Teaching for Transformative Experiences in Science: An Investigation of the Effectiveness of Two Instructional Elements

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This small-scale, exploratory study examines the effectiveness of two teaching elements (the artistic crafting of content and the modeling and scaffolding of perception and value) at fostering transformative experiences. The construct of a transformative experience was derived from Dewey’s work and is defined as an expansion of perception and value resulting 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 preintervention 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 transformative experience. Further, it was found that students from both classes who engaged in at least some form of transformative experience scored significantly higher than other students on a follow-up assessment of understanding but not on a postintervention assessment of understanding.

Many have argued that science education should enrich students’ everyday experience. This argument is inherent in the rhetoric of various science education reforms (DeBoer, 1991) and in prominent views of scientific literacy (Chun, Oliver, Jackson, & Kemp, 1999; Laugksch, 2000). Indeed, one would likely be hard-pressed to find a teacher, student, parent, or science educator willing to argue that science education should not enrich students’ everyday experience. Thus, it is surprising that we have not developed a body of research that examines the issue of how, or if, science concepts enrich the quality of students’ immediate, everyday experience. In general, the various perspectives on science education have focused more on how engagement in enriching experience fosters conceptual development/change and less on how engagement with concepts fosters enriched experiences.
In prior work (Girod, 2000, 2001; Pugh, 1999a, 1999b, 2000; Wong, Pugh, & The Dewey Ideas Group at Michigan State University, 2001), my colleagues and I have begun addressing the latter issue by turning to the work of Dewey. We find Dewey’s work particularly helpful because pragmatists such as Dewey were concerned with the consequences that concepts have on the experience of individuals (Cherryholmes, 1999; Posner, 1991). Further, Dewey (1934/1958) developed an extensive theory of aesthetic experience, which defines one important type of enriched experience. Unfortunately, Dewey’s writing on aesthetic experience was not well connected to his other writings on concept formation and education. Our goal has been to connect these aspects of Dewey’s work and make applications to the field of science education. In so doing, we develop the construct of a transformative experience. This construct represents one type of enriched experience that can take place as a result of engagement with a concept. I summarize our work in relation to this construct and then address the central question of this article: How can we teach for transformative experiences?

THE CONSTRUCT OF TRANSFORMATIVE EXPERIENCE

Late in his career, Dewey (1934/1958) turned to the arts because he felt the arts epitomized an optimal type of enriched 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)

An experience has various dramatic qualities, such as wholeness, uniqueness, and unifying emotion (Dewey, 1934/1958, chap. 3). However, as the quote suggests, an experience is centrally defined by an expansion of perception and value. In an experience, a person comes to see some aspect of the world (which may including other people or oneself) in a new way, to find new meaning in this aspect of the world, and to value this new way of seeing. Dewey felt that the arts had a unique power or mission to bring about such a transformation of perception and value (p. 104). Jackson (1998) comments, “One of [art’s] ultimate purposes, in Dewey’s view, is to reawaken our sensibilities, causing us to see once again what we have come to overlook” (p. 27).

For instance, if an individual truly has an experience in relation to an encounter with a Monet painting, then his or her future experience and
interaction with the world will be transformed. The individual may be so
moved by Monet’s renderings of the world, that he or she goes out and sees
the world through Monet’s eyes—seeing a celebration of light within shad-
ows and a brilliance of color within grays. In other words, the individual is
compelled to act, to see the world anew. And by doing so, the individual’s
perception and valuing of the world is expanded. He or she sees shadows
and grays more deeply and, at least for a time, attaches greater value to
them.

Although Dewey acknowledges that an experience is not confined to the
arts, he does not refer to the construct in other writings. However, as I will
try to illustrate, the construct appears to be inherent in his discussion of
concept formation. Dewey (1933) discusses concept formation in relation to
the process of reflective thinking. In this process, concepts, which he defines
as established meanings, develop out of ideas, which are possibilities in the
Deweyan scheme (p. 132). In other words, individuals (or communities)
start by holding a piece of knowledge as a possibility—a possible way of
seeing, examining, or experiencing the world. According to Dewey, this
idea (i.e., possibility) awakens anticipation and initiates action—a trying out
of the idea. He 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” (pp.104–105). If confirmed,
it becomes a concept. But how is an idea confirmed? This is where the
notion of an experience comes back into play.

Dewey argues that ideas are confirmed by the consequences that they
have on everyday experience. He (1929/1988) comments, “Ideas are worth-
less 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). By
“rearrange and reconstruct,” Dewey means that ideas invest aspects of the
world with new value and meaning; they “render them more significant,
more luminous to us, and make our dealings with them more fruitful”
ments 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).
Hence, in Dewey’s theory, a worthwhile idea fulfills the same function as art
in that it transforms perception and value. It allows one to see and expe-
rience (rearrange and reconstruct) aspects of the world in a new, meaning-
ful (more significant, more luminous, more fruitful) way.

As applied to science education, Dewey’s work suggests that science
concepts can engage individuals in transformative experiences, if those
individuals engage with the concepts as ideas (i.e., if they engage with them
as possibilities that need to be acted upon and tried out). Evidence that
science concepts can foster transformative experiences comes from the
personal accounts of scientists. For example, Dawkins (1998) comments, “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). For Dawkins, it was not art but the concepts found in science books that allowed him to see the world in a wonderful, new way.

To summarize much of what has been said, a transformative experience may be defined by three principle qualities: 1) active use of the concept, 2) an expansion of perception, and 3) an expansion of value. Active use means the individual seeks out or takes advantage of opportunities to use the concept as a potential lens for more fully perceiving the world (i.e., the individual engages with the concept as a conditionally held idea that needs to be acted upon and tried out). I contrast active use with nonactive use. Nonactive use occurs when individuals are highly coerced into using the concept. For instance, using the concept of inertia to answer a question on a physics test would be an example of nonactive use. On the other hand, spontaneously using the concept 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 concept that proves to be personally worthwhile brings about the other two qualities; namely, it brings about an expansion of perception and value as was explained above. Basically, individuals undergo transformative experiences when they actively use a concept, find that it allows them to see aspects of the world in a new way, and personally value this way of seeing.

