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Kevin James Pugh

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David Wong 8/
Major professor

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by

Kevin James Pugh

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ABSTRACT

IDEA-BASED, TRANSFORMATIVE EXPERIENCES:
WHAT ARE THEY AND HOW DO YOU FOSTER THEM?

by

Kevin James Pugh

Many have argued that science education should enrich students' everyday experience, but, surprisingly, this issue has not been systematically addressed by the field of science education. Much of the work in science education has focused on the issue of how enriched experience leads to the development of conceptual understanding, but relatively little work has focused on the issue of how conceptual understanding leads to the development of enriched experience. This dissertation is a collection of two articles, which address the latter issue.

The first article comprises section one of the dissertation and is entitled "Applying Pragmatism and Deweyan Aesthetics to Science Education: A Look at How Concepts Can Enrich Everyday Experience." This article develops the construct of an idea-based, transformative experience (a particular type of enriched experience) and an understanding of the role that concepts play in such experience, by synthesizing Dewey's writings on experience, aesthetics, and education. Such experience involves various dramatic qualities, but is centrally defined by an expansion of perception, meaning, and value, which results from active use of a concept. Three illustrative examples of idea-based, transformative experiences are provided. Implications include a focus on idea-based, transformative experience as the goal of science education. A discussion of how this goal

compares, contrasts, and relates to the standard goals of conceptual understanding/change and the development of thinking/participatory skills is provided.

The second article comprises section two of the dissertation and is entitled, "Teaching for Idea-based, Transformative Experiences in Science." This article is a report of a study which examines the effectiveness of two related teaching elements (the artistic crafting of content and the modeling and scaffolding of perception, meaning, and value) at fostering idea-based, transformative experiences. The elements were used in teaching a unit on adaptation and evolution in a high school zoology class. Student outcomes were compared with those of students in a roughly equivalent (as determined by a pre-intervention survey) class in which the same unit was taught using a case-based model of instruction. Results indicate that a significantly greater percentage of students in the experimental class (52.9 %) than students in the control class (22.7%) engaged in some degree of idea-based, transformative experience. In particular, students in the experimental class demonstrated significantly greater active use of the concepts and a significantly greater proportion of students in the experimental class reported an expansion of perception. Also, there was a consistent trend in the data with students in the experimental class expressing a greater increase in value. Further it was found that students (from both classes) who engaged in at least some form of idea-based, transformative experience scored significantly higher than other students on a follow-up assessment of understanding – suggesting a relationship between engagement in idea-based, transformative experiences and enduring conceptual understanding.

This dissertation is dedicated to Scott and JoAnne Pugh.

Although you are missed, your influence is still felt.

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INTRODUCTION

As I went through school, I learned to love science because I found that science ideas allowed me to better understand and appreciate the world around me. While taking my first geology class in college, I remember becoming fascinated by the way geology ideas allowed me to uncover the stories hidden inside the rocks and rock layers. So for me, the real value of science education is that an understanding of science concepts can enrich the value of the everyday experiences that we have in the world. Although similar views have been expressed by other scientists (Dawkins, 1989; Feynman, 1989) and science educators (Flannery, 1991) and in some definitions of scientific literacy (see Laugksch, 2000; Chung, Oliver, Jackson & Kemp, 1999), it had not become a serious topic of investigation within the field of science education. This dissertation represents the work I am doing to make it a serious topic of investigation.

Before moving forward, I need to say a few words about the format of this dissertation. Duke and Beck (1999) argue that the field of education should consider alternative formats for the dissertation. One of the alternative formats that they suggest is that the dissertation be a series of articles instead of the traditional book length document. This format is advantageous because 1) it allows doctoral students to focus on the type of writing they will primarily use in future academic careers (i.e., it allows them to practice writing articles instead of books) and 2) it reduces the redundancy involved in first writing a book length dissertation and then rewriting it as a series of articles for publication. For these reasons, I have chosen to adopt this alternative format in the writing of this dissertation.[1]

This dissertation is essentially comprised of two related articles, which represent my research program over the past three years. The first article comprises section 1 of this dissertation and is entitled "Applying Pragmatism and Deweyan Aesthetics to Science Education: A Look at How Concepts Can Enrich Everyday Experience." This is a theoretical article which seeks to define and provide illustrative examples of what it means for science concepts to enrich the quality of everyday experience. In the article, I argue that the field of science education has not seriously addressed this issue and I seek to address it by turning to pragmatism; particularly to the Deweyan aesthetics. From Dewey's aesthetics and other writings on education, I develop the construct of an idea-based, transformative experience. Such experience involves various dramatic qualities such as completeness, uniqueness, and unifying emotion. However, it is most centrally defined by an expansion of perception, meaning, and value that comes as a result of learning a concept. Through this expansion, the individual's relationship with the world is transformed in an important and personally meaningful way. I then provide three illustrative examples or case studies of individuals engaging in such experience and compare and contrast idea-based, transformative experience as an outcome with other important outcomes in science education.

The second article comprises section 2 and is entitled "Teaching for Idea-based, Transformative Experiences in Science." This article is a practical application of the theory developed in the first article. In the second article, I report on a study which seeks to determine the effectiveness of a particular teaching approach at fostering idea-based, transformative experiences. This study provides an operational definition of idea-based, transformative experience, a description of and rationale for the particular teaching

approach, and an account of both its overall effectiveness and its effectiveness in comparison to an alternative approach.

Together the articles begin to address the issue of how an understanding of science concepts can enrich the value of the everyday experiences that we have in the world. The first article defines and illustrates what it means for science concepts to enrich everyday experience. The second article explores how idea-based, transformative experiences may be fostered in the science classroom. My future research will build on these articles by further clarifying the process involved in undergoing an idea-based, transformative experience, by further exploring the effectiveness of various teaching methods and environments at fostering idea-based, transformative experience, and by examining the qualities of individuals that contribute to or inhibit participation in idea-based, transformative experiences.

1. Due to series of articles format of this dissertation, a bibliography will be given at the conclusion of each section.

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SECTION 1

APPLYING PRAGMATISM AND DEWEYAN AESTHETICS TO SCIENCE EDUCATION:
A LOOK AT HOW CONCEPTS CAN ENRICH EVERYDAY EXPERIENCE

Abstract

Many have argued that science education should enrich students' lives, but, surprisingly, this issue has not been systematically addressed. Much of the work in science education has focused on the issue of how enriched experience leads to the development of conceptual understanding, but relatively little work has focused on the issue of how conceptual understanding leads to the development of enriched experience. This article turns to pragmatism (which has traditionally been concerned with the consequences that ideas have on experience) in order to address the latter issue. In particular a synthesis of Dewey's writings on aesthetics, experience, and education is used to develop the construct of an idea-based, transformative experience. Such experience is centrally defined by an expansion of perception, meaning, and value, which results from active use of a concept. Three illustrative examples of idea-based, transformative experiences are provided. Implications include a focus on idea-based, transformative experience as the goal of science education. A discussion of how this goal compares, contrasts, and relates to the standard goals of conceptual understanding/change and the development of thinking/participatory skills is provided.

Introduction

Posner (1991) comments that one of the essential elements of pragmatism is "an insistence that propositions be tested by their consequences, by the difference they make—and if they make none, set aside" (p. 35f). Similarly, Cherryholmes (1999) states, "The point for pragmatists is to assess the consequences in terms of making life better or worse, more pleasurable or painful, more productive or more unproductive" (p. 20). For pragmatists, the worth of ideas is determined by their consequences. As applied to science education, we might say that pragmatism places an emphasis on the difference that scientific concepts make in the lives of students. For me, this points to the real value of science education: its potential to provide students with an increased capacity to experience the world. Scientific concepts can open up aspects of the world for students and help them gain a greater understanding, appreciation, or emotional connection to various objects, events, or issues. They can provide students with worthwhile experiences and help them live more enriched and fulfilling lives.

Surprisingly, this aspect of science education has not been thoroughly researched. The slogan that education does or should enrich the quality of students' lives is often stated, but we have not developed a body of research which examines the issue of how, or if, scientific concepts enrich the quality of students' immediate, everyday experience. This point needs elaborating.

In general, the various perspectives on science education have focused more on how engagement in enriching experience leads to the development of scientific concepts and less on how engagement with scientific concepts leads to the development of enriched experiences. For instance, many perspectives (such as the Piagetian,

progressivist, discovery learning, constructivist, situative, and experiential learning perspectives to name a few) have examined the effects of everyday experience, hands-on (or minds-on) activity, "authentic" activity, collaborative group activity, apprenticeship experience, and/or field trip or wilderness experience on the learning of concepts or conceptual understanding (for examples, see Neathery, 1998; Carver, 1996; Brown & Campione, 1994; Roth, 1993; Linn & Songer, 1991; Tobin, Briscoe & Holman, 1990; Brown, Collins & Duguid, 1989; Duckworth, 1987; Bruner, 1960). However, few researchers have examined how the learning of concepts may lead to enriching experiences in students' everyday lives. Some researchers have begun studying the relevance of science education to students' everyday experience (Mayoh & Knutton, 1997; Newton, 1988; Lewis, Linn & Songer, 1991; 1972), however, as Cajas (1998) points out, there is a lack of research on student use of school science in everyday life. We simply do not know much about students' use (or lack thereof) of science concepts and whether such use constitutes enriched experiences for the students. In other words, we do not know much about the difference that science concepts make in the lives of students.

One of the issues we face in addressing this problem is the need for the development of a definition of "enriched experience." Just what does it mean for a science concept to lead to an enriched experience? I believe insights to this question can be gleaned by turning to aesthetics, as the field of aesthetics focuses on what might be called "meaningful," "optimal," or "enriched" experience. Some researchers have already begun to consider the applications of aesthetics to science education. For example, Flannery (1991) addresses the aesthetics of science education and one of the

points she raises is that scientific concepts allow scientists to engage in aesthetic experiences with such seemingly mundane things such as leaves and enzymes. Science seems to enrich the experiences that these scientists have with objects and events in the world. Similarly, Chun, Oliver, Jackson, and Kemp (1999) argue that an important aspect of scientific literacy is coming to experience the world more deeply and even aesthetically through the learning and doing of science. They also provide examples of how scientists have aesthetic or enriched experiences as a consequence of their scientific knowledge. However, we still do not have a rich definition of what an aesthetic experience is in this context. We also lack an understanding of the specific role that scientific knowledge plays in bringing about this experience. Here, I address this problem by turning to the work of one of the foremost pragmatists: John Dewey.

Dewey's work is particularly pertinent to this issue because he argued that experience should be, not only the means of education, but its end (see Dewey, 1938). Further, he developed a comprehensive theory of aesthetic experience (Dewey, 1958/34) and, as I will argue, provided a theory for understanding the role that scientific concepts play in such experience (Dewey, 1988/29; 1958/29; 1933). In this paper, I try to unite these previously disconnected aspects of his work and use them to develop a more concrete construct of an enriching or aesthetic experience with science ideas – what I term "idea-based, transformative experience." I then provide some illustrative examples of what I consider to be idea-based, transformative experiences and consider the implications.

Dewey's Theory of Aesthetics

In the latter part of his career, Dewey developed a theory of aesthetics to complement or extend his theory of experience. To do so, he turned to the arts because he felt that successful participation in the arts epitomized a particular type of aesthetic experience, what he called an experience. Jackson (1998) comments,

> Our interactions with art objects epitomize what it means to undergo an experience, a term with a very special meaning for Dewey. The arts do more than provide us with fleeting moments of elation and delight. They expand our horizons. They contribute meaning and value to future experience. They modify our ways of perceiving the world, thus leaving us and the world itself irrevocably changed. (p. 33)

In Art as Experience, Dewey (1958/1934) elaborates on what it means to undergo an experience, the generic traits of an experience, how an experience differs from ordinary experience, and how participation in the arts epitomizes an experience.

The Undergoing of "An" Experience

Art, says Dewey (1958/1934), "quickens us from the slackness of routine and enables us to forget ourselves by finding ourselves in the delight of experiencing the world about us in its varied qualities and forms" (p. 104). The power of the arts, according to Dewey, is that they allow us to more fully experience the world. They do not provide us with a momentary escape from this world, but instead take us to a deeper understanding and appreciation of the world we are in. The arts carry us "into a world beyond this world which is nevertheless the deeper reality of the world in which we live our ordinary experiences" (1958/1934, p. 195). When the arts perform their magic in

such a manner, we undergo a particular type of experience, what Dewey referred to as an experience. It is this type of experience, more than the arts themselves, that is at the heart of Dewey's aesthetics. In a sense, the arts simply served as a medium for discovering what it means to undergo an experience.

To get a feel for what it means to undergo an experience, imagine the last time you were moved by a painting, a dance performance, a novel, a film or other work of art. Your experience probably had a wholeness or completeness to it; the experience didn't just end randomly, but it ended with an realization, and understanding, a new found appreciation, an emotional release, or a resolution. It also likely had a unity and uniqueness to it; the experience was memorable and it stood out from other experience that preceded or followed it. It also likely involved salient emotion; feelings of tension, anticipation, fulfillment, satisfaction, sorrow, compassion, or others. Finally, and perhaps most significantly, you were likely changed in some small (or large) way by the experience. You developed a new understanding, appreciation, meaning, or way of looking at some object, event, or issue in the world. This brief description captures the generic traits of an experience. As outlined by Jackson (1998) these traits include 1) completeness, 2) uniqueness, 3) unifying emotion, and 4) the expansion of meaning and the attainment of full perception. Below I elaborate on these traits.

Completeness or Wholeness. Ordinary experience lacks a completeness or wholeness. It is often disjointed, interrupted, or terminated without reaching any consummation: "We put our hands to the plow and turn back; we start and then we stop, not because the experience has reached the end for the sake of which it was initiated but because of extraneous interruptions or of inner lethargy" (Dewey, 1958/1934, p. 35). An

experience is different. It does have a completeness. Dewey continues, "In contrast with such [ordinary] 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 experience" (p. 35). The completeness comes as the experience "is so rounded out that its close is a consummation and not a cessation" (p. 35). The consummation results from anticipation having reached a conclusion. It is the build up and final bringing about of this consummation that gives an experience its completeness.

Uniqueness. The completeness of an experience also gives it a uniqueness; it demarcates the experience from the general stream of experience. In contrast to ordinary experience, an experience stands out; it is memorable. An experience is identified by "those things of which we say in recalling them, 'that *was* an experience'" (Dewey, 1958/1934, p. 36). Part of the uniqueness of an experience is that it has a single quality which differentiates it from other experiences. Dewey (1958/1934) comments, "An experience has a unity that gives it its name, *that* meal, that storm, that rupture of friendship. The existence of this unity is constituted by a single *quality* that pervades the entire experience in spite of the variation of its constituent parts" (p. 37).

Unifying Emotion. As part of the completeness and uniqueness, an experience has a unifying emotion. This emotion is connected to the build up of anticipation toward a consummation. Dewey (1958/1934) states, "This consummation, moreover, does not wait in consciousness for the whole undertaking to be finished. It is anticipated throughout and is recurrently savored with special intensity" (p. 54). Just as a drama is held together and driven along by such emotion as suspense, so an experience is held

together and driven by emotion. In an experience, "emotion is the moving and cementing force" (Dewey, 1958/1934, p. 42). In addition, an experience brings with it a sense of fulfillment or satisfaction. It has intrinsic worth. Jackson (1998) states, "every such experience is partially an end in itself. It contains its own rewards. It is intrinsically worthwhile" (p. 10). He further explains that "intrinsic meaning is consummatory and final. It is meaning enjoyed for its own sake, as opposed to having a practical or utilitarian force" (p. 29). To sum up, an experience has completeness, uniqueness, unifying emotion, and ultimately it is savored for its intrinsic value. These traits help to define an experience, but they don't really convey the significance of an experience. The significance only emerges when we look at the last generic trait: expansion of meaning and attainment of full perception.

