that, although some learning is a response to a particular problem, other learning is an exploration of the possible (Prawat, 1993). In other words, learners get a sense of what might be and are inspired to move forward. Thus, learning not only results in understanding, it is also compelled by it. Dewey (1933, p. 335) clearly describes how ideas precede, rather than follow, inquiry: "There is no mistake more common in schools than ignoring the self-propelling power of an idea. Once it is aroused, an alert mind fairly races along with it. Of itself it carries the student into new fields; it branches out into new ideas as a plant sends forth new shoots."

The drama of anticipation and revelation of the possible animate learning differently than in the conceptual change, problem-driven view.

The accounts of student motivation provided by conceptual change and discourse perspectives, therefore, are incomplete. What is gained from a Deweyan perspective, from seeing educative experiences as dramatic events? To appreciate Dewey's view of motivation, one must first understand the role of anticipation in dramatic experiences (Dewey, 1934; Jackson, 1998; Prawat, 1993; Wong, Pugh, and the Dewey Ideas Group at Michigan State University, 2001). Consider this example: a person walks down a hallway, approaches a door, and opens the door. This is a mundane description of an ordinary occurrence. It means nothing. By contrast, consider: a person walks to open one of two doors, to encounter immediate pain or pleasure, to make an irreversible choice that will forever change the course of his/her life. This example (a loosely borrowed version of Stockton's [1907] short story, "The Lady or the Tiger") is a dramatic event, rather than a simple occurrence. What transforms the experience of this event, for either the person opening the door or the person reading the story, from an ordinary experience to a dramatic, aesthetic experience is the powerful feeling of anticipation it evokes. The elements of the event develop and cohere as the individual pushes forward and as the event pulls the individual with it. Similarly, consider science students for whom a science lab is little more than a series of activities to complete. Granted, students are active and there is experience. However, one would be hard pressed to characterize the lab as an unfolding drama of inquiry where one part leads to the next, where the activity is compelled by the anticipation of what might be. In both examples, the event not only happens but has an energy that connects its parts and moves it forward.

Anticipation is an inherent quality in all-powerful learning experiences. In effective conceptual change or discourse based science lessons, anticipation is a salient element of students' experience, though it may not be emphasized in the theory that inspired instruction.

Students look forward to the solution of a vexing problem (given that it is meaningful to them), just as they look forward to becoming members of a group.

However, in our view, it is not sufficient to claim that some form of anticipation can be found in students' experiences in these situations. The conceptual change and discourse perspectives might agree, with indifference, with this observation. Thus, we take the point further by making anticipation itself the heart and substance of worthwhile learning. In other words, when Dewey's position that education should lead to worthwhile experiences means that schooling should fill students' lives with anticipation. Now, the difference between Dewey's views and others' becomes more distinct and consequential. Not only should students learn concepts and how to talk science, they should look forward to the experience of using and developing concepts and discourse in the real world. They should desire to see where those concepts take them, to see how the concepts might transform their existence in the world. Similarly, students should have some sense of where their newly acquired language might take them and feel an urgency to move in that direction and develop their language further. For Dewey, good teaching initiates and sustains the drama of learning initiated by anticipation.

Anticipation is aesthetic. Anticipation both organizes and develops the educative experience and is, therefore, fundamentally intrinsic to this dramatic event. Unlike concepts or language, anticipation does not exist, in any meaningful sense, separately from specific experiences. In this way, it is quintessentially aesthetic in nature. Similarly, the value of concepts and language is typically associated with what is achieved through their use. Conceptual understanding facilitates problem solving; language enables participation with others. Although Dewey agrees that all educative experiences should be instrumental in this way, he would also

maintain that the aesthetic nature of intense experiences infuses them with intrinsic value. Educative, aesthetic experiences are worthwhile in both themselves and their yield.