TEACHING FOR 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 the subject matter. My colleagues and I have found that such experiences do take place for some students in science classrooms, and we have provided illustrative descriptions of such experiences (Girod, 2001; Pugh, 1999b, 2000). However, questions remain about how well such experiences can be fostered and what teaching methods are effective at fostering them. There are likely diverse ways to foster such experience and elsewhere we offer some general metaphors for teaching for transformative experience (Wong et al., 2001). Here I propose some more specific elements that might be important in teaching for transformative experience. The first of these I refer to as the artistic crafting of content. Dewey (1934/1958) 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 further clarified.

As mentioned, Dewey (1933) states that concepts are established meanings, whereas ideas are conditionally held meanings. In particular, they are possibilities that 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—a powerful possibility—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.

Thus, one of the central tasks of teaching for transformative experience is to reanimate concepts, craft them into ideas. As Dewey (1902/1990) states, the subject matter “needs to be psychologized; turned over, translated into the immediate and individual experiencing within which it has its origin and significance” (p. 200). It may be that some concepts are so commonplace now that they cannot be fully reanimated. However, for a concept to be reanimated, 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 (Brown, Collins, & Duguid, 1989; Lave & Wenger,
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. The goal would be to create a context where particular ways of experiencing the world through concepts are displayed and valued and to help students come to participate more centrally 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. Specifically, the teacher would display how a concept functions as a true idea for him or her by modeling everyday use of the concept to more fully perceive the world and by modeling the excitement or satisfaction that comes from doing so. The teacher would also provide supported opportunities for students to use the concept to expand perception, first in-class and then out-of-class. The goal is to help students move from having in-class, supported experiences with the concept to having out-of-class transformative experiences.

The purpose of this study is to conduct a small-scale, exploratory investigation into the effectiveness of these elements at fostering transformative experiences. This goal was pursued by implementing these two instructional 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 compared with the outcomes of students in another class. The latter students were taught the same content using the case-study method, which is a different but well-regarded approach to science education. Hence, the research questions are 1) how effective are the two instructional elements (taken together) at fostering transformative experience? and 2) are these instructional elements more effective than the case-study method?

METHOD

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 that 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 deemphasized 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 and 6% were minorities. The comparison class had a total of 24 students; however, two students chose not to participate in the study. Of the remaining 22, 45% were females and 5% were minorities. Both classes contained predominately 10th-grade students. I taught a unit on adaptation and evolution in both classes during the intervention period, which lasted 2.5 weeks. For a month prior to the intervention, I visited the class regularly and taught occasionally so that students would be accustomed to my presence. Toward the end of the intervention, both classes (along with other zoology classes) went on a field trip to the zoo. This was done so that students could experience a context that afforded the use of the concepts of adaptation and evolution. Students toured the zoo in intermixed groups of about 10 with a zoo guide who talked about the endangered species.

Comparison of the Two Teaching Approaches

The experimental condition consisted of implementing the elements of teaching for transformative experience described previously. 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. I next 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. In addition, both approaches involved a deliberate structuring of content and use of modeling and scaffolding. However, the specific nature of the content structuring and the modeling and scaffolding differed (see Table 1).
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 value. First, I wanted students to appreciate and become interested in animals. So I had them talk about their favorite animal. Next, I told the students about some of my favorite animals, shared some of the more unique encounters I’ve had with wild animals, and even showed some home video footage of a moose and grizzly bear I had seen over the summer. Then I expressed my fascination with animals and told the students that the purpose of the upcoming unit was to learn to better appreciate animals; for the next few weeks, zoology would be an animal appreciation course. I explained,

What we want to do this week is learn more about how every animal is truly an amazing design. Because every animal . . . is designed to survive and thrive in a particular environment. And when you learn how to see animals in terms of how they’re adapted to their environment, every animal becomes an amazing creation.

Then I foreshadowed some of ways we would learn to appreciate animals. For example, I told them we could learn to see the polar bear as a walking greenhouse and even the common cat as a marvel of nature.

My goal here was to awaken students’ anticipation about how the concept of adaptation could allow them to see animals in an exciting, new way. I wanted students to be alive with the idea (i.e., the possibility) of seeing

Table 1. Comparison of teaching approaches used in the experimental and control conditions

<table>
<thead>
<tr>
<th>Content structured through . . .</th>
<th>Idea-Based Class</th>
<th>Case-Based Class</th>
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<tbody>
<tr>
<td><strong>An artistic crafting of content:</strong></td>
<td>Concepts of adaptation and evolution were presented as compelling ideas which could transform the way we see, think about, and appreciate animals.</td>
<td><strong>The use of a case-study:</strong> Concepts of adaptation and evolution emerged through a class inquiry into the issue of endangered species.</td>
</tr>
<tr>
<td><strong>Perception, meaning, and value</strong></td>
<td>(How to experience science ideas)</td>
<td><strong>Inquiry</strong> (How to do science)</td>
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*Note.* Both combined direct instruction with much class discussion and group activities.
and appreciating animals for their adaptations. The subsequent week of
instruction on adaptation centered on the goal of seeing and appreciating
animals through the lens of adaptation. I crafted the concept of evolution
in a similar way with a similar purpose in mind. A told the students that
evolution was another lens—a historical lens—that we could use to appreciate
animals. I wanted them to realize that every animal has a historical
record hidden within it and that evolution is the lens that allows us to read
that record.