Expansion of Meaning and Attainment of Full Perception. Jackson (1998) states that these are the most general and significant of the traits. An experience may vary in its degree of completeness, uniqueness, and unifying emotion, but unless there is an expansion of meaning and attainment of full perception then it is not an experience (p. 112). In an experience, a person comes to see, attach meaning to, and value something in a new way. The arts are explicitly created for this purpose. In Dewey's view their mission is to "reawaken our sensibilities, causing us to see once again what we have come to overlook" (Jackson, 1998, p. 27). The arts are a distortion of ordinary experience, which reveals or amplifies certain aspects and allows us to perceive these aspects once again in ordinary experience.

For example, in a discussion of Dewey's aesthetics and art education, Jackson (1995) describes how Van Gogh's famous painting of a pair of peasant boots deepens our

perception of the boots and subsequently leads us to expand our perception of the ordinary world. He comments,

> Our perception of the weariness and dignity embodied in the artist's depiction of those common objects readies us to look upon the ordinary world (and not just the boots it contains!) in a new way. It encourages us to push beyond surface appearances, to reach down toward a level of meaning that only a steady gaze and calm reflection have the power to reveal (p. 32).

In a similar way, a good drama can transform our perception of other people and ourselves, or a dance performance may transform our perception of the human body and its movements. Further, Dewey felt that the resultant expansion of perception was generative. Jackson (1998) explains, "The centrality of perception in Dewey's theorizing about the arts, and about experience in general, can hardly be overemphasized. Not only must we perceive art objects in order to appreciate their worth, but doing so is at least one means by which we come to better perceive other objects and events, including ourselves and others" (p. 113). This is why Dewey felt that aesthetic experiences with the arts were so important. Such experiences not only broaden our perception of a few isolated objects, but they can infuse our everyday world with new significance. Further, this expansion of perception is closely tied, indeed inseparable from, an expansion of meaning and value. As we come to perceive an object in a new light, we attach new significance and meaning to that object; we appreciate it more, care about it more, and have more of an emotional attachment to it. Jackson (1998) states, "We can only love . . . what we fully perceive" (p. 61). Reciprocally, Dewey (1958/1934) suggests that we can only fully perceive those objects which we care about (p. 256).

In essence, to undergo an experience is to come to see something in a personally meaningful, new way. This act of perceiving is accompanied by a consummation of anticipation, an expression of emotion, and is savored for its own intrinsic worth. Such experiences are fundamentally transformative in that they transform our relationship with the world. Through expanding our perception we come to interact with the world in new way. We see it differently and attach different meaning to it. In so doing, we transform not only the world, but ourselves. Hence, I prefer to refer to such experience as "transformative" experiences. It seems more descriptive and practical than Dewey's term of "an" experience.

The Undergoing of an Idea-based, Transformative Experience

Transformative experience is not confined to the arts. Jackson (1998) makes a distinction between art-centered aesthetic experiences (or just art-centered experiences) and aesthetic experiences in general or naturally occurring aesthetic experiences. When transformative experience takes place in connection with a deliberate work of art, then we have an art-centered experience. When such an experience develops naturally in some other context, we have a naturally occurring aesthetic experience. To these two distinctions, I would like to add a third: idea-based, transformative experiences. An idea-based, transformative experience occurs when a concept functions like an art object to foster a transformative experience. This assertion comes from a reinterpretation of Dewey's construct of an idea in light of his aesthetics.

The construct of an idea became increasing important to Dewey as his career progressed. One has only to compare the origin version of How We Think (1991/1910) to its revised edition (1933) to see that the construct of an idea figures much more

prominently in his later thinking (see also, Prawat, in press). Here, I give an overview of Dewey's use of the term idea. Then I describe how I am extending the construct of an idea to the realm of aesthetics.

Role of Ideas in Dewey's Transactional Philosophy

For Dewey, ideas became the key to developing a theory of learning and development that dissolves the Cartesian dualism between mind and world (Prawat, 1996). Thus to understand Dewey's usage of the term "idea," it helps to situate the term in the context of the development of his non-Cartesian philosophy. From the earliest days of his academic career, Dewey (and pragmatism as a whole) sought to rid philosophy of the Cartesian dualistic thinking that separated mind and world (Russell, 1993). Dewey felt that such thinking lead to numerous other dualisms (for examples, see Prawat, 1996) which were problematic for education (Dewey, 1938; Prawat, 1995). Thus, one of Dewey's primary undertakings was the development of a transactional view of experience which dissolved the separation of mind and world. Dewey's (1896) first major step towards developing a transactional view of experience was the production of a paper titled "The Reflex Arc Concept in Psychology." In this paper, he criticizes the reflex arc concept which presents a mechanistic relationship between stimulus and response (i.e. the stimulus causes the response). He argues that this was a dualistic and simplistic view, one which suggests that sensation (perception of stimulus) is separate from thought and action (response). Dewey argues that we cannot cleanly separate these. Reflex is not an arc where the stimulus causes the response, but rather a circuit where the response also determines the stimulus. For example, suppose we have a candle flame as a stimulus for a child. The significance of this stimulus depends on the child's prior

experience and responses. If the child has reached for the flame and been burned before, the child will likely respond by not reaching for it again. Mounce (1997) in reference to this same candle example states, "This shows that the stimulus derives its significance, derives its status *as* a stimulus, from the way it enters into the child's life" (p. 130). The key point here is that the stimulus-response pattern needs to be seen as an interactive circuit, not a unidirectional and isolated arc.

In later work, Dewey extended the circuit concept to refer to the relationship between a person and the environment. Sleeper (1986) describes Dewey as a transactional realist; meaning that both the person and environment are constantly being transformed as they interact with each other. Sleeper (1986) explains,

> Dewey makes repeated use of his earlier thesis of the reflex arc essay, now viewed in terms of the active involvement of the organism in its environment. He now wants to argue that the behavioral circuit of the organism involves a pattern of interaction in which the physical stimulus operates causally to effect a response that transforms the existential situation in which the organism exists. The organism's involvement with its environment is described as a relation of reciprocal causation or interaction. It is this relation for which Dewey adapted the term transaction in his later years, in order to emphasize its reciprocal causality aspect and to direct attention to its transformational effect on both the organism and the environment (p. 142).

In other words, the circuit now involves an organic interrelation between a person and the environment (physical and social) where the environment transforms the person but the person in turn transforms the environment. By developing this notion of a transaction,

Dewey was able to define experience, not as the property of an individual, but as the evoked response of a person in interaction with his or her environment. Thus Dewey (1938) comments, "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" (p. 39). Further on, he explains,

> An experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment, whether the latter consists of persons with whom he is talking about some topic or event, the subject talked about being also part of the situation; or the toys with which he is playing; the book he is reading (in which his environing conditions at the time may be England or ancient Greece or an imaginary region); or the materials of an experiment he is performing. The environment, in other words, is whatever conditions interact with personal needs, desires, purposes, and capacities to create the experience which is had" (p. 43-44).

Recently, Prawat (1995; 1996; 1997; 1998) has been arguing that Dewey used the construct of an idea as a tool for describing the transactional nature of experience. Particularly, ideas are used to dissolve the notion that knowledge exists in the head and is somehow separated from the world. Prawat (1996) states, "Ideas offer a solution to the mind-world problem because they – at least the way Dewey defined them – can move back and forth across the barrier that separates mind from world" (p. 223). Ideas can move across the barrier separating mind from world – or be "skin-transversable" in

Bentley's (1954) terms – because they are defined by Dewey in the context of having an idea. Let me explain.

To have an idea is to engage in an experience; one that involves anticipation (a savoring of the perceived consequences of the idea), action (a trying out of the idea), and evaluation (an assessment of whether the idea "worked"). Dewey discussed ideas in relation to this process and it is through this process that ideas move back and forth across the barrier separating mind from world. Here is how the process enfolds. Out of a body of socially constructed knowledge, individuals (often working within communities) develop ideas through abduction, which is a perceptual/metaphoric process (see Prawat & Peterson, 1999). These ideas do not need to be original. Abduction is not just a description of how original ideas develop, but also a description of how we come to learn disciplinary concepts such as the sphericity of the earth, to take an example from Dewey (1933). What's critical is that the ideas are held as possibilities, because it is the conditional nature of ideas that defines them as ideas:

> There is a time during our investigation when meaning is only suggested; when we hold it in suspense as a possibility rather than accept it as an actuality. Then the meaning is an *idea*. An idea thus stands midway between assured understanding and mental confusion and bafflement. While meaning is *conditionally* accepted, accepted for use and trial, it is an idea, a supposal. When it is *positively* accepted, some object or event is understood" (Dewey, 1933, p. 132).

It is also the conditional nature of ideas that puts the process of having an idea in motion. Because ideas are possibilities they generate anticipation about the consequences

of the idea. Each idea, according to Dewey (1933) "is anticipatory of some possible future experience" (p. 117); meaning, an idea suggests some courses of action and directions of inquiry and there is anticipation (hope, excitement, and/or curiosity) about what will occur, what will be understood, what will be seen, and what will be discovered. This anticipation then initiates action – a trying out of the idea – and it is through this anticipation and action that the idea moves out of the head and interacts with the world. Dewey (1933) comments, "the idea after it is formed is tested by acting upon it, overtly if possible, otherwise in imagination. The consequences of this action confirm, modify, or refute the idea" (p.104-105). Prawat (1995) adds, "What is overlooked, according to Dewey, is that objects of knowledge talk back, which is to say, they offer up surprises or inconsistencies that are either integrated into the concept (resulting in greater overall coherence) or that result in blockage. In the latter case, the idea is rejected or reworked" (p. 19). Thus, an idea initially transforms a person's perception and interaction with the world. This leads to a transformation of the world, either through physical altering of it or through a transformation of the meanings attached to it (Jackson, 1998). Then, through the interaction between person and world, the idea itself is transformed, which leads to further transformation of the person's perception and interaction with the world. In this way, an "organic" relationship develops between person and world which is mediated by the idea. In this model, ideas never attain a "True" status, but they do go through a verification process before attaining established meaning – or becoming concepts, to use Dewey's (1933) language. I now pause from my rapid sketching of the process of having an idea to discuss the process of verification in more detail, for it is chiefly this process that will lead us back to Dewey's aesthetics.

The Aesthetic Qualities of Ideas

The process of idea verification was central to Dewey's philosophy and pragmatism as a whole. As mentioned above, ideas are tested and testing establishes the organic relation between person and world. But what exactly is this testing process and how are ideas verified? At first, it seems to be synonymous with the hypothesis testing that goes on in empirical research. And indeed, Dewey was influenced by the scientific movement taking place at the turn of the century (Sleeper, 1986). In the revised addition of How We Think, Dewey (1933) describe the testing and verification of ideas in much the same way as we would describe hypothesis testing. However, in other works, the verification process begins to take on a more personal and, I argue, a more aesthetic quality.

Perhaps we can best begin understanding this alternative type of verification by looking at pragmatism as whole. As was mentioned at the beginning of this paper, a key tenant of pragmatism is that the worth of ideas is determined by the difference they make; whether they bring about positive consequences. Dewey developed his own conception of what it means for an idea to "make a difference." For him, an idea makes a positive difference if it transforms our perceptions of the world in a way that renders the world more meaningful: "Ideas are worthless except as they pass into actions which rearrange and reconstruct in some way, be it little or large, the world in which we live" (1988/1929, p. 111). By "rearrange and reconstruct," Dewey means that ideas invest aspects of the world and everyday experience with new value and meaning. Dewey (1958/1929) clarifies this point in the following statement:

> Thus there is here supplied, I think, a first-rate test of the value of any philosophy [or idea] which is offered us: Does it end in conclusions which, when they are referred back to ordinary life-experiences and their predicaments, render them *more significant, more luminous to us, and make our dealings with them more fruitful?* Or does it terminate in rendering things of ordinary experience more opaque than they were before, and in depriving them of having in "reality" even the significance they had previously seemed to have? (p. 7, emphasis added).

Hence, the worth of an idea is tied to what an idea does for an individual (or community) in his or her everyday life. Prawat (1998) adds, "Judgments about the worth of an idea are based on what the idea does for the individual, the extent to which it opens up new experiences for a person as he or she interacts with objects and events in the environment" (p. 204).

What does it mean for there to be an opening up of new experiences and a rendering of ordinary life-experiences "more significant, more luminous to us, and make our dealings with them more fruitful?" Dewey is not clear on this point. However, these qualities of verification seem to closely resemble the qualities of transformative experience. As mentioned, the two most central traits of transformative experience are an attainment of full perception and an expansion of meaning. When we engage in a transformative experience, we come to see some aspect of the world more fully and we attach new meanings to those aspects of the world. An idea, or more correctly a worthwhile idea, is one that allows us to see and experience (rearrange and reconstruct) aspects of the world in a new, meaningful (more significant, more luminous, more fruitful) way.

Evidence that ideas can bring about an expansion of perception, meaning, and value in much the same way that art does comes from the accounts of scientists who have written about their own experiences. For instance, Bentley Glass (1962) explains that science contributes not only to our understanding of order, but to our understanding of beauty and meaning. He explains that anyone can have an intuitive appreciation and "take delight in the green of the wood." However, scientific understanding of leaf structure, photosynthesis, and ecological interdependence of living things allows for a deeper appreciation which "detracts not all from intuitive appreciation while it adds immeasurably to it" (p. 222). A similar account comes from Richard Feynman. He (1989) comments,

> I have a friend who's an artist, and he sometimes takes a view which I don't agree with. He'll hold up a flower and say, "Look how beautiful it is," and I'll agree. But then he'll say, "I, as an artist, can see how beautiful a flower is. But you, as a scientist, take it all apart and it becomes dull." I think he's kind of nutty . . . There are all kinds of interesting questions that come from a knowledge of science, which only adds to the excitement and mystery of a flower. It only adds. (p. 11)

Thus it appears that the process of engaging with a scientific idea is in many ways similar to engaging in a transformative experience. Dewey himself never described transformative experience (an experience) in relation to idea verification, however it is my opinion that making this connection will provide us with an enriched understanding of both ideas and transformative experience.

Here I reconceptualize what it means to have an idea in light of transformative experience – or I could just as easily say that I reconceptualize what it means to have a transformative experience in light of ideas. To review quickly, transformative experience occurs when some art object or performance interacts with an individual in such a way that there results an expansion of perception and meaning. This experience has a completeness, a uniqueness, and a unifying emotion, and it is intrinsically valued. I propose that scientific concepts can also interact with the individual in such a way that there results an expansion of perception and meaning. And this experience also has a completeness, a uniqueness, and a unifying emotion, and it is intrinsically valued. When a concept functions in this manner, it becomes an idea in the Deweyan sense and the experience of having this idea is what I call an idea-based, transformative experience.