To repeat a point made earlier, instruction generated or analyzed from conceptual change or discourse perspectives can have aesthetic qualities. The point we are making is that these important qualities of learning are either less likely to occur or less likely to be noticed when instruction or analysis, respectively, is grounded in these perspectives. To bring out the aesthetic qualities in learning, we propose that science education should be organized around a fundamentally different curricular unit. Rather than understanding concepts or appropriating language, learning science should be about having ideas-based experiences (Pugh, 1999).

Three Qualities of Aesthetic Understanding

One strategy for understanding Dewey's perspective is to compare and contrast it, as we have in the preceding section, to other important views of learning. Another approach to understanding the meaning of ideas is to explore their pragmatic consequences - that is, their effect on the lives of teachers and students. This is our goal in the empirical portion of this article. In order to transform the conceptual ideas of aesthetic understanding to practical activity, we first had to identify and operationalize important qualities of aesthetic understanding. Then, these qualities formed a framework that guided our approach to teaching and the design of our assessment. Although we acknowledge the complexity of the idea of aesthetic understanding, in the interest of coherence and simplicity, we chose to focus on three important qualities. All aesthetic understanding is dramatic or compelling, transforming, and unifying.

Dramatic or Compelling

Transformative experience is “active and alert commerce” with the world – “commerce” being the forward moving transaction between testing ideas and undergoing the consequences.

The drama of powerful learning comes from the anticipation internal to this process. Dewey's emphasis on ideas and anticipation supercedes the problem-solving mechanism of conceptual change in that learning can be both driven by problems and inspired by possibilities. In addition, Dewey's account gives a prominent place for emotion, the varied feelings of anticipation, in the experience of learning. In contrast to the discourse perspective, subject matter has greater prominence in Dewey's account of what motivates students. In educative experiences, anticipation about testing ideas in the world, rather than social participation, compels students' engagement.

For Dewey, experience is a negotiated process between action and undergoing (being acted upon) that ends in expanded perception. The goal of an experience is to resolve these perceptions into some meaningful, unified experience. Dewey calls "dynamic organization" the process by which people negotiate action and undergoing; the process by which they organize their perceptions and rectify their structures into a coherent whole. "That which distinguishes an experience as esthetic is conversion of resistance and tensions, of excitations that in themselves are temptations to diversion, into a movement toward an inclusive fulfilling close" (1934, p. 56). People work hard to make their conceptions or experiences "fit," and when they do, understanding becomes aesthetic. "The doing may be energetic, and the undergoing may be acute and intense. But unless they are related to each other to form a whole in perception, the thing done is not fully esthetic" (p. 50).

Because of this flux, an experience is an emotional state that fuses actions, events, and emotion into a unified whole. This drama and affective unification also provide an aesthetic quality to experience.

It is not possible to separate in a vital experience the practical, emotional, and intellectual from one another and to set the properties of one against the characteristics of the others. The emotional phase binds parts together into a whole; "intellectual" simply names the fact that the experience has meaning; "practical" indicates that the organism is interacting with events and objects that surround it. The most elaborate philosophic or scientific inquiry and the most ambitious industrial or political enterprise has, when its different ingredients constitute an integral experience, esthetic quality (Dewey, 1934, p. 55).

Dewey believed aesthetic experiences are recursive, not circular, but perhaps spiraling. Rather than coming to a final conclusion, people are compelled to seek other experiences. To “get it” is not to come to rest, as can be connoted by other perspectives. For Dewey, understanding often generates more thinking and more action – even more than the logical problems associated with problem-solving perspectives - as people ask themselves which route to pursue or where and how else might these ideas be useful. We believe aesthetic understanding is not an endstate but only a jumping off point that compels people to learn more.

Students may make statements like the ones below, which would qualify as evidence of the compelling power of experience:

"I can't wait to tell others about this!"

"I've really been thinking a lot about this."

"Learning about this has made me want to learn about other things."

The compelling nature of experiences can be thought of as facilitating "ideas-on-the-brain." Students who think about ideas, want to talk about them, pursue them in other ways and in other settings, have ideas-on-the-brain, which is an indicator of the compelling, forward-looking nature of experience.