In the case-based class, content was structured around an endangered
species case study. 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 worldwide 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
deranged, 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 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. This inquiry was completed over three class
periods. Subsequent instruction involved a more formal discussion of how
to recognize various adaptations and completion of an animal artifact lab
(see later discussion). The concept of evolution was taught in a similar way
through an extension of the endangered species case study.

Hence, in the idea-based class, I presented the concepts directly as comp-
pelling ideas, and I tried to emphasize what was so compelling about them
and how they could lead to transformative experiences. In the case-based
class, the concepts emerged out of the students’ inquiry into the problem
of endangered species, and I merely helped to formalize the students under-
standing (while also guiding their inquiry).

Modeling and Scaffolding

In the idea-based class, modeling and scaffolding was used to help students
participate in the experience of seeing and appreciating the world through
the lens of adaptation. Here I will describe some of the modeling and
scaffolding used for teaching the concept of adaptation. Similar methods
were used in teaching evolution. 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 the polar bear as a walking greenhouse (polar bear fur employs clear,
hollow fibers to trap heat like a greenhouse). At times I also talked about my current experiences of seeing or thinking about adaptations in my everyday life. For instance, one day I began class by stating, “While driving here, I passed a bunch of Canadian geese and I started to think, I began to wonder, ‘Why do they have a black head and white neck? What’s the adaptive purpose?’” I also talked with the students about how my daughter and I were observing the adaptation of birds that came to her homemade birdfeeder. After sharing experiences such as these, I sometimes asked the students if they had any similar experiences. If so, I let them share these experiences. I even modeled my own beliefs about science and education to create a classroom environment that valued transformative experience with the content. I told the students,

My personal perspective is science isn’t worth much [to you] if it doesn’t sort of make the world more meaningful to look at; help you to understand things or make some part of your world more interesting . . . . When I teach, what I really want you to do is to try and be able to see things in a new way, in a different way.

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. For instance, I used the students’ shoes as a metaphor for discussing the relationship between form, function, and environment. Then I helped them identify key animal forms we could pay attention to (feet, color, covering, etc.) when observing animals. The next day, I guided the students as they identified the adaptations of animals in videos (including the bear and moose mentioned earlier). The following day, the students completed a lab in which they worked in groups to describe the adaptations of various animal artifacts (shark jaws, wolf pelt, mountain goat and moose hair, fox and cat skull, deer hoof, and others).

These same basic activities (minus the shoe metaphor) were used in the case-based class as well, subsequent to their inquiry into the problem of endangered species. However, in the idea-based class, statements about the significance of learning to see adaptations, out-of-school opportunities for seeing adaptations, and my own fascination with animal adaptations (see previous discussion) were carefully embedded in the activities. For instance, both classes completed the animal artifacts lab. But in the idea-based class, I more carefully framed the activity in terms of its potential to expand perception and value. I told the students directly that we were going to practice observing adaptations in actual animal artifacts so that we could learn to see these adaptations in the animals we might encounter outside of class and better appreciate them. As I mingled with the students during the lab, I also took opportunities to say things like,
“Look, this is so cool. Check out how the wolf has different types of fur. See if you can figure out what the different types of fur might be for.” In the case-based class, I simply introduced the lab as an opportunity to practice seeing adaptations (but I did connect it to the issue of endangered species). I also pointed out such things as the different types of wolf fur, but I left out the “this is so cool” part. Another difference between the classes was that in the idea-based class, I connected the activities to my original efforts of crafting the concept of adaptation into a compelling idea. So, for instance, I reiterated the notion that every animal is an amazing creation, and the activities were presented as a means to help us appreciate the animals for the amazing creations that they are. Also, through these activities and the modeling that accompanied them, I revisited things that had been previously foreshadowed, such as how the polar bear can be seen as a walking greenhouse.

In the idea-based class, I followed up these activities with other activities designed to help and encourage the students to look for adaptations outside of class. As a class, we discussed adaptations we might see outside of class, including human creations based on (or analogous to) animal adaptations. Finally, on a Monday at the end of the adaptation unit, I had the students write about any out-of-class experiences they had of seeing and thinking about adaptations over the weekend. Students who did have such experiences were allowed to share their experiences with the rest of the class. Hence the students themselves became models of expansion of perception. So, overall, the activities in the idea-based class were designed to support students as they moved from having peripheral, in-class participation in the experience of seeing animals through the lens of adaptation to having their own out-of-class experiences.

The case-based class also involved the use of modeling and scaffolding. Some modeling and scaffolding of how to see animals in terms of adaptations was inherent in the activities mentioned previously. However, I avoided specific attempts to model experiences I was having of seeing the world through the lens of adaptation. For example, I did not mention the Canadian geese. I also avoided specific scaffolding statements and activities that encouraged the students to use the idea of adaptation to see their everyday world differently. For instance, I did not have them write and talk about examples of adaptations they had seen over the weekend. I also avoided direct statements that conveyed my enthusiasm for seeing the world through the lens of adaptations. I did not tell them how fascinated I was with certain animals and their adaptations. However, in the case-based class, I did make specific attempts to model the process of scientific inquiry and to scaffold the students’ efforts in researching endangered species. Hence, both classes involved some deliberate modeling and scaffolding, but the nature of this modeling and scaffolding differed.
VARIABLES

Operational Definition of Transformative Experience

The three key qualities of a transformative experience are 1) active use of the concept, 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, evolution, or both. Expansion of value was defined as an increase in interest in animals and the zoo trip because of the concepts of adaptation, evolution, or both. It was also defined as finding the concepts of adaptation and evolution interesting and worth learning because the concepts expanded their perception (i.e., because the concepts allowed them to see animals in a new way and to better appreciate and understand the animals).