First of all, the unifying emotion of such experience is connected to the anticipation generated by the idea. In a drama, anticipation is the force that drives the plot forward, that forges a connection between past and future events. Similarly, anticipation is the force that moves an idea-based, transformative experience forward and establishes a unity between different phases of the experience. One anticipates what will revealed, appreciated, understood, explained, or experienced by putting the idea into action (i.e., an expansion of perception, meaning, and value is anticipated and savored). Anticipation moves the experience toward consummation by bringing about the test of the idea; the individual is moved to see the world through the lens of the idea. When the idea does provide a meaningful, new way of seeing the world, when it does illuminate some object, event, or issue, when it does create an expansion of perception and meaning, then the anticipation comes to a fulfillment and the experience reaches a consummation.

It is this build up and consummation of anticipation that gives the experience its completeness or wholeness. It also gives the experience a uniqueness that sets it apart from other experiences. Finally, the experience is valued for its immediate intrinsic meaning; for the expansion of meaning and value that occurs. An idea-based, transformative experience may also have utility value, but it will be valued at least partially for the immediate expansion of meaning and value.

Once again, evidence for this point comes from the accounts of scientists. For instance, Dawkins (1998) comments, "Of course science pays its way; of course it is useful. But that is not all it is" (p. 6). He later explains this point with an example, "I can think of very few science books I've read that I've called useful. What they've been is wonderful. They've actually made me feel that the world around me is a much fuller, much more wonderful, much more awesome place than I ever realized it was" (p. 37). Dawkins clearly felt the science books and the concepts in them had a usefulness, but he primarily valued them for the expansion of perception and meaning they brought about.

Summary

Dewey (1933) comments, "The fact is that an idea, intellectually, cannot be defined by its structure, but only by its function and use. Whatever in a doubtful situation or undecided issue helps us to form a judgment and to bring inference to a conclusion by means of anticipating a possible solution is an idea, and nothing else is" (p. 136). After completing his work on aesthetics, Dewey could have rewritten the statement as follows: "The fact is that an idea, intellectually, cannot be defined by its structure, but only by its function and use. Whatever leads to a fuller perception and an expansion of meaning and value is an idea, and nothing else is." This statement is similar to the original, but is a

step away from Dewey's earlier focus on problem solving and a step closer (I believe) to his aesthetics.

Illustrative Examples

In the previous section, I described the theoretical processes and qualities involved in an idea-based, transformative experience. In this section, I offer a more concrete picture of an idea-based, transformative experience by providing descriptions of what I consider to be three genuine transformative experiences with science ideas. Each of these accounts vary greatly in terms of the context, the individual undergoing the experience, the nature of the idea, and the degree to which the account is personal and introspective or empirical and scientific. Hence each account provides a unique perspective on an idea-based, transformative experience.

Arches Re-seen

The first example of an idea-based, transformative experience is a personal account of my own experience with some geological principles. In college, I had the privilege of taking a geology course from a professor who was alive with the ideas of geology. He loved geology and in class he often shared his experiences of seeing the earth in terms of geology. The accounts of his experiences were always filled with enthusiasm and were quite contagious. Soon I began anticipating having the type of experiences that my professor had. I wanted to read the stories hidden in the rocks as he did. I remember one moment when this desire was fulfilled in a most profound way for me. I was driving through Arches National Park in Utah – a place that I was quite familiar with. I spend many of my childhood and teenage days exploring the array of sandstone structures in Arches. But this day, as I drove my car to the top of a rise that

overlooks a large expanse of the park, I saw the land as I had never seen it before. I now saw the band of rock before me as a massive layer of sandstone laid down millions of years ago by a sea which moved in and out of the area. I saw how two different areas of rock, one to the east and one to the west, were part of a single rock bed that had been bowed upward into a hump and then the center had collapsed back in. I saw how all the fins (parallel rows of rock walls) making up the Fiery Furnace were the result of the rock cracking as it was being bent. And I now knew that it was out of these fins, that the arches developed. I saw the area as it is, as it was millions of years ago, and as it would be millions of years from now. It was fascinating. And it was profoundly moving. At that moment, I gained a much greater appreciation for and emotional connection to the park. Before this experience, I had begun to lose much of my interest in the park. I was disenchanted by all the people that now visited the park, all the tour busses, the lines to get in, and so on. It began to lose its sense of wildness, mystery, and adventure that so captivated me as a youth. But now that I could perceive the area through a geological lens, it all became new, fascinating, and intriguing. I was once again an explorer in a mysterious land. Only now instead of exploring what paths I could find through the rocks, I was exploring what stories I could find hidden in the rocks. My new experience, my expansion of perception and meaning, was all made possible by a few simple geological ideas. Whereas my previous aesthetic experiences in Arches were, what Dewey would term "naturally occurring," this aesthetic experience was idea-based.

Dat an Exploding Volcano!

The second example comes from observing my daughter who was three at the time. When I first began studying Dewey and developing an understanding of what I

later came to call idea-based, transformative experiences, I was struck by the degree that my daughter and other young children displayed the qualities of such experiences – particularly the qualities of expansion of perception and value. I do not know if it is because young children are more open and expressive, or because the world is so new to them, but they seem to be more susceptible to such experiences. For instance, my daughter was into learning about space objects. But she did not just learn about them, she liked to see and experience her world in terms of space objects. For example, she liked to be Saturn who would run around "orbiting" the table with her stuffed cat who was her moon Titan. So I decided to do a more formal observation of her experience by teaching her about volcanoes and observing the consequences (see Pugh, 1998). My wife and I played a role in constructing her experience because we at times pointed how things like a shaken up bottle of pop resembled a volcano. What emerged from this interaction was a transformative experience with a very simple idea: the idea that certain objects and events can be seen as lava and eruptions.

During the course of the observation (which lasted about a month) my daughter began perceiving her world in terms of lava and eruption and she found this to be very meaningful way of seeing the world. For instance, she once commented, "Sometimes my hair goes wild like lava. Sometimes it goes flying up like lava." Another time, my wife was attempting to chop nuts in the blender, but whenever she turned the blender on, the nuts would go flying all over the place. After a few attempts, my daughter looked over and said, "Dat an exploding volcano." A few days later, McKinley began seeing herself in terms of volcanoes and lava. After I read an earth book with her, she started running around her room, pretending she was lava, saying things like, "I'm so big I just want to

get out [of the earth]. I get out and burn down a house." She also began to compare a lot viscous liquids to lava. For instance, one evening she was helping her mom make zucchini bread. When they poured oil into the mixture, she said it was like lava because it's runny. When they next added honey, they compared it to lava as well. The next morning we had pancakes for breakfast and she started talking about how she was pouring lava on her pancakes.

Finally, toward the end of the study, my daughter dropped a cup of milk on the floor. Now, she is not a child that handles mishaps well. She is either blessed or cursed with high intensity emotions, and as a result, she ran around the kitchen screaming, "Mommy! I need a cup of milk! Mommy!" But miraculously, just as suddenly as she exploded, she calmed right down. A transformation came over her face as she stopped yelling and looked down at the cup lying on the ground. Then she looked over at me and asked, "Did the bubbles get bigger and bigger until it exploded?" I immediately recognized that she was thinking back to a discussion we had about the shaken up pop bottle. She was now using this idea of bubbles getting bigger to see the event of spilled milk in a new (and thankfully for us, meaningful) way.

Overall, my daughter found that seeing and experiencing the world in terms of lava and volcanoes was very fulfilling. She often became very animated when she was able to see something in this way, and once she even commented, "I wish I could read about and learn about lava all the time. I wish I could go to your school and learn about the earth."

Inertia and a Niece in Motion

The third example of an idea-based, transformative experience is taken from a recent study of mine (see Pugh, 1999). In this study, I taught a physics unit in a 7th grade general science class and assessed the degree to which students became engaged with and had experiences with the physics ideas (inertia and Newton's laws). The students' engagement and experiences varied, but one student typified an idea-based experience. I'll call this student Ed. Ed clearly underwent an expansion of perception and value. In a discussion of why he found the physics ideas worth learning, Ed described how the ideas were expanding his perception: "I can look at, like, when two cars crash into each other, I can look at that in a different way, and when I watch a movie I can look at that in a different way. Now I'm going to see things that I'm used to seeing in a different way." As examples of how the ideas changed the way he saw things, Ed described numerous instances where he saw ordinary events through the lens of physics ideas. For instance, Ed said he thought about inertia when he saw his niece slide across the recently mopped kitchen floor. Ed stated that the event, "Made me think of inertia because she's running and running and running and she tries to stop and she just keeps going until the door, until the door acts on her." Similarly, Ed thought about inertia when driving with his grandma: "I asked her questions to find out what she thought of, why she thought you slide to the [side of the] car. Then we kept talking about it 'til we got to Sears. . . She thought the answer to the thing was gravity, then I explained the thing until we got to Sears." In addition, Ed thought about force pairs when watching a scene in The Man in the Iron Mask where a man tries to hang himself but has the whole barn collapse on him. He also thought about force pairs while watching a Bill Ney the Science Guy program

with bikes. He thought about how the tire pushing backward on the road makes the bike move forward. He thought that was pretty neat. Finally, Ed's perception of jumping was also transformed: "[The teacher] had a question like 'How can Michael Jordan jump as high as he can?' And it made me think about stuff like that in a different way. . . Now I think about jumping and stuff like that as force pairs."

Moreover, Ed didn't simply see the world in a new way – he found this to be a very meaningful way of seeing the world. As evidence that Ed valued this way of seeing, Ed (like a new convert) often tried to share his new way of seeing with others. For example, he talked with his parents about Newton's Laws and he tried to explain inertia to his grandmother. He also explained inertia to his uncle and showed how inertia could be used to explain his daughters crash. And, much to Ed's delight, his uncle took interest in Ed's explanation and later relayed it to his wife. Ed also made some direct comments which indicate that he came to value the physics ideas and find them fascinating precisely because they allowed him to see ordinary objects or events in a new way. In reference to the physics ideas, Ed commented, "I think they're kind of fascinating. . . [They] made me think about things I hadn't thought about before, like why you slide when the car takes a turn. And why water stays in the bottom of the bucket when you spin it around. . . Made me think about stuff that I'm not used to thinking about in that way." Thus, Ed expanded his perception of the world in learning the physics ideas, and he attached new meaning to both ordinary events and the physics ideas themselves as his perception expanded.

Ed's experience contrasted with the experiences of other students in the class. For instance, one student learned the content and actually enjoyed the class a lot. However, when asked if she cared about the content taught, she replied, "Not really. It's not like a

big thing, Newton's laws. It's not so much that it was boring, because it wasn't. It was actually kind of exciting [the class], but it's just that I don't sit there and think about it." She also reported that she did not apply the concepts at all to her life. So for her, learning the concepts did not make much of a difference in her life – it did not lead to any transformative experiences.

Summary

Although each of these examples is quite different, they all share the commonality that an idea (be it simple or more complex) allowed an individual to more fully perceive aspects of the world, such as rocks, a spilled cup of milk, or a drive to Sears. Moreover, each individual found significant meaning and value in this new way of perceiving. In my own personal example, I'm able to identify the dramatic qualities of an idea-based, transformative experience, such as the anticipation, the consummation that came as I was able to read the stories in the rock, and the uniqueness (the experience still stands out in my memory). It is likely that these qualities were also present in the other experiences, but this can only be inferred.

Implications

In terms of educational practice, the construct of an idea-based, transformative experience offers a different desired outcome or goal for science education. Here, I clarify the uniqueness of idea-based, transformative experience as an outcome by contrasting it with two of the most important outcomes in science education today: conceptual understanding/change and the development of thinking/participatory skills. The conceptual change perspective (Posner, Strike, Hewson & Gertzog; 1982; West & Pines, 1985; Strike & Posner, 1992; Dole & Sinatra, 1998) is perhaps the dominant

perspective in science education, and the outcome that it focuses on is the degree to which students develop more sophisticated conceptual understandings of scientific concepts. Other perspectives, such as the constructivist perspective (see Tobin, 1993), also focus on conceptual understanding as a central outcome. Conceptual understanding is simply a logical outcome to focus on. Obviously, we want our science students to acquire (or construct) knowledge of scientific concepts and we would rather have them develop a deep, meaningful understanding than memorize a bunch of facts and definitions.

The construct of an idea-based, transformative experience does not oppose this goal, but rather extends it. It states that, not only should we help students develop conceptual understandings, but we should also help them to have enriching, transformative experiences with their conceptual understandings. Another way of clarifying the difference, is that instead of focusing exclusively on students' conceptual understanding "in the head," an idea-based, transformative experience perspective focuses on the individual's (or group's) relationship with the world and how that relationship is mediated by the conceptual understandings. For instance, it does not focus exclusively on students' level of conceptual understanding of the principle of inertia, but on how this conceptual understanding mediates the students' interactions with objects and events in the world, as was shown above in the case of Ed. In this way, an idea-based, transformative experience perspective is similar to the phenomenographic perspective on science education presented by Marton (1986). Marton explains that instead of focusing on conceptual understanding itself, as most investigations of concepts do, the phenomenographic perspective takes "man-world relations as the subject matter"

(p. 31) and considers how concepts mediate that relationship. The difference between the phenomenographic and idea-based, transformative experience perspective is that the latter pre-identifies a particular person-world relationship (namely a transformative experience) and considers the mediational role that concepts play in bring about this particular relationship. To conclude, conceptual understanding obviously plays a central role in an idea-based, transformative experience and hence it is important as a means – but I don't think it should be the primary end of science education.

Other perspectives on science education focus relatively more on the development of various thinking or participatory abilities. For instance, many science educators have advocated the development of inquiry or scientific thinking skills (Zuckerman, Chudinova & Khavkin, 1998; Kuhn, Schauble & Garcia-Mila, 1992; Kuhn, 1993; 1989; Schauble, Klopfer & Raghavan, 1991; Schauble, 1990; Duckworth, 1987), scientific discourse (Herrenkohl & Guerra, 1998; Scott, 1998; Crawford & Kelly, 1997; Lemke, 1990), and participation in scientific communities (McGinn & Roth, 1999; Richmond, 1999; 1998; Roth, 1993). Overall, these educators emphasize the importance of getting students to engage in doing authentic scientific activity (such as conducting scientific experiments or participating in scientific, discourse communities), because presumably it is through such participation that the various skills are developed (Piaget, 1977; Bruner, 1960; Lave & Wenger, 1991; Vygotsky, 1978). An idea-based, transformative experience perspective acknowledges the importance of these outcomes, but changes the focus somewhat. Instead of the focus being on getting students to engage in <u>doing science as scientists do it</u>, the focus is on getting students to <u>engage with scientific concepts as scientists do</u>. This does not mean that students need to engage with scientific

concepts at the same intellectual level as scientists. Rather, it means that students should engage with the concepts as idea (i.e., as exciting possibilities for experiencing and making sense of the world) like scientists do. They should have experiences of using science concepts to expand their perception and meaning like the experiences described in the accounts of the scientists presented earlier.

Both the processes of engaging students in doing what scientists do and experiencing scientific concepts as scientists experience them are important – and likely related. However, I think the latter has been far more neglected in science education research and theory. The construct of an idea-based, transformative experience makes this latter process more salient and, hopefully, more important to science educators.