Transforming

Dewey's epistemology highlights how a new entity is created in the dramatic experience of learning. This "event" or "situation" exists only in the transaction of the individual, world, and idea. Dewey's concept of transaction highlights two key features of aesthetic experience. First, it describes how learning can truly have intrinsic value. Other perspectives tend to portray concepts and language as tools or means to an end and, in our opinion, struggle to explain how learning can occur for "its own sake."

Second, Deweyan transaction illuminates how dramatic experiences are transformative. As the individual acts on the world, the world necessarily acts on the individual. Each is influenced and changed by the other. The unfolding of an experience is the mutual development of the individual and world. This mutual transformation as individual and world transact is a key element in Dewey's epistemology. Dewey (1934, p. 39) writes, "Experience does not go on simply inside a person. It does go on there, for it influences the formation of attitudes of desire and purpose. But that is not the whole story. Every genuine experience has an active side which changes in some degree the objective conditions under which experiences are had."

As an example, a friend tells a story about his childhood in which he came to be aware of the idea of adaptation. Suddenly, everywhere he looked he saw evidence of why and how living things survived. He literally "saw" adaptation all around him and was changed by the revealing power of this idea. Neither he nor his world exited this transaction the same. This is the potential of aesthetic experience. Through action, or more specifically, the transaction between individual and world, experience is transformative.

In short, the new relationship between person and world is the "product" of learning. This view contrasts with conceptual change perspectives where individuals' conceptions or

representations alter to fit the world. In addition, individuals are changed only to the extent that their understandings change. Dewey describes a change in being – a change in thinking, acting, and feeling.

The discourse perspective describes transformation of identity and participation and, in this regard, resonates with Dewey's emphasis on the whole person. However, discourse perspectives, especially those influenced by the work of Lave and her colleagues (Lave, 1988; Lave & Wenger, 1991), tend to see transformation as a progression toward an established practice. Individuals move from peripheral to more central, more legitimate tasks as they become part of a community of activity. Similarly, learning can be described by the degree to which individuals have appropriated the language of a community such as science. This view of transformation contrasts with Dewey's in two ways. First, as in the conceptual change perspective, there is little discussion of how the learners' worlds are transformed as they develop. Second, instead of convergence toward the conventions of an established group, Deweyan transformation allows for more individuality of experience, often spawning creative leaps and more divergent thought. It seems to us that some account for variation from norms is essential to account for how new ideas and new practices can emerge from established groups.

To operationalize this quality of aesthetic understanding, some examples of statements students may make after a transformative experience are helpful:

In reference to a transformed world:

"I see the world in a whole new way."

"I can't help but see the idea everywhere now."

In reference to a transformed person:

"I feel differently about myself."

"I can see myself continuing to study this."

Another indicator of transformative experience would occur if a student articulated new opinions, beliefs, or goals for him/herself. For example, Brieana, a student in our study stated, "I'm thinking about becoming a geologist." In her telling, she had not previously entertained this idea. Through her engagement with substantive ideas, she was transformed into someone who may become a geologist.

Unifying

In aesthetic experience, learners are drawn forward in anticipation of consummation of an experience. “In contrast with such (ordinary) experience, we have an experience when the material experienced runs its course to fulfillment. (The experience) is so rounded out that its close is a consummation and not a cessation” (Dewey, 1934, p. 35).

Consummation – the coming together of the various parts and incidents, the completion of development – not only marks the endpoint of an experience but is anticipated through the entire event. To consummate an experience is to see how formerly disparate elements fit together. The coming together of parts is the drama inherent in great art, riveting stories, and engaging scientific inquiry.

For example, in learning about the periodic table of the elements, one comes to understand it as an organized representation of the building blocks of molecules and matter. Learners begin to view relationships between elements and molecules differently. This relationship begins to make more sense, and learners can make predictions based on their knowledge. The periodic table resolves into a more unified representation rather than consisting of disconnected facts to be understood separately. Concurrently, individual elements come into

relief. One can speak more accurately and more comprehensibly about sodium and chlorine as individuals because their atomic relationships are better understood.