Control Variables

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

Instruments

An initial survey was given immediately preceding the intervention to identify any preexisting differences between the classes. This survey contained five Likert scale items (e.g., “I am interested in the actual science ideas that have been taught in this class”; “I love learning about animals”) that students responded to on a 6-point scale with 1 = strongly disagree and 6 = strongly agree. It also contained two frequency items (e.g., 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?) that students responded to on 6-point scale with 1 = never and 6 = more than once a day. Finally it also contained four open-response items (e.g., 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).

After the 1st week of the intervention, a class assignment was used to determine whether students were actively using the concept of adaptation.
Students were asked to write about any instances of thinking about or seeing examples of adaptation or endangered species that they could remember. At the conclusion of the zoo trip, a survey was given to assess the degree to which students engaged in the qualities of transformative experience while at the zoo. This survey contained four open-response items asking students to describe how they perceived animals differently on this trip (if they did), examples of when they thought about the concepts of adaptation or evolution (if they did), and why the concepts made the trip more interesting (if they did). For example, one item read, “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.”

A postintervention survey was administered at the conclusion of the intervention (after the trip to the zoo). This survey contained six Likert scale items assessing situational interest adapted from Mitchell’s (1993) Interest Survey. It also contained four 6-point Likert scale items (1 = strongly disagree and 6 = strongly agree) assessing students’ interest in the concepts of adaptation and evolution as well as their perception of the worthwhileness of learning these concepts (e.g., “I am interested in the idea of adaptation that was taught the past couple weeks,” “The idea of evolution is worth learning”). The survey also contained four frequency items that asked students to report the number of times they talked with others about the concepts outside of class and the number of times they thought about or saw examples of the concepts (e.g., When outside of class, how often did you think about adaptations or see examples of adaptations?). 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. In addition, the survey contained nine open-response items. Two of these items asked students to write down instances of having thought about or seen examples of the concepts (e.g., If you did think about and see examples of adaptations, list the examples. Give details.). Two more asked students to comment on how their perception of animals had changed during the unit, if it had at all (e.g., 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.). One item asked students to comment on any change in their interest in animals (i.e., Has your interest in animals changed over the past two weeks? If so, explain how your interest in them has changed). The final four open-response items asked students to explain why they found the concepts interesting or worthwhile, if they did at all (e.g., If you are interested in the idea of adaptation, explain why you find it interesting).

An assessment of understanding, consisting of six open-response items, was also given at the conclusion of the intervention. These items were designed to assess students’ conceptual understanding (as opposed to basic recall). Below is a sample item:
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?).

A month after the intervention, a follow-up assessment of understanding was administered. This assessment contained two open-response items similar to those on the prior assessment of understanding. At the same time, a follow-up survey was administered. This survey contained four items assessing everyday use of the concepts (e.g., How often do you think about or see examples of adaptation?). Students responded by marking the appropriate category on a 6-point scale, where 1 = never, 2 = rarely, 3 = occasionally, 4 = regularly, 5 = frequently, and 6 = all the time. It also contained four items assessing students’ interest in the concepts (e.g., “I like learning about evolution”) and two items assessing the degree to which students value the concepts because they expanded their perception (e.g., “I value the idea of evolution 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 6-point Likert scale, where 1 = strongly disagree and 6 = strongly agree. As additional data sources, the classrooms were videotaped, and postintervention interviews were conducted with some students.

ANALYSES

The open-response items were coded into categories by two independent raters (a description of these categories is given with the results). Interrater 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. Two independent raters using a scoring rubric also coded responses to the assessments of understanding. 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 pretest items and control variables. A one-sided test was used for the experimental variables.1
RESULTS

In this section, I will first report the specific results for each of the instruments. With the exception of the initial survey, I will first give an overview of how the idea-based class performed and then address the differences between the idea-based class and the case-based class. Next, I will provide an overall report of the differences between the classes in terms of the three qualities of transformative experience (i.e., active use, expansion of perception, and expansion of value). Finally, I will report on differences between the classes in terms of the percentages of students who fully and partially underwent transformative experiences.

CONTROL VARIABLES

Situational Interest

For each student, the six situational interest items on both the initial survey and the postintervention 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 \( M = 3.9 \) on a 6-point scale; \( SD = .88 \) and fairly high level of situational interest on the postintervention survey \( M = 4.7; SD = .72 \). There were no significant differences between the two classes.

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 \( (SD = 6.2) \). The mean for students in the case-based class was also 43.4 \( (SD = 8.1) \).

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 transformative experiences. No significant differences were found on measures of use of class content, interest in class content, interest in learning about animals,
knowledge and use of the concepts of adaptation and evolution, or interest in the concepts of adaptation and evolution.

Class Assignment

All 17 of the participating students in ideas-based class and 18 of the 22 participating students in the case-based class completed an in-class writing activity. Overall, the majority of students in the idea-based class reported in this activity that they saw examples of adaptations or thought about or talked to others about adaptations over the weekend following the 1st week of the intervention (students were not required or asked to use the concept of adaptation in this way). Moreover, there was a large difference between the two classes. In the idea-based class, 71% of the students were able to describe at least one valid experience of seeing, thinking about, or talking with others about adaptations or endangered species (descriptions were considered valid if students referred to adaptations or endangered species in a scientific sense). 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, $U (N = 35) = 67.5$, $p < .01$.

An example of how a student in the idea-based class was using the concept of adaptation to see and think about the 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

Twelve students in the idea-based class and 19 students in the case-based class were able to attend the zoo trip. Of the students in the idea-based class who attended, 25% reported that their perception had changed in that they now thought about the animals in terms of adaptation or evol-
tion. 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). Because 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 adaptations or evolution. And just under half (42%) reported that the concepts of adaptation and evolution made the trip to the zoo more meaningful. 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 2). 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.

Postintervention 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 experienced a greater expansion of value than students in the case-based class.