Future Directions

As the construct of an idea-based, transformative experience is a new one, there is a broad range of future research directions. An important theoretical issue that needs to be addressed, is the issue of control and agency in a transformative experience. At first, Dewey's model of an idea seems to emphasize the individual as the agent of action. In Dewey's model, the interaction between the individual and a concept awakens anticipation and this anticipation leads to deliberate action. The individual consciously seeks out opportunities to try out the concept (now an idea) and use it to see and experience the world differently. For example, when I went to Arches, I went there with the purpose of seeing and experiencing the world differently. I anticipated seeing Arches through the lens of geological concepts well in advance. However, in other cases, conscious anticipation and deliberate action on the part of the individual may be less central in instigating an idea-based, transformative experience. Instead, some

affordances in the environment seem to trigger the use of an idea as lens. For instance, in the case of my daughter's experience and Ed's experience, a salient affordance, such as a spilled cup of milk or a niece sliding across the floor, seemed to trigger the use of the idea and the engagement in a transformative experience. They likely did not consciously choose to see those events through the lens of volcanoes and inertia respectively, rather they did so automatically. Hence, conscious anticipation and deliberate action may not be as central to engagement in an idea as Dewey suggests. More agency may have to be attributed to the affordances in the environment.

However, the is another way to consider the issue. This is to attribute agency to the idea itself. In other words, it is the idea that instigates the action and experience. This may seem like a strange place to put the agency, but it is one Dewey may have intended. For instance, he (1933) comments, "There is no mistake more common in schools than ignoring the self-propelling power of an idea. Once it is aroused, an alert mind literally races with it. Of itself it carries the student into new fields; it branches out into new ideas as a plant sends forth new shoots" (p. 269). Elsewhere he states, "A central idea moves of its own accord to application; it seeks opportunities for operation in use to bring other facts into line" (p. 273). In is important that Dewey uses the qualifier "once aroused." Clearly, a particular concept will not simply lead all students to action and application. Rather, an individual interacts with a concept in such a way that an idea immerges (a compelling possibility). But once this idea immerges it becomes an agent for action. In a sense, we get swept away by the idea and we "can't help" but see and interact with the world in a new way.

This discussion leaves us with the question of where the agency is in an idea-based, transformative experience. Is it primarily in the individual, the affordances in the environment, the idea itself, or some combination/interaction of these? Future work needs to clarify this issue.

In addition, to this work, we also need to research the individual characteristics that contribute to or inhibit engagement in such experiences. For instance, what role might identity, self-concept, prior knowledge, or gender play? We also need to research the types of learning environments that contribute to or hinder participation in idea-based, transformative experiences. We need to identify and describe those teachers or teaching environments which may already be effective at fostering such experiences. In addition, we need to hypothesize about possible teaching methods that will be effective and try these methods out.

One of the difficulties that will have to be faced in trying to accomplish these lines of research is the development of appropriate instruments or techniques for assessing transformative experience. This is no easy task, because it requires that we not only pay attention to what happens in the classroom, but to what happens in students' everyday experience. It also requires that we not only pay attention to cognitive and behavioral process, but to affective process such as meaning and value as well. The difficulties of assessing transformative experience, sheds light on why this type of outcome has not been extensively pursued in empirical research.

In conclusion, this paper argues that we should follow the spirit of pragmatism and pay more attention to the difference that science concepts make in the lives of students. We should pay attention to how (or if) science concepts enrich students'

everyday experience. The construct of an idea-based, transformative experience defines what it means for a science concept to lead to an enriching experience and specifies the application of pragmatism, particularly Dewey's aesthetics, to science education. Hopefully this work will be helpful in considering the difference that science concepts make in the lives of our students.

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SECTION 2

TEACHING FOR IDEA-BASED, TRANSFORMATIVE EXPERIENCES IN SCIENCE

Abstract

This study examines the effectiveness of two related teaching elements (the artistic crafting of content, and the modeling and scaffolding of perception and value) at fostering idea-based, transformative experiences. The construct of an idea-based, transformative experience was derived from Dewey's work and is defined by an expansion of perception, meaning, and value which results from active use of a concept. The elements were used in teaching a unit on adaptation and evolution in a high school zoology class. Student outcomes were compared with those of students in a roughly equivalent (as determined by a pre-intervention survey) class in which the same unit was taught using a case-based model. Results indicate that a significantly greater percentage of students in the experimental class (52.9 %) than students in the control class (22.7%) engaged in some degree of idea-based, transformative experience. Further it was found that students who engaged in at least some form of idea-based, transformative experience scored significantly higher than other students on a follow-up assessment of understanding – suggesting a relationship between the undergoing of an idea-based, transformative experience and enduring conceptual understanding.

Introduction

"Science education should enrich the quality of students' everyday experience." "Science classes should make a difference in students' lives." Statements to this effect are often uttered by science teachers, science educators, parents – even students. And they are statements I wholeheartedly believe in. These statements reflect particular attitudes about what the goal of science education should be. Science education should enrich, expand, and enlighten the experiences that students have in the world – both during and after class. I surmise that most people would agree that this is at least one of the important goals for science education. Thus I find it somewhat surprising, and unfortunate, that we know little about the effectiveness of science education at achieving this goal. Science education researchers have not carefully examined such important questions as: Can or does the acquisition of scientific concepts enrich the quality of students' experience? If so, how? What does it mean to have an "enriched" experience in connection to science learning? What teaching methods foster the undergoing of enriched experiences? In this study I begin to answer these questions by first defining what it means for a scientific concept to bring about an "enriched" experience in the life of a student, and then by examining the effectiveness of some teaching elements at fostering such experiences.

Elsewhere (Pugh, under review) I argue that the field of science education has focused more on how enriching experiences can foster the acquisition of scientific concepts and less on how the acquisition of scientific concepts can foster enriched experiences. One of the difficulties of accomplishing the latter is that we lack a rich conception of what an "enriched" experience is. How would one recognize when a

science concept led to an enriched experience? What would such an experience look like? What would its defining qualities be? My colleagues and I have sought to answer these questions by re-examining the work of John Dewey. Why Dewey? First of all, Dewey was one the foremost pragmatists and as a whole, pragmatism is concerned with the consequences that concepts or proposition have on experience (Cherryholmes, 1999). Dewey in particular was deeply concerned with conceptualizing the nature of experience and in fleshing out the relationships between experience and leaning or education as a whole. He argued that experience should not only be the means of education, but the outcome of education (see Dewey, 1938) and he theorized about the way in which concepts may lead to certain types of experiences (Dewey, 1933). Second, in his work on aesthetics, Dewey displayed a specific interest in conceptualizing what might be called "enriched," "meaningful," or even "optimal" experience. This work is foundational to developing a current conception of what an enriched experience in science may be. Unfortunately, these aspects of his work have been underappreciated, and as a result, their potential to provide us with an understanding of what it means for concepts to engage students in particularly meaningful experiences has not been realized. My colleagues and I have attempted to develop this unrealized potential in various writings (Wong, Packard, Girod & Pugh, in press; Wong, Pugh & Dewey Ideas Group, 2000; Girod, 2000; Prawat, 1999; 1998; 1995; Pugh, 1999a; 1999b). Here I summarize this work.

The Construct of Idea-based, Transformative Experience

In his writings on aesthetics, Dewey (1958/1934) develops a construct of a particularly meaningful type of experience – what he refers to as an experience. Jackson (1998) comments,

> Our interactions with art objects epitomize what it means to undergo an experience, a term with a very special meaning for Dewey. The arts do more than provide us with fleeting moments of elation and delight. They expand our horizons. They contribute meaning and value to future experience. They modify our ways of perceiving the world, thus leaving us and the world itself irrevocably changed. (p. 33)

The arts provide us with special experiences that are in some ways more significant, more meaningful, and more human than ordinary experience. Such experiences often involve dramatic qualities such as anticipation, salient emotion, unity, uniqueness, and consummation (Dewey, 1958/1934; Pugh, 1999a). However, even more significant are the consequences that they have on our future experience. Such experiences are fundamentally transformative in that they transform our perceptions of the world and the meaning and value we attach to the world.

For instance, an individual's encounter with a Monet painting may involve various dramatic qualities. But the real defining feature of an experience (what I prefer to term transformative experience) is that it transforms the individual's future experience and interactions with the world. The individual may be so moved by Monet's renderings of the world, that she goes out and sees the world through his eyes – she sees a celebration of light within shadows and a brilliance of color within grays. In a word, she

is compelled to act; to see the world anew. And by doing so, her perception and valuing of the world is expanded. She sees shadows and grays more deeply and, at least for a time, attaches greater value to them.

Transformative experiences are not confined to the arts, and I (Pugh, 1999a) have argued that educational concepts can play a special role in engaging individuals in transformative experiences just as art objects do. Every concept is a potential idea (Wong et. al., 2000), and ideas are fundamentally about transforming our perception of the world. As Dewey (1933) defined them, ideas are possibilities (as opposed to concepts which are established meanings) and as such they can awaken anticipation which leads us to act on the world. Ideas which fail to do this are worthless according to Dewey. He (1988/1929) states, "Ideas are worthless except as they pass into actions which rearrange and reconstruct in some way, be it little or large, the world in which we live" (p. 111). When we act on the ideas, we use them as lenses for viewing the world. Ideally, these ideas then expand our perception by illuminating various aspects of the world (objects, events, issues, other people—even ourselves). And with this expansion of perception comes an expansion of meaning and value. We come to attach more significance, affection, interest, emotion, etc. to those aspects of the world that are illuminated by the ideas. And consequently, we also attach more value to the ideas themselves.

In essence, ideas (like art objects) can lead to transformative experiences, what I call "idea-based," transformative experiences. In fact, Dewey felt that the test of ideas was the degree to which they did transform our ordinary experience in meaningful ways. In talking about how we may judge the value of any philosophy (or idea), Dewey (1958/1929) asks, "Does it end in conclusions which, when they are referred back to

ordinary life-experiences and their predicaments, render them more significant, more luminous to us, and make our dealings with them more fruitful?" (p. 7). In interpreting Dewey, Prawat (1998) adds, "Judgments about the worth of an idea are based on what the idea does for the individual, the extent to which it opens up new experiences for a person as he or she interacts with objects and events in the environment" (p. 204).

To summarize much of what has been said, an idea-based, transformative experience may be defined by three principle qualities: 1) active use of the idea, 2) an expansion of perception, and 3) an expansion of value. As stated above, ideas are possibilities which awaken anticipation and engender action. Active use means the individual seeks out or takes advantage of opportunities to use the idea as a lens for more fully perceiving the world. I contrast active use with non-active use. Non-active use occurs when individuals are highly coerced into using the idea. For instance, using the idea of inertia to answer a question on a physics test would be an example of non-active use. On the other hand, spontaneously using the idea of inertia to try to understand why your stomach is rising and dropping on a roller coaster ride is an example of active use. Active use of any idea (that proves to be personally worthwhile) brings about the other two qualities (an expansion of perception and value), as was explained above. Basically, individuals undergo idea-based, transformative experiences when they actively use an idea, find that it allows them to see aspects of the world in a new way, come to value this way of seeing, and, as a consequence, attach more value to the idea itself.

Teaching for Idea-based, Transformative Experience

Dewey's description of transformative experiences is not so much an account of what actually happens in education as it is a description of educational possibilities – of

the meaningful experiences students can have as a result of their interactions with ideas. My colleagues and I have found that such experiences do happen in science classrooms and we have provided illustrative descriptions of such experiences (Pugh, 1999b; under review; Girod, 2000). However, questions remain about whether such experiences can be fostered and what teaching methods are effective at fostering them. Wong et. al. (2000) state that there may be diverse ways to foster such experience and offer some general metaphors for teaching for transformative experience. Here I propose some more specific elements that might be important in teaching for transformative experience (see also Pugh, 1999a). The first of these, I refer to as the artistic crafting of content. Dewey (Dewey, 1958/1934) believed that the arts were particularly effective at engaging individuals in transformative experiences, because artists carefully craft together elements of ordinary material (paint, marble, language, etc.) in such a way that they have the potential to awaken anticipation, engender action, and transform perception. In Dewey's language, artists convert ordinary materials into eloquent media. By analogy, we may hypothesize that teachers can engage students in transformative experience through a similar process of crafting ordinary materials. However, in the teachers' case, the material is not paint or stone, but content. The teachers' task is to craft ordinary (and uninspiring) concepts into powerful ideas that have the potential to instigate action, transform perception, and expand value. This distinction between concept and idea needs to be clarified.

Dewey (1933) makes a clear distinction between concepts and ideas. Concepts are established meanings whereas ideas are conditionally held meanings; possibilities which inspire anticipation, action, and emotion. Many of the seemingly mundane science

concepts taught today were once powerful ideas. For instance, the view of the sun as the center of the solar system was once a powerful idea to the contemporaries of Copernicus. It instigated action in astronomers and theologians alike and it transformed their perception and value, not only of the heavenly orbs, but also of God's plan and man's place in the order of the universe. However, in most science classrooms today, the power of this idea to inspire action and transform perception and value is largely lost. The idea has become a standardized concept to be learned and understood (Wong et. al., 2000).

Thus, one of the central tasks of teaching for transformative experience is to re-animate concepts; craft them into ideas. It may be that some concepts are so common place now that they cannot be fully re-animated. However, for a concept to be re-animated, it does not have to be made into a possibility in terms of whether it is true or false. It can be a possibility in terms of what it may do for the individual – what thoughts it may foster, what objects it may illuminate, what issues it may explain, and what experiences it may create. The job of the teacher is to identify the significant elements of a concept. Why is the concept important? What anticipation might it foster? What can the concept explain, reveal, or illuminate? What experiences can it create for students? And then focus instruction around these elements. In this way, the teacher can craft an idea out of a concept as an artist crafts a sculpture out of rock.

The second element of teaching for transformative experience involves an apprenticeship approach. Sociocultural approaches, which take participation as the outcome, often appeal to the apprenticeship as a general model of instruction (see Brown, Collins and Duguid, 1989). In the apprenticeship model, the goal is to create a particular learning or discourse community and help students come to participate more centrally in

that community. Teaching for transformative experience would take a similar approach. However, instead of the focus being on participation in cultural communities and practices, the focus is on participation in particular experiences (which could be considered a form of cultural practice). Hence, the goal is to create a context where particular ways of experiencing the world through concepts are displayed and valued, and to help students come to participate in these experiences.

Potentially, this can be accomplished through the specific modeling and scaffolding of use, perception, and value on the part of the teacher. In other words, the teacher would model how he or she uses the concept to more fully perceive the world and would also model the increased valuing of aspects of the world and the concept itself, which arises as a result of using the concept (i.e., the teacher would display how the concept functions as a true idea for him or her). The teacher would also provide scaffolded support to help students do the same. Scaffolding would involve providing in-class, supported opportunities for students to use the concept to expand perception and value. It would also involve providing support for student use of the concept in their everyday lives. This may be accomplished by doing such things as letting the class discuss how, when, or where they could use the concept, and by letting them share examples of how they are using the concept to expand their perception and their valuing. The goal is to help students move from having in-class, supported experiences with the concept, to having out-of-class transformative experiences. In other words, to help them engage with the concept as an idea.

The purpose of this study is to determine the effectiveness of these elements at fostering idea-based, transformative experiences. This goal was pursued by

implementing the elements in a high school science class and assessing students in terms of the degree to which they underwent such experiences. To help ground the results, student outcomes were also compared with the outcomes of students in another class. The latter students were taught the same content using different, but "good," methods. Hence, the research questions are 1) how effective are the stated elements of teaching for transformative experience at fostering idea-based, transformative experience? and 2) are they more effective than the alternative "good" methods?

