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Theoretical Perspectives on Learning in an Informal Setting

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Abstract: Research into learning in informal settings such as museums has been in a formative state during the past decade, and much of that research has been descriptive and lacking a theory base. In this article, it is proposed that the human constructivist view of learning can guide research and assist the interpretation of research data because it recognizes an individual's prior knowledge and active involvement in knowledge construction during a museum visit. This proposal is supported by reference to the findings of a previously reported interpretive case study, which included concept mapping and semistructured interviews, of the knowledge transformations of three Year 7 students who had participated in a class visit to a science museum and associated postvisit activities. The findings from that study are shown in this report to be consistent with the human constructivist view of learning in that for all three students, learning was found to be at times incremental and at other times to involve substantial restructuring of knowledge. Thus, we regard that the human constructivist view of learning has much merit and utility for researchers investigating the development of knowledge and understanding emergent from experiences in informal settings. The theoretical and practical implications of these findings for teachers and staff of museums and similar institutions are also discussed. © 2003 Wiley Periodicals, Inc. J Res Sci Teach 40: 177–199, 2003

At the beginning of the 1990s, Feher (1990, p. 35) observed that "the study of learning in science museums is a field in its infancy." The intervening years have seen considerable growth and development in this field of research, although it can be regarded as having been in a formative stage throughout the decade. In an often cited review, Ramey-Gassert, Walberg, and Walberg (1994, p. 345) claimed that "much of the literature pertaining to learning in museums is anecdotal and craft wisdom," suggesting the lack of clarity and theoretical underpinning for such research. Indeed, Ramey-Gassert et al. frequently referred to "learning" and "museum learning" without defining or distinguishing between the two.

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By the middle of the decade there was widespread acceptance of the cognitive, affective, and social aspects of the learning experiences of visitors to museums and similar institutions[1] (Rennie & McClafferty, 1996), and Falk and Dierking (1992) had drawn attention to the physical, social, and personal contexts in which learning occurs. The highly stimulating and novel physical and social environments of museums has been linked to ineffective learning by visiting school students by some (Anderson, 1994; Kubota & Olstad, 1991). Others have argued that students enjoy visits to science museums tremendously and that increased interest and enjoyment of science activities constitute extremely valuable learning outcomes (Ayres & Melear, 1998; Ramey-Gassert et al., 1994), outcomes that persist over time (Rennie, 1994; Wolins, Jensen, & Ulzheimer, 1992). Not surprisingly, teachers and students engaged in visits to science museums regard having fun to be a major objective for their visit to the Queensland Sciencentre in Australia (Lucas, 1999, 2000), although they are not necessarily entirely comfortable with the notion that school work should be fun. Ansbacher (1998) argued that placing emphasis on museum learning as fun may be antithetical to the learning outcomes desired by teachers. Citing Dewey, he reasoned that if the experience is mainly fun, the learner may have learned something, but not necessarily what the teacher or museum educator had planned. The implication is that visitors may learn to pursue further fun rather than further learning.

A distinction has frequently been made between formal learning, such as might occur in the formal setting of schools, and informal learning, such as might occur in the informal environments of museums and similar locations. However, Dierking (1991) argued that the distinction may not be appropriate because ‘‘learning is learning, and it is strongly influenced by setting, social interaction, and individual beliefs, knowledge, and attitudes’’ (p. 4). In doing so, she stressed the complexity of the learning process in which setting has an important but not necessarily dominant role. In a similar manner, Hofstein & Rosenfeld (1996) pointed out that students in school classrooms can experience informal learning activities typically developed for out-of-school locations. They made the important recommendation that ‘‘future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science’’ (p. 107).

Schauble, Leinhardt, & Martin (1997) contrasted ‘‘museum learning’’ and ‘‘school learning,’’ although the distinction is somewhat vague. They appear to equate museum learning with learning in museums, but a number of research studies (e.g., Anderson, Lucas, Ginns, & Dierking, 2000; Falk & Dierking, 1997) established that learning may continue well past the time span of a visit to a museum. While acknowledging visitors to a museum may learn from an exhibit, Rennie & McClafferty (1996) posed the question of whether learning has occurred if visitors cannot ‘‘link that knowledge to situations beyond their visit’’ (p. 74). The answer surely depends on the definition of learning that one chooses to adopt. What is clear is that researchers interested in learning associated with visits to museums and similar locations need to recognize that learning is multifaceted and unbounded by time, institution, or social context.