Table 3 summarizes the results of the items assessing active use of the concepts. For illustrative purposes, means and standard deviations were calculated for the frequency items by converting the categories to a 6-point numeric scale with 1 = never and 6 = more than fifteen times. As Table 3 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. Also, 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 an example of thinking about or seeing adaptation, 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.”

Overall, there were significant differences between the two classes in terms of reported use of the concepts in everyday life. Students in the idea-based class reporting that they talked to others about adaptations
Table 3. Postintervention survey results: Active use items

<table>
<thead>
<tr>
<th>Variable</th>
<th>Response Categories</th>
<th>Idea-Based Class ((n = 17))†</th>
<th>Case-Based Class ((n = 22))</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of times that students</td>
<td>Never</td>
<td>12%</td>
<td>55%</td>
<td></td>
</tr>
<tr>
<td>talked with others about</td>
<td>Once or twice</td>
<td>41%</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>adaptation outside of class</td>
<td>Three–five times</td>
<td>41%</td>
<td>9%</td>
<td>**</td>
</tr>
<tr>
<td>others about adaptation outside of class</td>
<td>Six–nine times</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>adaptation outside of class</td>
<td>Ten–fifteen times</td>
<td>0%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More than fifteen times</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Mean (Standard deviation)††</td>
<td>2.41 (.80)</td>
<td>1.69 (.99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of times that students</td>
<td>Never</td>
<td>0%</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>thought about adaptations or</td>
<td>Once or twice</td>
<td>41%</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td>saw examples of adaptations</td>
<td>Three–five times</td>
<td>24%</td>
<td>5%</td>
<td>**</td>
</tr>
<tr>
<td>outside of class</td>
<td>Six–nine times</td>
<td>18%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ten–fifteen times</td>
<td>12%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More than fifteen times</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Mean (Standard deviation)</td>
<td>3.18 (1.22)</td>
<td>1.91 (.87)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of examples that students were able to provide of thinking about or seeing examples of adaptation</td>
<td>Provided no valid examples</td>
<td>29%</td>
<td>73%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provided one valid example</td>
<td>24%</td>
<td>23%</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Provided more than one valid example</td>
<td>47%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Mean (Standard deviation)</td>
<td>2.19 (1.28)</td>
<td>1.5 (.91)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of times that students</td>
<td>Never</td>
<td>25%</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td>talked with evolution outside of class</td>
<td>Three–five times</td>
<td>56%</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>others about evolution</td>
<td>Once or twice</td>
<td>38%</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Three–five times</td>
<td>6%</td>
<td>0%</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Six–nine times</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ten–fifteen times</td>
<td>0%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More than fifteen times</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Mean (Standard deviation)</td>
<td>2.13 (1.63)</td>
<td>1.23 (.43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of examples that students were able to provide of thinking about or seeing examples of evolution</td>
<td>Provided no valid examples</td>
<td>75%</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provided one valid example</td>
<td>19%</td>
<td>5%</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Provided more than one valid example</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at \( p < .05 \) level. ** Significant at \( p < .01 \) level.
† Note: one student was absent during the week of instruction on evolution and did not respond to the evolution items on the survey. Hence there is only an \( n \) of 16 for these items.
†† \( Never = 1, More \ than \ fifteen \ times = 6. \)
more frequently, \( U (N = 39) = 92.5, p < .01 \), and thought about or saw examples of adaptation more often, \( U (N = 39) = 73, p < .01 \). Likewise, students in the idea-based class reporting that they talked to others about evolution more frequently, \( U (N = 38) = 98, p < .01 \), and thought about or saw examples of evolution more often, \( U (N = 38) = 109.5, p < .05 \). In addition, students in the idea-based class were able to provide a greater number of valid descriptions of having thought about or seen examples of adaptation, \( U (N = 39) = 88, p < .01 \), and evolution, \( U (N = 38) = 139.5, p < .05 \).

Table 4 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 2-week intervention in that now they see and think about animals in terms of adaptations, evolution, endangered species, or all three. 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 in the case-based class (76% compared with 32%) and the difference was statistically significant, \( \chi^2 (2, N = 39) = 7.69, p < .05 \).

Table 5 presents the results of the items assessing expansion of value. 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Response Categories</th>
<th>Idea-Based Class ( (n = 17) )</th>
<th>Case-Based Class ( (n = 22) )</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in the way students think about animals</td>
<td>• Has changed in that now they think about animals in terms of adaptations, evolution, and/or endangered species</td>
<td>76%</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Has changed in other ways</td>
<td>6%</td>
<td>14%</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>• Has not changed</td>
<td>18%</td>
<td>55%</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at \( p < .05 \) level.
Table 5. Postintervention survey results: Expansion of value items