Methods

Context

This study took place in a large, suburban high school in the Midwest. It involved two zoology classes. The zoology course is a semester long course which students may take after first completing a semester long general biology course. Prior to the intervention, both classes had been taught by a veteran teacher who de-emphasized vocabulary and facts and focused on the development of conceptual understanding and inquiry skills. The main classroom activities were lab work (usually done in groups) and class discussion, however lectures were included on a regular basis. The teacher organized the zoology class around a series of veterinarian case studies. The intervention was introduced about a month and a half into the semester. Hence the students were accustomed to participating in a progressive type of school context which emphasized student involvement, understanding, inquiry, and real world application.

Intervention

One of the zoology classes was randomly chosen as the experimental condition. This class had a total of 20 students. However, two students were not included in the

study because they were special education inclusion students and a third student chose not to participate. Of the remaining 17, 53% were females, 6% were minorities, and the mean grade level was 10.1. The comparison class had a total of 24 students, however two students chose not to participate in the study. Of the remain 22, 45% were females, 5% were minorities, and the mean grade level was 10.3. The author taught a unit on adaptation and evolution in both classes during the intervention period, which lasted two and a half weeks.

Comparison of the two teaching approaches. The experimental condition consisted of implementing the elements of teaching for idea-based, transformative experience. The comparison condition consisted of implementing a case-based approach, similar to the instructional method used by the regular classroom teacher. I will hereafter refer to the experimental condition as the idea-based class and the comparison condition as the case-based class. Below I describe the central similarities and differences between the approaches.

Both approaches may be considered progressive in that they emphasize student activity in the form of class discussion and engagement in group projects and lab activities. In fact, a few of the same lab activities were used in both classes. However, the structuring and contextualizing of the activities differed, as will be explained. Also, both approaches could be considered apprenticeship type models of instruction. Both involve modeling and scaffolding, but the specific nature of this modeling and scaffolding differs, as will be explained. Also, the structuring of the content differs. In the idea-based class, the content was organized around an artistic crafting of content – around an attempt to present the significance of the concepts and their ability to transform

perception and valuing of aspects of the world. This could be done in many ways. Below I describe how attempts were made to artistically craft the concept of adaptation and I describe the specific type of modeling and scaffolding used.

Instruction began with the viewing of some home videos of wild animals (some deer, a moose, a grizzly bear, some cutthroat trout). Students were allowed to share their own thoughts about animals, including what animals they found interesting. I then presented the concept of adaptation as a scientific lens which allows us to see, appreciate, and understand animals in a whole new way. I explained that every animal (even the most ordinary pet) is an amazing creation that is intricately designed to survive and thrive in a particular environment. I explained that an understanding of adaptation allows us to appreciate animals for the amazing creations that they are. My goal here was to awaken students' anticipation about how the concept of adaptation could allow students to see animals in an exciting, new way. I wanted students to be alive with the idea (i.e, the possibility) of seeing and appreciating animals for their adaptations. In addition, I concluded that the relationship between form, function, and environment was the core essence of the concept of adaptation that allows one to see animals differently. So I emphasized this aspect of the concept and used the students' shoes as a metaphor for discussing the relationship between form, function, and environment.

The subsequent week of instruction on adaptation centered around the goal of seeing and appreciating animals through the lens of adaptation. This instruction involved deliberate modeling and scaffolding of expansion of perception and value. In terms of modeling, I often talked about how I perceived animals in terms of their adaptations. And I talked about how understanding their adaptation made these animals so much more

interesting to me. For instance, I expressed my fascination at being able to see a polar bear as a walking greenhouse. At times I also talked about my current experiences of seeing or thinking about adaptations in my everyday life (e.g., "While driving here, I passed a bunch of Canadian Geese and I began to wonder, 'Why do they have a black head and white neck? What's the adaptive purpose?'"). In terms of scaffolding, I first engaged the students in a discussion of how to see animals in terms of adaptations and guided them in their initial attempts. Then I provided more in class opportunities where the students could take a more central role in seeing and valuing adaptations. The students discussed various animals and their adaptations and did a lab where they worked in groups to describe the adaptations of various animal artifacts (shark jaws, wolf pelt, fox skull, deer hoof, and others). Finally, I provided opportunities for the students to write about and then share their own out-of-class, everyday experiences of seeing and thinking about adaptations.

In the case-based class, content was structured around a case-study: endangered species. The class was divided into groups, with each group representing researchers from a different continent. The groups were told that the endangerment of species was a world wide problem and that each group was to do the following: 1) identify some important species that were becoming endangered on their continent, 2) explain why they were becoming endangered, 3) explain what could be done about it, and 4) present their findings to the rest of the class. Groups were given materials and class time over a few days to conduct their research. After the groups presented their findings, the class engaged in a general discussion of what types of animals were becoming endangered and why. This discussion led to a discussion of the relationship between animals and their

environment—which is essentially the concept of adaptation. Subsequent instruction involved a more formal discussion of how to recognize various adaptations and completion of the animal artifact lab. This instruction did involve modeling and scaffolding of how to do scientific inquiry, however it did not involve specific modeling and scaffolding of expansion of perception and value.

The teaching of evolution involved similar artistic crafting, modeling, and scaffolding in the idea-based class and an extension of the endangered species case-study in the case-based class. Toward the end of the intervention, both classes went on a field trip to the zoo. This was done so that students could experience a context which afforded the opportunity to use the concepts of adaptation and evolution to expand perception and value. Students toured the zoo in groups of about 10 with a zoo guide who talked about the endangered species. Students from the idea-based class, case-based class, and other zoology classes were intermixed in the groups.

Variables

Operational Definition of Idea-based, Transformative Experience. There are three key qualities of an idea-based, transformative experience: 1) active use of the idea, 2) an expansion of perception, and 3) an expansion of value. For the purposes of this study, active use was defined as talking to other people about the class concepts (adaptation and evolution) when outside of class, and thinking about or seeing examples of the concepts when outside of class. Expansion of perception was defined as a change in the way that students saw or thought about animals, because of the concepts of adaptation and/or evolution. Expansion of value was defined as an increase in interest in animals and the zoo trip, because of the concepts of adaptation and/or evolution. It was also defined as

finding the concepts of adaptation and evolution interesting and worth learning, because the concepts expanded their perception (allowed them to see animals in a new way and to better appreciate and understand the animals).

Control Variables. Situational interest and level of understanding were included as control variables. Situational interest refers to the degree that students enjoy class activities and the class itself (Schiefele, 1991; Hidi, 1990). Situational interest and level of understanding were used to help determine the validity of the case-based class as a comparison condition, by indicating whether it is represents "good" instruction in that students learned the content and enjoyed the class.

Instruments

A variety of instruments were used to assess student outcomes. An initial survey was given immediately preceding the intervention in order to identify any pre-existing differences between the classes. This survey contained Likert scale, frequency, and open response items. After the first week of the intervention, a class assignment asked students to write about any instances of thinking about or seeing examples of adaptation or endangered species that they could remember. Reponses were used as data to determine whether students were actively using the concept of adaptation. At the conclusion of the zoo trip, a survey was given in order to assess the degree to which students engaged in the qualities of an idea-based, transformative experience while at the zoo. This survey contained 4 open response items. A post-intervention survey was administered at the conclusion of the intervention (after the trip to the zoo). This survey contained 4 Likert scale, 4 frequency, and 8 open response items assessing the degree to which students engaged in the qualities of idea-based, transformative experiences with

each of the concepts (adaptation and evolution) during the intervention. It also contained 6 Likert scale items assessing situational interest adapted from Mitchell's (1993) Interest Survey. An assessment of understanding, comprised of 6 open response items, was also given at the conclusion of the intervention. A month after the intervention, a follow-up survey was administered. The follow-up contained 10 Likert scale items assessing engagement in the qualities of an idea-based transformative experience, and 2 open response items assessing level of understanding. As additional data sources, the classrooms were videotaped and post-intervention interviews were conducted with about the half the students (see Appendix A for a list of the items on each instrument).

Analyses

The open-response items were coded into categories by two independent raters. Inter-rater reliability on all items was greater than .81. On responses where there was disagreement, the raters discussed the response until consensus was reached. A Chi-square test was used to determine significant differences between classes for this nominal data. Responses to the assessment of understanding and follow-up assessment of understanding were also coded by independent raters using a scoring rubric. Scores assigned by the two raters were averaged. Inter-rater reliability was greater than .74 for all items. For each assessment, the averaged scores on each item were summed and the t-test was used to determine significant differences between classes. The Mann-Whitney test was used to determine significant differences on the Likert scale and frequency items. A two-sided test was used for the pre-test items and control variables. A one-sided test was used for the experimental variables.[1]

Results

For each of the measures (with the exception of the initial survey), I first give an overview of how the idea-based class performed. Then I address the differences between the idea-based class and the case-based class.

Control Variables

Situational Interest. For each student, the 6 situational interest items on both the initial survey and the post intervention survey were averaged. Negatively worded items were reverse scored so that a higher number indicates a higher level of situational interest. Overall, students in the idea-based class reported a moderate level of situational interest on the initial survey (mean of 3.9 on a 6 point scale; S.D. = .88) and fairly high level of situational interest on the post intervention survey (mean of 4.7 on a 6 point scale; S.D. = .72). There were no significant differences between the two classes. Overall, the results indicate that students in both classes enjoyed the class during the intervention period.

Assessment of Understanding. Overall, students in the idea-based class were able to accurately describe and apply the concept of adaptation, however they still had some misunderstandings regarding the evolutionary processes by which adaptations come about. The mean score for the class was 43.4 on a scale of 58 (S.D. = 6.2). The mean for students in the case-based class was also 43.4 (S.D. = 8.1).

Experimental Variables

Initial Survey. Results from the initial survey suggest that the two classes were comparable in terms of the likelihood that students would engage in idea-based, transformative experiences. No significant differences were found on measures of use of

class ideas, interest in class ideas, or interest in learning about animals. The only significant ($p < .05$) difference found was that students in the case-based class agreed more strongly with the statement "The ideas taught in this class are worth learning." However, there was not a significantly (or substantively) larger percentage of students in the case-based class who reported that they found the concepts worth learning because the concepts expanded their perception (see Appendix B).

Class Assignment. Overall, the majority of students in the idea-based class reported using the concept of adaptation over the weekend following the first week of the intervention. A majority reported on an in-class writing assignment that they saw examples of adaptations or thought about or talked to others about adaptations or endangered species, even though they were not required or asked to use those concepts over the weekend. Moreover, there was a large difference between the two classes. 71% of the students in the idea-based class were able to describe at least one valid experience of seeing, thinking about, or talking with others about adaptations or endangered species. In contrast, only 17% of the students in the case-based class described at least one valid example. Moreover, 12% of the students in the idea-based class gave multiple examples whereas none gave multiple examples in the case-based class. The difference between classes was significant that the $p < .01$ level.

Descriptions were considered valid if students referred to adaptations and endangered species in a scientific sense. For instance, one student wrote that he told his dad that "he needed to adapt his thinking to the `90's." This was not considered a valid example of talking to others about adaptation. On the other hand, a valid example of how

a student was using the concept of adaptation to see and think about his world differently was given in the following report:

> "Well, I'm a runner and I put in 7 or more miles this weekend. While I was running, I thought about which animal would be the best distance runner. What I came up with is the wolf. The wolf has [a] huge territory, and in order to guard it, and to get/find prey, it must always move. Sure it can't sprint 75 mph like a cheetah, but it can run forever."

After completing the writing assignment this student shared his example with the class and further explained that he thought it was the long legs on the wolf that made it a good distance runner. He also explained that he saw some rabbits and evaluated whether they were adapted for long or short distance running (or hopping) and why.

Zoo Survey. 5 of the 17 students in the idea-based class and 3 of the 22 students in the case-based class were not able to attend the zoo, because of other school commitments or failure to bring a permission slip. These students were generally some of the more attentive and engaged students, so it is possible that results from the zoo survey are slightly biased in a negative direction.

Of those from the idea-based class who did attend the zoo trip, 25% reported that their perception had changed in that they now thought about the animals in terms of adaptations or evolution. However, 50% reported that they thought about adaptation or evolution at least sometimes on their own when viewing the animals (i.e., they thought about the concepts in addition to times when a zoo guide or someone else pointed out an adaptation or evolutionary characteristic). Since just one student reported on the initial survey that he thought about adaptation or evolution when at the zoo, it is likely that

almost half changed their perception. In addition, just over half (58%) were able to write down a valid instance of thinking about or seeing examples of adaptation or evolution. And just under half (42%) reported that the concepts of adaptation and evolution made the trip to the zoo more meaningful. However, all of those who did report that the concepts made the trip more meaningful explained that they did so by expanding their perception (i.e., by helping them better understand, appreciate, or think about the animals). For instance, one student wrote that the ideas made the trip more meaningful "because when you know about adaptations/evolution, you notice/make connections to little things that you might not have otherwise noticed."

No significant differences were found between the two classes on responses to the zoo survey. However, on three of the four items, there was a difference of more than 20 percentage points, with the idea-based class having a greater percentage (see table 1). These three items assess active use and expansion of perception. Hence, taken together, they provide a trend suggesting that a slightly greater percentage of students in the idea-based class may have actively used the concepts and experienced an expansion of perception while at the zoo.

Table 1
Zoo Survey Results

Variable	Response Categories	Idea-based Class	Case-based Class
Change in the way students think about the animals they see at the zoo	Has changed in that on this trip, they thought about adaptations, evolution, or endangered species	25%	5%
	Has changed in some other way	42%	37%
	Didn't change	33%	58%
Degree to which students thought about adaptations or evolution	Thought about adaptations or evolution on their own at least some times	50%	26%
	Thought about adaptations or evolution after guide or someone else brought it up	17%	16%
	Didn't think about evolution or adaptation	33%	58%
Number of examples students provided of thinking about or seeing examples of adaptations or evolution	Provided more than one valid example	0%	5%
	Provided one valid example	58%	32%
	Didn't provide any valid examples	42%	63%
Degree to which students thought the concepts of adaptation and evolution made the trip more meaningful or interesting	Thought that knowing about adaptation and/or evolution did make the trip more meaningful	42%	47%
	Did not think the ideas made it more meaningful	58%	53%

No significant differences were found.

Post Intervention Survey. Overall, the majority of students in the idea-based class reported actively using the concepts and experiencing an expansion of perception. Moreover, they reported using the concepts more frequently than students in the case-based class and a greater percentage of students in the idea-based class reported experiencing an expansion of perception. Results for the expansion of value items were more mixed and it is unclear whether students in the idea-based class experience a greater expansion of value than students in the case-based class.

Table 2 summarizes the results of the items assessing active use of the concepts. Four of these items asked students to report the number of times that they talked with others about the concepts outside of class and the number of times that they thought about or saw examples of the concepts. Students responded by marking one of six categories: never, once or twice, three-five times, six-nine times, ten-fifteen times, or more than fifteen times. For illustrative purposes, means and standard deviations were calculated by converting the categories to a 6 point numeric scale with 1 = never and 6 = more than fifteen times. As table 2 shows, the majority of students in the idea-based class talked to someone about the concepts at least once and thought about or saw examples of the concepts at least once. The other two items asked students to write down the instances of thinking about or seeing examples of the concepts that they could remember. The majority of students in the idea-based class were able to give at least one valid example of thinking about or seeing examples of adaptation, but only 25% were able to give at least one valid instance of thinking about or seeing examples of evolution. As mentioned earlier, those examples where adaptation was referred to in the scientific sense were considered valid. For instance, one student explained, "When I got home, I

thought about the adaptations my dog and cat had. Like why my dog has long strong legs, because she runs a lot. Or my cat's whiskers. They are the same length as the width of her body. So she can use them to see if she will fit into small spaces." This was considered a valid example.