Explicit definitions of what is meant by the term *learning* have been notably absent from much of the published literature on learning in museums and similar locations during the 1990s. For example, Lucas, McManus, & Thomas (1986) implied, but did not state, that learning constitutes the acquiring of ideas. If so, research on learning in museums would attempt to assess the amount of information acquired by visitors to museums, but Lucas et al. pointed out that ‘‘knowing *how* people learn might be more important than knowing *what* they learn’’ (p. 343, emphasis in original). In some research reports (e.g., Serrell, 1997) it appears that the process of learning is of interest, and in others (e.g., Gilbert & Priest, 1997) the product of learning is the main focus. It is conceivable that the professional background and motivations of researchers have an important role in determining the focus on learning; however, Falk & Dierking (1997) pointed out that learning is neither a process nor a product, but a combination of the two.

References to constructivist views of learning appeared frequently in the science museum literature (Borun, Massey, & Lutter, 1993; Feher, 1990; Hein, 1995; Lucas et al., 1986). A common factor of such references is the recognition of the importance of visitors' prior knowledge, their alternative conceptions, and the individual nature of the construction of meaning from experiences encountered in the museum. The importance of social interactions is recognized to varying degrees. In general, learning is represented as conceptual change, and some researchers refer specifically to a conceptual change theory of learning. However, there are exceptions, an example being the use by Falk (1997) of the term *conceptual development* in the limited sense of being able to repeat specific facts and concepts represented by the exhibits.

In recent years some researchers have adopted a social construction of knowledge framework for research in science museums (Falk & Dierking, 1997; Gilbert & Priest, 1997; Schauble et al., 1997). To do so, they needed to make clear what they meant by "learning." For example, Falk and Dierking (1997, p. 216) asserted that

> Learning is the process of applying prior knowledge and experience to new experiences; this effort is normally played out within a physical context and is mediated in the actions of other individuals. In addition, learning always involves some element of emotion and feeling.

This definition highlights the process of learning in the physical, social, and personal contexts of the learner. Gilbert & Priest (1997) viewed learning "as the development and use of mental models by individuals" (p. 751). In this definition of learning, the products of learning in the form of mental models are highlighted. According to Gilbert and Priest (1997, p. 750), a mental model is "an internal representation of an object, states of affairs, or a sequence of events or processes, of how the world is, and of physiological and everyday social actions." Both definitions are applicable to learning in formal and informal, in-school and out-of-school contexts and, despite the different emphases, may be considered to be complementary and consistent with Ausubel, Novak, and Hanesian's (1978) theory of meaningful learning.

The theory of meaningful learning has influenced some research of learning associated with field trips to museums and other out-of-school locations (Anderson, 1999; Balling, Falk, & Aronson, 1995; Dierking, 1991; Dierking & Falk, 1994; Falk & Dierking, 1997; Orion, 1993); perhaps this is because it relates so specifically to the individual's role in making meaning as discrete bits of information are added to cognitive structures. Valsiner and Leung (1994, p. 211) described the knowledge construction process, a synonym for learning, in terms of a transformation of the knowledge structure of an individual. According to Valsiner and Leung, the process is constrained but not determined by the relationship between the environment and the individual. Although framed in Piagetian terms, their description of the structure of knowledge and transformations between individuals' knowledge states is highly reminiscent of Ausubel et al.'s theory. More recently, Chinn and Brewer (1998) referred to snapshots of what people know at different times, implying the existence of "states of knowledge," and they pointed out that researchers "infer that knowledge change is triggered by events involving *new data, new conceptions, reflection* and *social pressures*" (p. 101, emphasis in original). They claim that "there are few if any comprehensive theories of knowledge acquisition at present. Rather, most current theories are fragments of theories that address one, two or three of the issues" (p. 110).

In examining the nature and character of learning emergent from individuals' experiences in informal contexts, one might draw on a variety of theoretical frameworks. In fact, many studies of visitor learning to date have been conducted in an atheoretical way (Ramey-Gassert et al., 1994). The choice of an appropriate theoretical framework, we would argue, depends largely on the nature of research questions and/or interpretative structure associated with the study. In view of the evidence from the literature that many studies of visitor learning have been conducted without a theoretical foundation, we suggest that one theoretical approach that might serve this purpose is a human constructivist perspective on learning (Mintzes & Wandersee, 1998; Mintzes, Wandersee, & Novak, 1997). This view of learning is, in part, represented in Figure 1 in the form of a concept map. The concept map situates human constructivism in terms of other processes and descriptions of learning within a constructivist paradigm. The human constructivist view of learning recognizes that individuals' present conceptions are products of diverse personal experiences, observations of objects and events, culture, language, and teachers' explanations. Such conceptions are not necessarily consistent with academic knowledge structures. Furthermore, Mintzes et al. (1997) made the important point that "common instructional practices, including those of good teachers and textbooks, are a major source of misunderstanding" (p. 413). This is also true of learning in science museums (Anderson, 1999; Lucas, 1999).