<table>
<thead>
<tr>
<th>Variable</th>
<th>Response Categories</th>
<th>Idea-Based Class (n = 17\†)</th>
<th>Case-Based Class (n = 22)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in students’ interest in animals</td>
<td>• Has increased because of the concepts they have learned</td>
<td>23.5%</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Has increased for other reasons</td>
<td>18%</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Didn’t increase because they were already interested in animals</td>
<td>23.5%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Didn’t change</td>
<td>35%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>“I am interested in the idea of adaptation”</td>
<td>Mean (standard deviation)††</td>
<td>3.94 (.77)</td>
<td>3.68 (1.36)</td>
<td></td>
</tr>
<tr>
<td>Reasons for finding adaptation interesting</td>
<td>• It has expanded their perception</td>
<td>86%</td>
<td>81%</td>
<td></td>
</tr>
<tr>
<td>(for those who did find it interesting, (n = 30))</td>
<td>• They like to learn</td>
<td>7%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Other</td>
<td>7%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>“The idea of adaptation is worth learning”</td>
<td>Mean (standard deviation)</td>
<td>4.26 (.83)</td>
<td>4.36 (1.22)</td>
<td></td>
</tr>
<tr>
<td>Reasons for finding the adaptation worth</td>
<td>• It has expanded their perception</td>
<td>40%</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>learning (for those who did find it worth</td>
<td>• It’s important to learn/everything is worth learning</td>
<td>40%</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>learning, (n = 32))</td>
<td>• It has utility value</td>
<td>20%</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Other</td>
<td>0%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>“I am interested in the idea of evolution”</td>
<td>Mean (standard deviation)</td>
<td>3.78 (.91)</td>
<td>3.86 (1.17)</td>
<td></td>
</tr>
<tr>
<td>Reasons for finding evolution interesting</td>
<td>• It has expanded their perception</td>
<td>60%</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td>(for those who did find it interesting, (n = 26))</td>
<td>• They like to learn</td>
<td>20%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• It has utility value</td>
<td>0%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Other</td>
<td>20%</td>
<td>31%</td>
<td></td>
</tr>
<tr>
<td>“Idea of evolution is worth learning”</td>
<td>Mean (standard deviation)</td>
<td>4.06 (.77)</td>
<td>3.80 (1.33)</td>
<td></td>
</tr>
<tr>
<td>Reasons for finding evolution worth learning</td>
<td>• It has expanded their perception</td>
<td>50%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>(for those who did find it worth learning, (n = 30))</td>
<td>• It’s important to learn/everything is worth learning</td>
<td>36%</td>
<td>44%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• It has utility value</td>
<td>0%</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Other</td>
<td>14%</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at \(p < .05\) level.
†Note: one student was absent during the week of instruction on evolution and did not respond to the evolution items on the survey. Hence there is only an \(n\) of 16 for these items.
††Strongly disagree = 1, Strongly agree = 6.
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 concepts. 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 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 a 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. If this group of students is combined with those who clearly reported increased interest in animals due to the concepts, then the percentage of students who likely expanded their valuing of animals raises to 47% in the idea-based class and 27% in the case-based class. However, this difference is not statistically significant.

On average, students in the idea-based class slightly agreed that the concepts of adaptation and evolution were interesting and worth learning. Answers to the open-response items (e.g., If you are interested in the idea of adaptation, explain why you find it interesting) were coded into 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 something (i.e., they allowed them to understand things, appreciate things, see things in a different way, and so on). A second category included responses indicating the students found the concepts interesting because they liked to learn (i.e., they found it interesting to learn any new concepts) or they 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). 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 experience, whereas the others do not. 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. Forty percent 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.” Sixty percent 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. Of the students who did find the concepts interesting, worthwhile, or both, 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. However, the only statistically significant difference was for the item assessing reasons why the students found the concept of evolution worth learning, $\chi^2 (3, n = 30) = 2.07, p < .05$.

Follow-Up Survey

Each of the students who participated in the study completed a follow-up survey. In the analysis, the two items assessing frequency of use of the
concept of adaptation were combined as were the two items assessing frequency of use of the concept of evolution (as mentioned earlier, these items used a common 6-point scale where 1 = never, 2 = rarely, 3 = occasionally, 4 = regularly, 5 = frequently, and 6 = all the time). The two items assessing interest in adaptation and the two items assessing interest in evolution were similarly combined. Table 6 summarizes the results. 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, $t(37) = 2.55, p < .05$, 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.

Sixteen of the participating students in the idea-based class and 20 of the participating students in case-based class completed the follow-up assessment of understanding. Students in the idea-based class performed well on the adaptation item but poorer on the evolution item. Hence, on average, they seem to have maintained an understanding of the principle of adaptation, but their understanding of the evolutionary processes seems to have declined 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, $t(34) = 2.56, p < .05$.

Table 6. Follow-up results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (Standard Deviation)</th>
<th>Idea-Based Class</th>
<th>Case-Based Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active use of the concept of adaptation</td>
<td></td>
<td>2.53 (.58)</td>
<td>2.05 (.60)*</td>
</tr>
<tr>
<td>Interest in adaptation</td>
<td></td>
<td>4.15 (1.03)</td>
<td>3.98 (1.84)</td>
</tr>
<tr>
<td>Value concept of adaptation because it expands perception</td>
<td></td>
<td>4.35 (1.00)</td>
<td>3.80 (1.30)</td>
</tr>
<tr>
<td>Active use of the concept of evolution</td>
<td></td>
<td>2.37 (.75)</td>
<td>2.28 (.70)</td>
</tr>
<tr>
<td>Interest in evolution</td>
<td></td>
<td>3.94 (1.34)</td>
<td>3.85 (.89)</td>
</tr>
<tr>
<td>Value concept of adaptation because it expands perception</td>
<td></td>
<td>3.76 (1.48)</td>
<td>3.73 (.97)</td>
</tr>
<tr>
<td>Understanding of the concepts of adaptation and evolution</td>
<td></td>
<td>10.9 (4.61)</td>
<td>7.4 (4.67)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(n = 16)</td>
<td>(n = 20)</td>
</tr>
</tbody>
</table>

*Significant at the $p < .05$ level.
GENERAL TRENDS

Table 7 helps to summarize the results across instruments and identify general trends. 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 that were not indicators of a 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 ($\phi^2$). 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 ($\tau^2$). Cohen (1988) states that, as a general rule of thumb, .01 is small, .09 is medium, and .25 is large. Table 7 uses a bar graph to illustrate the magnitude and direction of the effect sizes.