Overall, there were significant differences between the two classes in terms of reported use of the concepts in everyday life, with students the idea-based class reporting that they talked to others more about the concepts and thought about or saw examples of them more often. In addition, they were able to provide significantly more valid descriptions of having thought about or seen examples of the concepts. All of these differences were significant at at least the $p < .05$ level. On average, students in the idea-based class reported that they talked with others about the concepts a little more than "once or twice," while students in the case-based class reported that they talked with others about the concepts a little less than "once or twice." On average, students in the idea-based reported seeing or thinking about adaptations approximately "three-five times" and seeing or thinking about evolution approximately "once or twice." On the other hand, students in the case-based class, on average, reported seeing or thinking about adaptations approximately "once or twice" and seeing or thinking about evolution a little more than "never." In addition, 71% of students in the idea-based class were able to provide at least one valid description of thinking about or seeing examples of adaptation (almost half provided more than one), whereas only 28% in the case-based class were able to do so (with only one student providing more then one valid example). Also, a greater percentage of students in the idea-based class (25%), than students in the case-

based class (5%), were able to write down a valid example of seeing or thinking about evolution.

Table 2
Post Intervention Survey Results: Active Use Items

Variable	Response Categories	Idea-based Class	Case-based Class	Sig.
Number of times that students talked with others about adaptation outside of class	Never	12%	55%	
	Once or twice	41%	32%	
	Three-five times	41%	9%	**
	Six-nine times	6%	0%	
	Ten-fifteen times	0%	5%	
	More than fifteen times	0%	0%	
	Mean (Standard Deviation)	2.41 (.80)	1.69 (.99)	
Number of times that students thought about adaptations or saw examples of adaptations outside of class	Never	0%	27%	
	Once or twice	41%	64%	
	Three-five times	18%	5%	**
	Six-nine times	18%	0%	
	Ten-fifteen times	12%	5%	
	More than fifteen times	6%	0%	
	Mean (Standard Deviation)	3.18 (1.22)	1.91 (.87)	
Number of examples that students were able to provide of thinking about or seeing examples of adaptation	Provide no valid examples	29%	73%	
	Provided one valid example	24%	23%	**
	Provided more than one valid example	47%	5%	
Number of times that students talked with others about evolution outside of class	Never	25%	64%	
	Once or twice	56%	32%	
	Three-five times	6%	0%	**
	Six-nine times	6%	0%	
	Ten-fifteen times	0%	5%	
	More than fifteen times	6%	0%	
	Mean (Standard Deviation)	2.19 (1.28)	1.5 (.91)	
Number of times that students thought about evolution or saw examples of evolution outside of class	Never	44%	77%	
	Once or twice	38%	23%	
	Three-five times	6%	0%	*
	Six-nine times	0%	0%	
	Ten-fifteen times	0%	0%	
	More than fifteen times	13%	0%	
	Mean (Standard Deviation)	2.13 (1.63)	1.23 (.43)	
Number of examples that students were able to provide of thinking about or seeing examples of evolution	Provide no valid examples	75%	95%	
	Provided one valid example	19%	5%	*
	Provided more than one valid example	6%	0%	

* Significant at $p < .05$ level. ** Significant at $p < .01$ level.

Table 3 summarizes the results for the expansion of perception items and illustrates that most of the students in the idea-based class reported experiencing an expansion of perception. 76% reported that the way they think about or see animals had changed during the two-week intervention in that now they see and think about animals in terms of adaptations, evolution, and/or endangered species. For instance, one student commented that the way he thinks about animals has changed in that now "I actually look at them and think about how they live and what helps them survive in Michigan weather. . . . Like, I wonder what that color is for or if their fur is thick or why is half his body one color." In addition, the proportion of students who reported an expansion of perception was far greater in the idea-based class than the case-based class (76% compared to 32%). This difference was significant at the $p < .05$ level.

Table 3
Post Intervention Survey Results: Expansion of Perception Items

Variable	Response Categories	Idea-based Class	Case-based Class	Sig.
Change in the way students think about animals	Has changed in that now they think about animals in terms of adaptations, evolution, and/or endangered species	76%	32%	*
	Has changed in other ways	6%	14%	
	Has not changed	18%	55%	

* Significant at $p < .05$ level.

Table 4 presents the results of the items assessing expansion of value. Items assessing expansion of value asked students to describe their interest in and valuing of the concepts as well as how their interest in animals had changed (if at all). Responses to the item assessing a change in students' interest in animals (Has your interest in animals changed over the past two weeks? If so, explain how your interest in them has changed?)

were coded into four categories. Included in the first category were those responses indicating that the students' interest in animals increased because of the concepts they learned in class. For instance, one student explained, "Before we learned about the adaptations and evolution of species, I really didn't know much about animals. Now that I know this, I find it more interesting to learn about animals." Included in a second category were responses indicating that the students' interest in animals had increased, but for reasons unrelated to the class ideas. A third category included statements by students that their interest had not increased because they were already interested in animals. The fourth category included all other responses indicating that the students' interest in animals had not increased. The first category was considered an indicator of expansion of value and 23.5% of the students in the idea-based class fit into this category.

Overall, it is not clear whether there was a difference between the two classes in terms of the degree to which the students' interest in animals changed. About an equal percentage of students in the idea-based class and case-based class (23.5% and 18% respectively) reported that their interest in animals had changed because of the concepts they learned. However, another 23.5% of the students in the idea-based, and 9% of the students in the case-based class, reported that their interest in animals did not change because they were already interested in animals. Some or all of these students may also have experienced an expansion in value with respect to animals. This is because all of these students (except for one in the case-based class) did report experiencing an expansion in perception. Moreover, I conducted follow-up interviews with some of these students and, when asked directly, they did say that they found it interesting to think about animals in terms of the concepts. For instance, one student explained that he now

thought about animals in terms of evolution and I asked him if he found that to be an interesting way to think about animals. He responded, "Yeah, I mean before this class, I mean, I didn't really think about that much. Just they're here. They've been here. You don't think where they came from or how they got here." Thus the concepts did seem to add value to animals, but the students tended to have dichotomous view of interest: you were either interested in animals or you were not. Hence they did not report being more interested in animals even though the concepts gave them a meaningful, new way of perceiving animals.

Students' interest in and perception of the worthwhileness of the concepts were assessed by four, six point Likert scale items (1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = slightly agree, 5 = agree, 6 = strongly agree). In addition, four open response items were used to assess the reasons why students found the concepts interesting or worthwhile (e.g., If you are interested in the idea of adaptation, explain why you find it interesting). These responses were coded into the four categories. One category included responses that indicated the students were interested in the concepts or found them worth learning, because the concepts expanded their perception of some thing (i.e., they allowed them to understand things, appreciate things, see things in a different way, and so on). A second category varied slightly depending on the item. For the interest items, it included responses indicating the students found the concepts interesting, because the students liked to learn (i.e., they found it interesting to learn any new or different concepts). For the worth learning items, it included responses indicating the students found the concepts worth learning, because they perceived the concepts to be important to learn, they thought everything was worth learning, or they simply felt

learning itself was important. A third category included responses indicating that the students found the concepts interesting or worth learning, because the concepts had utility value (i.e., they would be helpful or needed for future endeavors—classes, exams, college courses, jobs, etc.). A fourth category encompassed all additional reasons for finding the concepts interesting or worth learning. The first category represents one of the qualities of a transformative, idea-based experience, whereas the others do not.

On average, students in the idea-based class slightly agreed that the concepts of adaptation and evolution were interesting and worth learning. Of those who answered the open response items, 86% indicated that they were interested in adaptation because it expanded their perception in some way. For example, one student explained, "I just never really thought about adaptation when I saw them [animals]. But I do now and I find it interesting." No responses from either class fit in the "utility value" category, so that category was dropped for this item. 40% indicated that the concept of adaptation was worth learning because it expanded their perception. For example, one student felt the concept of adaptation was worth learning because "It helps you think more clearly about animals." 60% found evolution interesting because it expanded their perception and 50% reported that evolution was worth learning because it expanded their perception.

It is unclear whether there was a difference between the two classes on reports of their interest in and perception of the worthwhileness of the concepts. Students in both classes reported roughly equal levels of interest in the concepts and roughly equal views on the worthwhileness of learning the concepts. However, there was a consistent trend in the responses to the items assessing reasons why students found the concepts interesting and worth learning. On these items, a greater percentage of the students in the idea-based

class, than students in the case-based class, reported that they found the concepts interesting and worth learning because the concepts expanded their perception. But, although some of these differences appear substantively different, only one was statistically different. Hence, a slightly greater percentage of students in the idea-based class, than in the case-based class, may have experienced an expansion of value in the sense that they valued the concepts because of the way that the concepts allowed them to perceive the world in a meaningful way.

Table 4
Post Intervention Survey Results: Expansion of Value Items

Variable	Response Categories	Idea-based Class	Case-based Class	Sig.
Change in students' interest in animals	Has increased because of the concepts they have learned	23.5%	18%	
	Has increased for other reasons	18%	23%	
	Didn't increase because they were already interested in animals	23.5%	9%	
	Didn't change	35%	50%	
"I am interested in the idea of adaptation"	Mean (standard deviation)	3.94 (.77)	3.68 (1.36)	
Reasons for finding adaptation interesting (for those who did find it interesting)	It has expanded their perception	86%	81%	
	They like to learn	7%	6%	
	Other	7%	13%	
"The idea of adaptation is worth learning"	Mean (standard deviation)	4.26 (.83)	4.36 (1.22)	
Reasons for finding the adaptation worth learning (for those who did find it worth learning)	It has expanded their perception	40%	29%	
	It's important to learn/everything is worth learning	40%	29%	
	It has utility value	20%	35%	
	Other	0%	6%	
"I am interested in the idea of evolution"	Mean (standard deviation)	3.78 (.91)	3.86 (1.17)	
Reasons for finding evolution interesting (for those who did find it interesting)	It has expanded their perception	60%	38%	
	They like to learn	20%	25%	
	It has utility value	0%	6%	
	Other	20%	31%	
"Idea of evolution is worth learning"	Mean (standard deviation)	4.06 (.77)	3.80 (1.33)	
Reasons for finding evolution worth learning (for those who did find it worth learning)	It has expanded their perception	50%	13%	
	It's important to learn/everything worth learning	36%	44%	*
	It has utility value	0%	38%	
	Other	14%	6%*	

* Significant at $p < .05$ level.

Follow-up Survey. The follow-up survey contained four items (two each in reference to the concepts of adaptation and evolution) assessing everyday use of the concepts. Students responded to the items by marking the appropriate category on a six-point scale where 1 = never, 2 = rarely, 3 = occasionally, 4 = regularly, 5 = frequently, and 6 = all the time. It also contained four items (again, two for each concept) assessing students' interest in the concepts and two items (one for each concept) assessing the degree to which students valued the concept "because it makes things in the world (such as plants, animals and humans) more interesting or meaningful." Students responded to these items by marking the appropriate category on a six-point Likert scale where 1 = strongly disagree and 6 = strongly agree.

As table 5 illustrates, students in the idea-based class still reported using the concepts of adaptation and evolution, but, on average, they did so either "rarely" or "occasionally." In addition, they still reported that, on average, they "slightly agreed" that the concepts were interesting and that they valued them because the concepts expanded their perception of things in the world. In terms of differences between classes, the idea-based class scored significantly higher on the active use of the concept of adaptation items (difference significant at $p < .05$ level), but not on the active use of the concept of evolution items. No significant differences were found on the interest items or the valuing of the concepts because they expand perception items.

Included with the follow-up survey was an assessment of understanding. This assessment contained two open response items which asked students to 1) choose one of the animals examined during a lab and describe both its adaptations and how those adaptations help it survive in a particular environment, and 2) describe how these

adaptations could have come about (i.e., describe the evolutionary processes involved). The mean on this assessment was 10.9 out of a possible 19 points, for students in the idea-based class. Of the two open response questions, students performed much better on the first question. Hence, overall, they seem to have maintained an understanding of the principle of adaptation, but their understanding of the evolutionary processes seems to have decline during the month following the intervention. Nevertheless, students in the idea-based class did score significantly higher on this assessment than students in the case-based class (difference significant at the $p < .05$ level).

Table 5
Follow-up Survey Results

Variable	Mean (standard deviation)	
	Idea-based class	Case-based class
Active use of the concept of adaptation	2.53 (.58)	2.05 (.60)*
Interest in adaptation	4.15 (1.03)	3.98 (.84)
Value concept of adaptation because it expands perception	4.35 (1.00)	3.80 (1.30)
Active use of the concept of evolution	2.37 (.75)	2.28 (.70)
Interest in evolution	3.94 (1.34)	3.85 (.89)
Value concept of adaptation because it expands perception	3.76 (1.48)	3.73 (.97)
Understanding of the concepts of adaptation and evolution	10.9 (4.61)	7.4 (4.67)*

*significant at the $p < .05$ level.

General Trends

Table 6 helps to summarize the results across instruments and identify general trends. In order to place the results on a roughly comparable scale, effect sizes were calculated for each item. In doing this, all categorical items were recoded into dichotomous variables by collapsing those categories which were not indicators of an idea-based, transformative experience. For instance, the responses in relation to the item "explain why you find the idea of adaptation worth learning" were collapsed into two

categories: 1) students found the idea of adaptation worth learning because it expanded their perception, and 2) all other categories. Effect sizes for these dichotomous variables were determined by computing the squared Cramer's phi coefficient (ϕ^2). Effect sizes for the results of all other items (which were all on an ordinal scale) were determined by computing the squared Kendall's rank order correlation coefficient (τ^2).[2] Cohen (1988) states that, as a general rule of thumb, .01 is small, .09 is medium, and .25 is large. Table 4 uses a bar graph to illustrate the magnitude and direction of the effect sizes.