This quality of emerging unity is not easily detected in discourse perspectives' accounts of learning outside of group or community unity. Again, however, this is unity associated with participation not subject matter knowledge. In the conceptual change perspective, in contrast, sense making and connection are intimately related. In the cognitive paradigm, to understand is to make connections. Although both Deweyan and conceptual change perspectives seem to emphasize how learning is unifying, Dewey pushes the idea to the next level. What makes powerful learning fundamentally aesthetic is that it takes on a profoundly moving, spiritual character. Jackson (1998, p. 149) explains: "I think what Dewey means is that it is during those moments of full perception, when we are totally absorbed in what this object or event or idea is like, that the various components of our psychological being – our ability to think, to feel, to appreciate, to experience through all of our senses- come into play at once. At such moments our various capacities not only are realized (i.e., become real) but are also momentarily fused and unified. Only then do we experience what it is like to be fully human." When ideas engage all our faculties, when we realize greater coherence in our world, when we expand our capacity to think, feel, and act, we experience a kind of transformation of ourselves that is deeply and innately compelling. This is the intrinsic, aesthetic value of educative experience.

Student statements like the following, may be evidence of the unifying potential of experience:

"This is all starting to fall into place for me."

"The world is beginning to make more sense."

"I get it and it's so cool!"

Summary

Central to aesthetic understanding is the idea of aesthetic experience. Students learn through a process of changed perception, a virtual transformation of their world and themselves as they seek to verify content ideas. Aesthetic understanding brings unification or coherence to students' understanding and necessarily moves them out into the world as a result of the intensely compelling nature of experience. What exits aesthetic experience is a more rich, multifaceted understanding that incorporates conceptual knowledge, skills, dispositions, feelings, attitudes, actions, and emotions and value. To value is to see the relative worth, utility, or importance. Value can be placed on an object, skill, or idea in ways that are not necessarily connected to instrumental outcomes. In fact, we argue that instrumental value too often guides teaching and learning. Worth, utility, and importance should be guided instead by aesthetic outcomes - those outcomes that lead to more pleasing or beautiful results. People should not always learn because of what knowledge can do for them, or what it may buy them in the future. The goal of learning should be having aesthetic experiences, coming to aesthetic understanding, and developing value for ideas beyond the purely instrumental. Table 1 summarizes the three perspectives on science learning.

Table 1. Summary of three perspectives on science learning

	Conceptual understanding via conceptual change theory	Discourse-based understanding	Aesthetic understanding
Representative theoretical work	Posner et al.'s (1982) "Toward a theory of conceptual change"	Lemke's (1990) Talking Science	Dewey's (1934/1980) Art as Experience
Definition of knowledge	In the head Representations and concepts	In the group In language and participation with others	In action in the world (physical and social)
Central curricular unit	Concepts Disciplinary knowledge	Language, participation	Ideas, experiences
What motivates learning	Problems Logical inconsistencies Cognitive dissonance	Desire to participate in a group Anticipated identity or role in the group	Anticipation of possibilities Desire to try out ideas
How learning occurs	Accommodation of new knowledge with prior knowledge Stimulated by cognitive disequillibrium or dissonance	appropriating language Moving from peripheral to central participation in a group	Having aesthetic experiences with subject-matter ideas
Role of teacher	Help students identify, confront and replace misconceptions with accepted canonical ways of knowing Emphasis on individual cognitive structures	Help students adopt socially accepted norms or ways of talking about science Scaffold identity development and emphasize community of shared meaning-making	Help students to see possibilities and potentials for science ideas to re-shape and re-vitalize the world Emphasis on truth and beauty as ideas are verified in world
Role of learner	Must recognize misconceptions, then accommodate or replace them with "correct" ideas	Active in constructing and co-constructing knowledge with other students, teacher, and society or culture at-large	Active in verifying potential of ideas Process of verification is both individual as well as socially and culturally situated

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