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 7 illustrates that the results for the expansion of value items show a consistent trend in that, on all substantive differences, students in the idea-based class expressed 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 $\phi^2 = .04$, which is
Table 7. Relative effect size for items across all instruments

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Case-Based Class</th>
<th>Idea-Based Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>From writing assignment: Number of valid examples of seeing, thinking about, or talking with someone about adaptations or endangered species</td>
<td></td>
<td><strong>$\chi^2 = 29$</strong></td>
</tr>
<tr>
<td>From zoo survey: Thought about or saw examples of adaptation or evolution at the zoo at least sometimes on their own</td>
<td></td>
<td>$\chi^2 = .06$</td>
</tr>
<tr>
<td>Provided at least one valid example of seeing or thinking about adaptation or evolution</td>
<td></td>
<td>$\chi^2 = .04$</td>
</tr>
<tr>
<td>From post-intervention survey: Number of times talked with others about adaptation</td>
<td></td>
<td><strong>$\chi^2 = .18$</strong></td>
</tr>
<tr>
<td>Number of times thought about or saw examples of adaptation</td>
<td></td>
<td><strong>$\chi^2 = .28$</strong></td>
</tr>
<tr>
<td>Number of valid examples of seeing or thinking about adaptation</td>
<td></td>
<td><strong>$\chi^2 = .23$</strong></td>
</tr>
<tr>
<td>Number of times talked with others about evolution</td>
<td></td>
<td><strong>$\chi^2 = .16$</strong></td>
</tr>
<tr>
<td>Number of times thought about or saw examples of evolution</td>
<td></td>
<td><strong>$\chi^2 = .14$</strong></td>
</tr>
<tr>
<td>Number of valid examples of seeing or thinking about evolution</td>
<td></td>
<td><strong>$\chi^2 = .08$</strong></td>
</tr>
<tr>
<td>From follow-up survey: Active use of the concept of adaptation items</td>
<td></td>
<td><strong>$\chi^2 = .14$</strong></td>
</tr>
<tr>
<td>Active use of the concept of evolution items</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Expansion of Perception Items</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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</td>
<td></td>
<td>$\chi^2 = .08$</td>
</tr>
<tr>
<td>From post-intervention survey: Perception changed in that how they see and think about animals in terms of adaptations, evolution, and/or endangered species</td>
<td></td>
<td><strong>$\chi^2 = .20$</strong></td>
</tr>
<tr>
<td><strong>Expansion of Value Items</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From zoo survey: Reported that knowing about adaptation and/or evolution made the trip more meaningful or interesting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From post-intervention survey: Interest in animals increased because of the concepts students learned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Found adaptation interesting because it expanded their perception</td>
<td></td>
<td><strong>$\chi^2 = .01$</strong></td>
</tr>
<tr>
<td>Found adaptation worth learning because it expanded their perception</td>
<td></td>
<td><strong>$\chi^2 = .05$</strong></td>
</tr>
<tr>
<td>Found evolution interesting because it expanded their perception</td>
<td></td>
<td><strong>$\chi^2 = .17$</strong></td>
</tr>
<tr>
<td>Found evolution worth learning because it expanded their perception</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From follow-up survey: Interest in adaptation items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value the concept of adaptation because it expands perception</td>
<td></td>
<td><strong>$\chi^2 = .04$</strong></td>
</tr>
<tr>
<td>Interest in evolution items</td>
<td></td>
<td><strong>$\chi^2 = .04$</strong></td>
</tr>
<tr>
<td>Value the concept of evolution because it expands perception</td>
<td></td>
<td><strong>$\chi^2 = .02$</strong></td>
</tr>
<tr>
<td>Effect Size Scale: 15 0 15 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant at $p < .05$ level  ** significant at $p < .01$ level  $\chi^2$ or $\chi^2 < .01$

similar to the results on most of the other expansion of value items. Hence, the general trend in the data suggests that students in the idea-based class may have experienced a slightly greater expansion of value.
DID STUDENTS FULLY UNDERGO TRANSFORMATIVE EXPERIENCES?

Thus far I have discussed the degree to which the idea-based class as a whole engaged in the qualities of 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 a transformative experience is more than just the sum of its qualities. To undergo a transformative 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, evolution, or both, as ideas? The answer is yes and no. Yes some students, in both classes, did experience this 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 concepts (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 transformative experiences.

In looking across all the data for evidence that a student engaged in all the qualities of a transformative experience, I was able to identify four students (23.5%) in the idea-based class and two students (9.1%) in the case-based class who did engaged in a genuine transformative experience. 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 natural 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 what 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 evolu-
tion 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, and 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 Transformative Experience

Other groups of students experienced lesser forms of idea-based transformative experiences. They reported an expansion of perception but did not clearly display one of the other two qualities. For instance, one group of students reported an expansion of perception and active use, but 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 reported an expansion of perception and value, but, surprisingly, these students only reported using the concepts about once or twice. One of these students from the case-based class did not even use the concepts when at the zoo. Two students (11.8%) in the idea-based class and three students (13.6%) in the case-based class fit into this group.

The rest of the students did not seem to engage in any form of transformative experience. They may have displayed one quality, but overall they did not engage in anything that could be considered a transformative experience. Eight 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 a transformative experience, 1 = engaged in a lesser form of transformative experience, and 2 = engaged in a genuine 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, $U(N = 39) = 129.5, p < .05$ (see Table 8). The effect size was in the medium range ($\tau^2 = .09$). Overall, just over half (52.9%) of 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 transformative experience.

**DISCUSSION**

The results suggest that, in the context of this study, an artistic crafting of content and a modeling and scaffolding of perception and value were relatively effective instructional elements for fostering transformative experiences. A little over half the students in the idea-based class engaged in some form of transformative experience. More specifically, a large majority of these students reported making active use of the concepts of adaptation, evolution, or both, 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. In addition, a large majority also reported experiencing an expansion of perception in relation to animals. 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 transformative experience. On average, students in the idea-based class

<table>
<thead>
<tr>
<th>Category</th>
<th>Idea-Based Class ($n = 17$)</th>
<th>Case-Based Class ($n = 22$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaged in a genuine transformative experience</td>
<td>24%</td>
<td>9%</td>
</tr>
<tr>
<td>Engaged in a lesser form of transformative experience</td>
<td>30%</td>
<td>14%</td>
</tr>
<tr>
<td>Did not engage in a transformative experiences</td>
<td>47%</td>
<td>77%</td>
</tr>
</tbody>
</table>

Overall difference significant at $p < .05$ level.
engaged in transformative experience to a greater degree than students in
the case-based class did. More specifically, the results across instruments
were 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. A consistent trend in the data suggests that the
idea-based class experienced a slightly greater expansion of value, but over-
all the results are inconclusive on this aspect.