Table 6

Relative Effect Size for Items across All Instruments

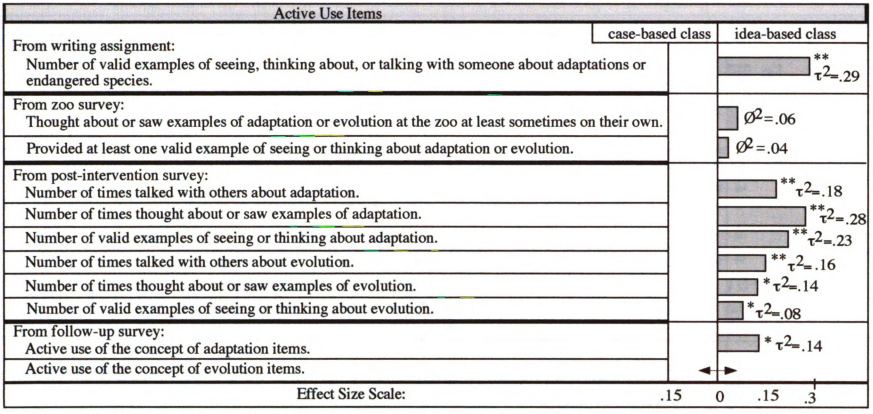

Table 6 (cont'd)

Expansion of Perception Items	
From zoo survey: Perception of animals at the zoo changed in that on this trip they thought about the animals in terms of adaptations or evolution.	$Ø^2 = .08$
From post-intervention survey: Perception changed in that now they see and think about animals in terms of adaptations, evolution, and/or endangered species.	$*Ø^2 = .20$
Expansion of Value Items	
From zoo survey: Reported that knowing about adaptation and/or evolution made the trip more meaningful or interesting.	◄►
From post-intervention survey: Interest in animals increased because of the concepts students learned.	◄►
Found adaptation interesting because it expanded their perception.	◄►
Found adaptation worth learning because it expanded their perception.	$Ø^2 = .01$
Found evolution interesting because it expanded their perception.	$Ø^2 = .05$
Found evolution worth learning because it expanded their perception.	$*Ø^2 = .17$
From follow-up survey: Interest in adaptation items.	$\tau^2 = .04$
Value the concept of adaptation because it expands perception	$\tau^2 = .04$
Interest in evolution items.	$\tau^2 = .02$
Value the concept of evolution because it expands percepetion	$\tau^2 = .02$
Effect Size Scale:	.15 0 .15 .3

* significant at $p < .05$ level. ** significant at $p < .01$ level. ◄►: $Ø^2$ or $\tau^2 < .01$

As the table illustrates, all of the differences on the active use items are in the direction of the idea-based class and most of these differences are statistically significant. Moreover, the effect sizes are generally in the medium to large range. Hence, on average, students in the idea-based class reported actively using the concepts (i.e., talking to other people about the concepts, seeing examples of the concepts, and thinking about the concepts when outside of class) significantly more often than students in the case-based class. A similar statement can be made about expansion of perception. Both items assessing expansion of perception found difference in the direction of the idea-based class.

Table 6 illustrates that the results for the expansion of value items show a consistent trend in that, on all substance differences, students in the idea-based class express more of an increase in value than students in the case-based class. However, only one of these differences was statistically significant and most effect sizes were in the medium to small range. Differences on the follow-up survey were particularly small and not much importance should be attached to them even though they trend in one direction. In addition, on three of the items, there was almost no difference between the class. However, one of these deserves a deeper look. As explained earlier, for the item assessing the degree to which students expanded their interest in animals, both the categories of "interest in animals increased because of the concepts students learned" and "interest in animals did not increase because the students were already interested" can be considered indicators of expansion of value. When these categories are combined, then there is a difference of 20 percentage points (with the idea-based class having the greater percentage) and an effect size of $\omega^2 = .04$, which is similar to the results on most of the

other expansion of value items. Hence the data generally trends in the direction of the idea-based class suggesting that students in that class may have experienced a slightly greater expansion of value, but overall the results are inconclusive.

Did Students Fully Undergo Idea-based, Transformative Experiences?

Thus far I have discussed the degree to which the idea-based class as a whole engaged in the qualities of an idea-based, transformative experience. This analysis reveals the probability that students in the class are actually engaging in such experiences and it allows for a more detailed between-class comparison. However, it does not answer the question of whether individual students did fully engage in such experience. This is because an idea-based, transformative experience is more than just the sum of its qualities. To undergo a transformative, idea-based experience, in all its fullness, is to experience a fusion of these qualities. Jackson (1998) explains that transformative experiences involve a fullness of perception. Full perception involves a total absorption in what an object, event, or concept is like and "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" (p. 149). When we fully undergo a transformative experience, our action, our perception, our valuing, and our cognition become united. We act on an idea (possibility), use it to perceive the world anew, and become deeply moved by this new way of perceiving.

Did any students fully experience this fusion? Did they fully engage with the concepts of adaptation and/or evolution as ideas? The answer is yes and no. Yes some students, in both classes, did experience some degree of fusion. They actively used the concepts on a number of occasions and this use led to a significant transformation of their

perception. In addition, they came to value the concepts, because the concepts expanded their perception. And they also developed a greater interest in aspects of the world that were illuminated by the concept (namely animals). But no, these students did not appear to engage in any experience as dramatic as what Jackson describes as full perception—they did not appear to engage in a "total absorption" with the concepts or to experience what it is like to be "fully human." It may be that such experiences are quite rare. In fact, Jackson acknowledges this, but is quick to point out that there are different degrees with which we may engage in transformative experiences. The students I mentioned did not engage in the most dramatic level of a transformative experience, but they clearly did engage in genuine idea-based, transformative experiences.

In looking across all the data for evidence that a student engaged in all the qualities of an idea-based, transformative experience, I was able to identify 4 students (23.5%) in the idea-based class and 2 students (9.1%) in the case-based class who did engaged in a genuine idea-based, transformative experience. In order to convey a sense for the type of experience that these students underwent, I provide an illustrative case-study of one of these students.

Case of Clifford. Clifford was a student in the idea-based class. He clearly experienced an expansion of perception as a consequence of the class concepts. He commented that the way he thinks about animals had changed and explained, "I now don't just look at [an] animal and say, 'That's cute.' I stop and think a little harder." Moreover, he explained that now, "I wonder if they are closely related to me as a human. I also think about their markings and how it helps them." Clifford also described many specific instances of actively using the concepts to expand his perception of the world.

For instance, he said he thought about the adaptations of birds of prey and wondered why the female is bigger than the male. He also thought about the panda bear and wondered why they were adapted to bamboo. In addition, he commented that he learned about an interesting specific adaptation of the panda bear. He explained that they "have a bone on their hand, a second thumb to help eat." Clifford also described thinking about adaptations while at the zoo. He said he wondered why the Golden Tamarin was such a bright color. He wondered if it had no nature predators to hide from and hence had not adapted to blend in. He wondered why the Mandrill's forearms had no hair, and he also wondered why the Lemurs huddled in groups. He wondered if this was a behavioral adaptation for staying warm or for grooming.

Another interesting example he provided has to do with Dumbo. Clifford explained that he saw the movie Dumbo and, for some reason, thought about his giant ears in terms of adaptations. He thought about how his huge ears were a great adaptation. He then thought about the big ears on real elephants and how they likely serve to keep the elephants cool. This last example is actually quite typical of how students applied the concepts in familiar contexts. Most students did not have the opportunity to see wild animals except at the zoo. However, they still thought about the concepts in the context of the things they did experience. For instance, many students looked for or thought about the adaptations or evolutionary qualities of their pets. Others, like Clifford, thought about the concepts while reading something or while watching a show, such as a nature show, Jaws, and of course Dumbo. Overall, Clifford reported talking to other people about the concepts and seeing examples of them or thinking about them a lot. He said he talked to other people about adaptation 3-5 times and thought about it or saw examples of

it 10-15 times. He talked to others about evolution 6-9 times and thought about it or saw examples of it more than 15 times. On the follow-up Clifford reported that he still used the concepts on a regular basis.

Clifford also experienced an expansion of value as a consequence of the concepts. He reported that knowing the concepts of adaptation and evolution made the trip to the zoo more meaningful or interesting "because it made me think a little harder about the animals." In addition, he reported being interested in the concepts and felt they were worth learning. Moreover he valued the concepts because they expanded his perception – they illuminated things, explained things, helped him understand things. For instance, he stated that he was interested in adaptation because "It's compelling to see how an animal changes to fit its environment. The peppered moth blows my mind." He felt the idea of adaptation was worth learning because, "it made me look past the animal and made me try to understand more about it." He also reported being interested in evolution "because so much [of] our past is unknown. This gives a probable answer." On the follow-up, Clifford still reported being interested in the ideas and agreed with the statement, "I value the idea of adaptation because it makes things in the world (such as animals, plants, and humans) more interesting or meaningful." He slightly agreed with the statement "I value the idea of evolution because it makes things in the world (such as animals, plants, and humans) more interesting or meaningful."

Students Who Experienced a Lesser Form of Idea-based, Transformative Experience. In addition to these students, other groups of students experienced lesser forms of idea-based transformative experiences. These students seemed to experience some, but not quite all of the qualities of such experiences. For instance one group of

students actively used the concepts a number of times and did experience a significant expansion of their perception. However, they did not clearly value the concepts because they expanded their perception or they did not clearly attach more value to animals because they were able to perceive them through the lens of the concepts. Three students (17.6%) in the idea-based class fit into this group (none in the case-based class did). A second group experienced an expansion of perception and they clearly valued the concepts, because of the way they expanded perception. They also attached more value to animals because they were able to see them differently. But, surprisingly, these students only reported using the concepts about once or twice. One did not even use the ideas when at the zoo. 2 students (11.8%) in the idea-based class and 3 students (13.6%) in the case-based class fit into this group.

It is unclear what exactly is going on with these students who reported engaging in some, but not all, of the qualities of an idea-based, transformative experience. With the first group it is possible that they actively tried out the concepts and found that the concepts did expand their perception, but not in a personally meaningful way. A second possibility is that they simply were not aware of an increase in value that did occur. As mentioned earlier, it may be harder to reflect on and recognize a change in value. The second group raises the question of how students could experience an expansion of perception and value without actively using the concepts. A possible explanation is that the students did use the concepts in the context of class activities to experience an expansion of perception and value. However they still were not motivated or able to use the concepts frequently in their everyday lives. Or perhaps they simply did not encounter many situations which afforded the use of the concepts.

These two groups point to the need for more studies which carefully describe student experiences. Obviously the situation is more complex than is suggested by Dewey's work and my extension of his work. Students don't fit neatly into the dichotomous categories of "underwent an idea-based, transformative experience" and "did not undergo an idea-based, transformative experience." Instead students engage in idea-based, transformative experiences to varying degrees and in varying ways. This study begins to describe some of these different ways, but future research needs to more carefully construct some pragmatic categories for classifying different types of experience and, subsequently, examine why students engage in such experiences to varying degrees and in varying ways.

The rest of the students did not seem to engage in any form of idea-based, transformative experience. They may have displayed one quality, but overall they did not engage in anything that could be considered a transformative experience. 8 students (47.1%) in the idea-based class and 17 students (77.3%) in the case-based class fit into this category. To get a sense for the overall difference across classes, I placed the students on an ordinal scale with 0 = did not engage in an idea-based, transformative experience., 1 = engaged in a lesser form of idea-based, transformative experience, and 2 = engaged in a genuine idea-based, transformative experience. As predicted, the students in the idea-based class scored higher, and a one-sided Mann-Whitney test revealed that the difference was significant at the $p < .05$. The effect size was in the medium range ($\tau^2 = .09$). Overall, just over half (52.9%) the students in the idea-based class and just under a quarter (22.7%) of the students in the case-based class engaged in some form of idea-based, transformative experience.

Discussion

In general, the results suggest that the proposed elements for teaching for idea-based, transformative experiences were moderately effective in the context of this study. The majority of students in the idea-based class reported making active use of the concepts, either at the zoo, in other aspects of their everyday life, or both. And, although frequency of use trailed off, students were still actively using the concepts a month later. The majority of students in the idea-based class also reported an expansion of perception in relation to animals. In addition, the majority of those who found the concepts interesting reported that they did so because the concepts expanded their perception. Also, around half who found the concepts worth learning, reported that they were worth learning because they expanded perception. Further, it appears that a little less than half experienced an increase in valuing of animals because of the concepts they learned and a little less than half felt that the concepts made the trip to the zoo more meaningful and interesting. After a month, the students on average still reported moderate interest in the concepts and slightly agreed that they valued the concepts because they expanded their perception.

The results also suggest that the case-based class was a valid control condition in that it did represent good science instruction. Students, on average, enjoyed the class and learned the content. There was no difference between the classes on these measures (i.e., measures of situational interest and the initial assessment of conceptual understanding). However, there were differences between the classes in terms of the qualities of an idea-based, transformative experience. Overall, the results across instruments are consistent in showing that the idea-based class reported greater active use of the concepts of adaptation

and evolution, and a greater percentage of students in the idea-based class reported an expansion of perception in relation to animals. However, results in relation to the third quality (expansion of value) are less clear. There is some evidence to suggest that the idea-based class experienced a slightly greater expansion of value, but overall the results are inconclusive on this aspect.

Why the Inconclusive Results for the Expansion of Value Items?

These findings raise the question of why the ideas-based class was more effective that the case-based class at fostering active use and an expansion of perception, but not clearly more effective at fostering an expansion in value. There are a few possibilities that are important to acknowledge. The most obvious possibility is that the elements of teaching for idea-based, transformative experiences are not as effective at fostering an expansion in value as they are at fostering the other qualities of an idea-based, transformative experience. An addition to or modification of these elements may be needed to foster a significant increase in expansion of value. Specifically, it may be important for the teacher to be very expressive in modeling the value that he or she gets out of engaging with the concepts. In addition it may be important to consistently encourage the students to share and discuss their own expansion of value. Upon review of the videotapes of the instruction, this is something I found to be lacking. I observed that during the scaffolding phase of the instruction, the students often talked about their experiences of using the concepts and how they were seeing animals through the lens of the concepts. However, they rarely expressed their emotions in relation to these experiences. They rarely talked about whether their experiences with the concepts were exciting, thrilling, disturbing, illuminating, and so on. In addition, they did not talk about

whether the animals were more interesting or "cool" when they saw them through the lens of the concepts. To put it in Dewey's language, they talked about the expansion of perception they were experiencing, but did not discuss whether they also experienced an expansion of meaning and value as a result of being able to "see" the world anew. Perhaps if I had been consistent at encouraging students to do this, they would have experienced more of an expansion of value or been more aware of the expansion of value they were experiencing. Nevertheless, it is important to note that around half the students in the idea-based class did express an expansion in value in one way or another. This percentage may be large compared to what takes place in a typical science classroom. In other words, the approach used in both the idea-based and case-based class may be good, but not great, at fostering an expansion of value.

A second possibility may be that value takes longer to develop than the other qualities. It may be that a longer intervention period is needed in order to observe significant results in terms of expansion of value. A third possibility is that measures of value may be less sensitive to change. As stated above, some students had dichotomous views of interest and had a hard time recognizing an increase in interest. Overall, the construct of interest and value is more abstract and harder to reflect on than other constructs, such as the number of times they talked with someone about the concepts.

What are the Reasons for the Content Differences and Individual Differences?

The current study was not designed to answer this question, nevertheless, it is an important question to acknowledge because there were significant content and individual differences. In terms of content, overall, the students in both classes actively used and valued the concept of adaptation more than the concept of evolution. It is possible that

the concept of adaptation more readily affords the undergoing of a transformative experience because the concept of adaptation is 1) easier to grasp, and 2) more easily "seen" in the real world. In other words, it might be less cognitively taxing to "see" the world in terms of adaptation than to "see" the world in terms of evolution. It's also possible that some students may intentionally abort transformative experiences with the concept of evolution because they reject the concept for religious reasons. Future research needs to address this issue. Does certain content afford transformative experiences more than content? If so, why and for what groups of students?

In addition to the content differences, there were large individual differences within each class. Such differences are to be expected as Dewey (1938) suggests that experience results from a transaction between the individual and his or her environment (see also Verula, Thomson & Rosch, 1992). It is likely that a number of factors are an important part of the transaction that takes place between the individual and environment. One of the factors that appears particularly important is self-concept (see Marcus & Nurius, 1986). In a previous study (Pugh, 1999b), I observed that students who underwent idea-based, transformative experiences had a self-concept that included being a science person. In other words, they saw themselves as someone who did science things, enjoyed science, associated with scientific people or things, and/or could imagine science being a part of their future self. Self-concept is likely important because of its influence on students' willingness to "surrender" to the possibilities the concept proposes. Dewey (1954/1934) argued that undergoing of an experience (i.e., a transformative experience) requires surrender – a momentary suspension of critical reflection and control. It requires an opening up to and submersion in the possibility of the experience.

In relation to science, this may entail a temporary suspension of critical reflection on a concept and a willingness to be moved by the concept and to undergo the consequences of acting on the concept "as if it were true." Self-concept likely mediates this process. Students who see themselves as a science person are likely more willing to surrender to the possibility of being moved by a science concepts, where as those who do not see themselves as science people – or even school people – may be more hesitant. In addition, self-concept may conflict with particular science concepts. For instance, one student saw himself as a science person, but he also saw himself as religious person and felt that that the concept of evolution conflicted with his religious beliefs. As a result, he had a transformative experience with the concept of adaptation, but he purposely avoided and attempt at seeing the world in terms of evolution. Because of his religious beliefs, which were central to his self-concept, he chose not surrender to the experience of seeing the world through the lens of evolution.

Is There a Relationship between Idea-based, Transformative Experience and Enduring Conceptual Understanding?

One of the unexpected findings from the study was that the idea-based class scored higher on the follow-up assessment of understanding. This result was particularly surprising given the fact that both classes scored equally well on the assessment of understanding given at the conclusion of the intervention. This outcome raises the possibility that there exists a relationship between engagement in idea-based, transformative experiences and enduring conceptual understanding. However, the results should be interpreted cautiously, because, although the same content was taught in both classes, different amounts of time were spent on specific aspects of the content and it is

possible that one or both of the assessments could have favored one of the classes (although there is no clear reason to suspect this is so).

In order to further examine the possibility of a relationship between engagement in idea-based, transformative experience and enduring conceptual understanding, I compared the assessment scores of those (in both classes) who engaged in at least some form of idea-based, transformative experience with those who did not. As would be predicted, a one-sided Mann-Whitney test revealed that the students who engaged in at least some form of idea-based, transformative experience scored significantly higher ($p < .05$) on the follow-up assessment of understanding but not on the original assessment of understanding.

Hence, there is some evidence to suggest that a relationship between engagement in idea-based, transformative experience and enduring conceptual understanding exists. However, further studies are needed to confirm this relationship. In addition, the nature of the relationship is unknown. Most likely there is an interactive relationship. One the one hand, active use and value likely contribute to enduring conceptual understanding. In fact, other studies have confirmed that interest contributes to deeper levels of conceptual understanding (for a review, see Schiefele, 1991). On the other hand, a deep and sophisticated level of understanding is likely needed in order for students to experience an expansion of perception, use the concepts, and develop value in regards to the concepts and the objects they illuminate.

Conclusions and Future Directions

In this study, the popular notion that science education should enrich students' everyday experience was translated to mean the science education should bring about

idea-based, transformative experiences. In other words, the learning of science concepts should allow students to act on the world in new ways, to more fully perceive the world, and to expand the meaning and value they attach to the world. Further, this study proposed that two teaching elements – namely the artistic crafting of content and the modeling and scaffolding of perception and value – would be effective at fostering idea-based, transformative experiences. Results indicate that these elements were effective at engaging about half the students in a high school zoology class in some degree of idea-based, transformative experience and the elements were relatively more effective than the elements of instruction used in the control condition (which were based on a case-based approach). Future research is needed to determine whether these findings hold up under different contexts and research designs. Also, this study does not address the question of the effectiveness of the two elements taken separately. Future research could examine this issue.

Additionally, the purpose of this study is not to suggest that the elements used in the intervention are the only methods which could effectively foster idea-based, transformative experiences, or that the these elements could not be used in conjunction with other approaches (including the case-based approach). As stated earlier Wong et. al. (2000) have argued that there may be many divergent ways of teaching for transformative experiences, and they provide some general metaphors for thinking about teaching from the perspective of transformative experience. This study identifies more specific elements of instruction that fit with these metaphors and suggests that these elements were relatively effective in the context of this study. However, others may identify alternative, effective elements. In fact, the results of this study suggest that the case-

based approach was effective at fostering at least some degree of idea-based, transformative experience with some students. There is still much work to be done on the issue of identifying teaching elements and combinations of teaching elements which are effective at fostering idea-based, transformative experiences.

Finally, as noted above, individual factors play an important role in the undergoing of an idea-based, transformative experience. Future research needs to identify the those factors that play a central role in the transaction which constitutes a *trans*formative experience. Such research will help us understand why some students do *not* engage in idea-based, transformative experiences and why others do engage in such experiences – but to varying degrees and in various ways.

Notes

1. A one-sided test was used because it was predicted that the idea-based class would perform better on the experimental variables and Whitte and Whitte (1997) suggest that the Mann-Whitney test is better used as a one-sided test.
2. The squared Cramer's phi coefficient provides a general effect size by giving a rough estimate of "the proportion of predictability between two qualitative variables" (Whitte & Whitte, 1997, p. 415). The squared Kendall's correlation coefficient provides a similar estimate.

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APPENDIX A

Instruments

Initial Survey

[redacted] Likert scale items, 1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = [redacted]y agree, 5 = agree, 6 = strongly agree.

Situational Interest Items:

Our class is fun.	(1) (2) (3) (4) (5) (6)
I actually look forward to going to science class this year.	(1) (2) (3) (4) (5) (6)
Our science class is dull.	(1) (2) (3) (4) (5) (6)
This year I like science.	(1) (2) (3) (4) (5) (6)
I don't find anything interesting about science class this year.	(1) (2) (3) (4) (5) (6)
My other classes are more interesting than science.	(1) (2) (3) (4) (5) (6)

Active Use Items:

When outside of class, how often do you talk with others about the ideas taught in this class (**not** including times you are completing a class assignment or studying for a quiz)?

(1) Never	(2) Once a month	(3) Once every two weeks	(4) Once a week	(5) Once a day	(6) More than once a day

When outside of class, how often do you think about the ideas taught in this class or use them in some way (not including times you are completing a class assignment or studying for a quiz)?

(1) Never	(2) Once or twice	(3) Three – five times	(4) Six – nine times	(5) Ten – fifteen times	(6) More than fifteen times

Perception Items:

When you see animals at the zoo, what sort of things do you think about? (It's OK to say you don't really think about anything)

When you see animals other places, such as in the wild, on the farm, or around the house, what sort of things do you think about? (It's OK to say you don't really think about anything)

Value Items:

I am interested in the actual science ideas that have been taught in this class. (1) (2) (3) (4) (5) (6)

If you are interested in these ideas, explain why find them interesting.

The ideas taught in this class are worth learning. (1) (2) (3) (4) (5) (6)

Explain why you find these ideas worth learning or why you do not find them worth learning.

I am interested in animals. (1) (2) (3) (4) (5) (6)

I love learning about animals. (1) (2) (3) (4) (5) (6)

Other base-line measure:

I know a lot about the ideas of adaptation and evolution. (1) (2) (3) (4) (5) (6)

Zoo Survey

Perception item:

Did you think about the animals differently on this trip to the zoo than on previous trips?
If so, explain how you thought about them differently.

Active use items:

Did you think about adaptations or evolution at the zoo?
If so, describe each time you thought about adaptations or evolution. **Give details** (what animals were you looking at? what did you think? why did you think about adaptations or evolution?)

If you did think about adaptations or evolution, did somebody else such as the museum guide first point out the adaptations or evolutionary characteristics, or did you think about them on your own?
Explain.

Value item:

Did knowing about adaptations and evolution make the zoo trip more meaningful or more interesting? (it's OK to say "no")
If so, explain why.

Post-Intervention Survey

For all Likert scale items, 1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = slightly agree, 5 = agree, 6 = strongly agree.

For all frequency items, 1 = never, 2 = once or twice, 3 = three – five times, 4 = six – nine times, 5 = ten – fifteen times, 6 = more than fifteen times.

Situational Interest Items:

Our class was fun the last 2 weeks.	(1) (2) (3) (4) (5) (6)
I actually looked forward to going to science class the last 2 weeks.	(1) (2) (3) (4) (5) (6)
Our science class was dull the last 2 weeks.	(1) (2) (3) (4) (5) (6)
The last 2 weeks I liked science.	(1) (2) (3) (4) (5) (6)
I didn't find anything interesting about science class the last 2 weeks.	(1) (2) (3) (4) (5) (6)
My other classes were more interesting than science the last 2 weeks.	(1) (2) (3) (4) (5) (6)

Active Use Items:

In the past two weeks, how often did you talk with others about the idea of adaptation outside of class? (circle the most correct response)

(1) (2) (3) (4) (5) (6)

When outside of class, how often do you think about adaptations or see examples of adaptations (circle the most correct response)?

(1) (2) (3) (4) (5) (6)

If you did think about and see examples of adaptations, list the examples. **Give details**:

In the past two weeks, how often did you talk with others about the idea of evolution outside of class? (circle the most correct response)

(1) (2) (3) (4) (5) (6)

When outside of class, how often do you think about evolution or see examples of evolution (circle the most correct response)?

(1) (2) (3) (4) (5) (6)

If you did think about and see examples of evolution, list the examples. **Give details**:

Perception Items:

Now when you see animals in the wild, on the farm, around the house, in books, or on TV, what sort of things do you think about? (It's OK to say you don't really think about anything)

Has the way you think about animals changed over the past two weeks?
If so, explain how the way you think about them has changed.

Value Items:

Has your interest in animals changed over the past two weeks?
If so, explain how you interest in them has changed.

I am interested in the idea of adaptation that was taught the past couple weeks. (1) (2) (3) (4) (5) (6)

If you are interested in adaptation, explain why find it interesting.

The idea of adaptation is worth learning. (1) (2) (3) (4) (5) (6)

Explain why you find this idea worth learning or why you do not find it worth learning.

I am interested in the idea of evolution that was taught the past couple weeks. (1) (2) (3) (4) (5) (6)

If you are interested in evolution, explain why find it interesting.

The idea of evolution is worth learning. (1) (2) (3) (4) (5) (6)

Explain why you find this idea worth learning or why you do not find it worth learning.

Assessment of Understanding

1. What is evolution? (2 pts)

2. Name four kinds of evidence that support evolutionary relationships between organisms and give an example of each. Explain how the evidence shows that the organisms are related through evolution. (12 pts)

3. How does the case of the moth of England represent an adaptive shift? (6 pts)

4. There was a population of lizards that lived on an island. A creek ran through the middle of the island, essentially cutting the population in half. The creek expanded in size, eventually becoming a wide, deep river. On one side of the river, there were mountains with cooler temperatures. On the other side, there was a tropical, hot climate. Describe two differences we might see in the lizard populations, and tell how those differences came about (what processes of evolution would be involved?) (10 pts)

5. Choose your favorite two (2) animals from what we have seen either in films, at the zoo, or at the species survival visit. Describe at least three adaptations each of the two animals has and explain how those adaptations give the animal survival advantages in their particular environment (be sure to include a description of their environment) (18 pts)

6. Imagine you are an explorer in a mountainous region. There a lots of rocks, some short grass, pine trees, and snow on the peaks. The temperature varies from 20 to 60 degrees in the summer and from - 30 to 30 degrees in the winter. It snows a lot in winter. Other animals in the area include, insects, fish in the streams and lakes, various birds, small rodents (mice, picas), deer, mountain sheep, black bears, and a few grizzly bears. You are lucky enough to discover a new creature. Describe this creature and list four ways that it is adapted to the environment. (10 pts)

Follow-up Survey

For all Likert scale items, 1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = slightly agree, 5 = agree, 6 = strongly agree.

For all frequency items, 1 = never, 2 = rarely, 3 = occasionally, 4 = regularly, 5 = frequently, 6 = all the time.

Active use items:

How often do you think about or see examples of adaptation?	(1) (2) (3) (4) (5) (6)
How often do you talk to other people about adaptation?	(1) (2) (3) (4) (5) (6)
How often do you think about or see examples of evolution?	(1) (2) (3) (4) (5) (6)
How often do you talk to other people about evolution?	(1) (2) (3) (4) (5) (6)

Value items:

I like learning about adaptation.	(1) (2) (3) (4) (5) (6)
The idea of adaptation is meaningful and interesting to me.	(1) (2) (3) (4) (5) (6)
I value the idea of adaptation because it makes things in the world (such as animals, plants, and humans) more interesting or meaningful.	(1) (2) (3) (4) (5) (6)
I like learning about evolution.	(1) (2) (3) (4) (5) (6)
The idea of evolution is meaningful and interesting to me.	(1) (2) (3) (4) (5) (6)
I value the idea of evolution because it makes things in the world (such as animals, plants, and humans) more interesting or meaningful.	(1) (2) (3) (4) (5) (6)

Follow-up assessment items:

In a lab, we looked at the adaptations of the snake, cat, wolf, shark, deer, and fox. Choose one of these animals and describe its adaptations. Also describe its environment and how the adaptations help it survive in that environment. (11 pts.)

Describe how the animal developed these adaptation. (8 pts.)

Appendix B

Table 7
Initial Survey Results

Variable	Response Categories	Idea-based Class	Case-based Class	Sig.
"I am interested in the actual science ideas that have been taught in this class."	Mean on 6 pt. scale (1=strongly disagree, 6=strongly agree):	3.5	4.1	
Reasons for finding them interesting (of those who did find them interesting)	They have expanded their perception	45%	56%	
	They like to learn	36%	25%	
	The ideas have utility value	9%	6%	
	Other	9%	13%	
"The ideas taught in this class are worth learning."	Mean on 6 pt. scale (1=strongly disagree, 6=strongly agree)	4.1	4.7	*
Reasons for finding them worth learning (of those who did find them worth learning)	They have expanded their perception	31%	32%	
	They are important to learn/everything is worth learning	31%	32%	
	The ideas have utility value	38%	32%	
	Other reason why they're worth learning	0%	5%	
Frequency with which students talk to others about class concepts, when outside of class	Never	19%	24%	
	Once a month	31%	14%	
	Once every two weeks	13%	24%	
	Once a week	31%	19%	
	Once a day	0%	19%	
	More than once a day	6%	0%	
Number of times that students thought about class concepts or used them in some way, when outside of class	Never	19%	15%	
	Once or twice	38%	50%	
	Three to five times	25%	15%	
	Six to nine times	19%	5%	
	Ten to fifteen times	0%	15%	
	More than fifteen times	0%	0%	
"I am interested in animals"	Mean on 6 pt. scale (1=strongly disagree, 6=strongly agree)	5.1	5.4	
What students think about when they see animals at the zoo	Think about adaptations, evolution, or endangered species	12%	10%	
	Think about other things or don't really think about anything	88%	90%	

Table 7 (cont'd)

What students think about when they see animals other places, such as in the wild, on the farm, or around the house	Think about adaptations, evolution, or endangered species	6%	5%	
	Think about other things or don't really think about anything	94%	95%	
"I love learning about animals"	Mean on 6 pt. scale (1=strongly disagree, 6=strongly agree)	4.8	4.7	
"I know a lot about the ideas of adaptation and evolution"	Mean on 6 pt. scale (1=strongly disagree, 6=strongly agree)	3.1	3.5	

* Significant at $p < .05$ level