It should be noted that these results indicate the effectiveness of the two
instructional elements taken together. The study does not indicate whether
one of the elements had a greater impact on the results or whether either
would be effective if taken separately. In addition, this study does not
address the issue of how these instructional elements could be used in
 collaboration with other science education methods (including case-based
methods). For instance, an artistic crafting of content and a modeling and
scaffolding of perception could be embedded within a larger case-study
format. Such a combination of methods may increase the overall likelihood
that students will engage in transformative experiences. These issues need
to be addressed in future research.

Overall, the results of this exploratory study support the theory that the
two instructional elements help foster transformative experiences. How-
ever, future studies conducted on a larger scale in different contexts and
with different populations of students are needed to validate these results.
In addition to (or as part of) such validation studies, other research is
needed to answer questions raised by the current study. Next, I list and
discuss these questions.

WHY THE INCONCLUSIVE RESULTS FOR THE EXPANSION
OF VALUE ITEMS?

The findings raise the question of why the idea-based class was more effec-
tive than 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 transformative
experiences are not as effective at fostering an expansion in value as they
are at fostering the other qualities of transformative experience. An addition
to or modification of these elements may be needed to foster a signif-
ican
t 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 expan-
sion 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 talked about their experiences of using the concepts and how they were seeing animals through the lens of the concepts. However, they failed to express their emotions in relation to these experiences. They did not talk 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.” 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 effective 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 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 previously, 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. Future research needs to examine these possibilities.

WHAT’S UP WITH THE STUDENTS WHO ENGAGED IN A LESSER FORM OF TRANSFORMATIVE EXPERIENCE?

As mentioned earlier, some students expressed experiencing an expansion of perception; however, they did not clearly express experiencing one of the other two qualities of transformative experience. One group failed to clearly express an expansion of value, whereas the other group failed to report much active use. There are a few possible explanations for this outcome that are worth mentioning. 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 that afforded the use of the concepts.

These two groups point to the need for more studies that 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 a transformative experience” and “did not undergo a transformative experience.” Instead students engage in transformative experiences to varying degrees and in varying ways. This study begins to describe some of these different ways, but future research needs to construct more carefully 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.

WHAT ARE THE REASONS FOR THE CONTENT AND INDIVIDUAL DIFFERENCES?

One interesting aspect of the results was the occurrence of 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. Further, certain students appeared to intentionally abort transformative experiences with the concept of evolution because they rejected the concept for religious reasons (see later discussion). Future research needs to examine more carefully this issue of how (or if) certain content affords transformative experiences more than other content (or other types of content).

In addition to the content differences, there were large individual differences within each class. Such differences are to be expected—as Dewey (1938) suggests, experience results from a transaction between the individual and his or her environment (Verula, Thompson, & Rosch, 1992). The nature of this transaction, as it relates to transformative experience, needs to be examined in future research. One aspect of this transaction that should be examined is the willful “surrender” of the individual to the context, content, and experience. Dewey (1934/1958) argued that the undergoing of an experience (i.e., a transformative experience) requires
surrender—a momentary suspension of critical reflection and control (Wong, Packard, Girod, & Pugh, 2000). 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.” A student’s self-concept likely mediates this process. Students who see themselves as science people (or at least see themselves as people who enjoy learning in school) are likely more willing to surrender to the possibility of being moved by science concepts. In addition, particular self-concepts 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 an attempt at seeing the world in terms of evolution. Because of his religious beliefs (which were very central to his self-concept), he chose not to surrender to the experience of seeing the world through the lens of evolution.

IS THERE A RELATIONSHIP BETWEEN TRANSFORMATIVE EXPERIENCE AND ENDURING CONCEPTUAL UNDERSTANDING?

Finally, 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 transformative experiences and enduring conceptual understanding. To further examine the possibility of a relationship between engagement in transformative experience and enduring conceptual understanding, I compared the assessment scores of those (in both classes) who engaged in at least some form of transformative experience with those who did not. As would be predicted, a one-sided t test revealed that the students who engaged in at least some form of transformative experience scored significantly higher on the follow-up assessment of understanding, \( t(34) = 1.96, p < .05 \), but not on the original assessment of understanding.

Hence, there does appear to be a relationship between engagement in transformative experience and enduring conceptual understanding. However, these 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 obvious reason to suspect this is so). In addition, although the questions
on the two assessments were very similar in nature, the follow-up likely assessed a more narrow range of conceptual understanding, as it consisted of just two open-response items (as opposed to six on the initial assessment). Further studies are needed to confirm this relationship between engagement in transformative experience and enduring conceptual understanding. In addition, the nature of the relationship is unknown. Most likely there is an interactive relationship. On 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 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

In this study, the popular notion that science education should enrich students’ everyday experience was translated to mean the science education should bring about 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 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 transformative experience and the elements were relatively more effective than the case-based methods used in a control condition. However, it is important to recognize that the present study was a small-scale, exploratory study, and the results need to be replicated.

I wish to thank Jere Brophy, King Beach, Walt Hapkiewicz, and especially David Wong and Dick Prawat for their guidance, support, and confidence. I also thank Philip Jackson and the Deweyan Ideas Group at Michigan State University for their insights and collegiality. Finally, I thank the reviewers for their helpful comments.

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 Witte and Witte (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” (Witte & Witte, 1997, p. 415). The squared Kendall’s correlation coefficient provides a similar estimate.
References


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