Human constructivism recognizes that at times learning can be gradual and assimilative, and at other times significant and rapid. The former condition implies an incremental change in the individual's conceptual understanding. The latter condition implies a substantial restructuring of the individual's knowledge. In the words of Mintzes et al. (1997),

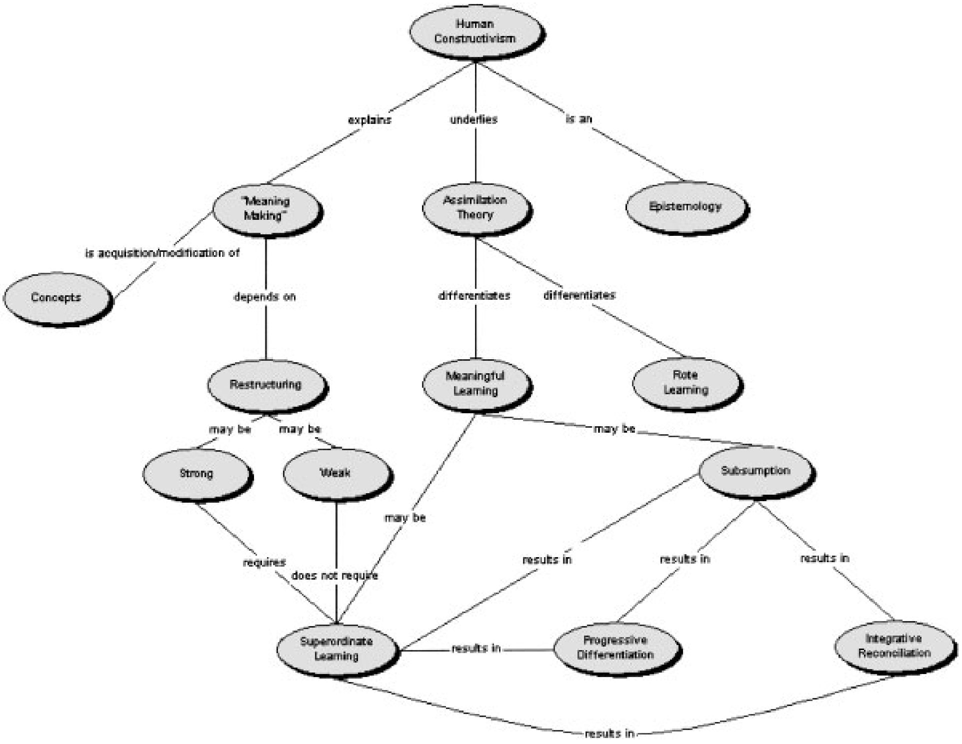

Figure 1. Concept map of human constructivism adapted from Mintzes and Wandersee (1998, p. 48).

> *conceptual change requires a restructuring of the knowledge framework, and this in turn results from the making and breaking of connections between concepts and sometimes the replacement or substitution of one concept with another.* (p. 415. emphasis in original)

In relation to learning in museums and similar locations, the human constructivist view of learning has potential to guide research and assist in the interpretation of research data because it recognizes the individual's prior knowledge and personal active involvement in knowledge construction, for example, during a museum visit. It also acknowledges the role played by individuals' present knowledge states—for example, as they exit a museum—in determining "the nature and quality of subsequent learning" (Mintzes & Wandersee, 1998, p. 52).

Finally, it recognizes the dynamic nature of knowledge construction—for example, the role of subsequent experiences, back in a formal classroom, say, in changing and restructuring knowledge developed from experiences encountered in the museum setting.

Research aimed at establishing details of students' knowledge states at various times associated with a visit to a museum, and understanding the conditions and processes by which changes in these knowledge states occur, would not only serve to test the utility of the human constructivist model of learning, but also provide valuable insights into students' learning experiences during such visits and the actions required of teachers and museum staff to enhance the learning outcomes. In this article we summarize the results of one such completed interpretive case study, conducted at the Billabong Primary School, and relate them to the human constructivist model of learning to demonstrate both the merit and utility of this theoretical framework. Finally, we discuss some theoretical and practical implications of the model for teachers and education staff of museums and similar institutions.

The Billabong Primary School Study

Methods

To provide a background to our analysis of the merit and utility of the human constructivist theory, a brief description of the methods used in the full Billabong Primary School follows. The Billabong Primary School study made use of interpretive case study methods (Stake, 1995) consistent with our belief that neither the processes of knowledge construction nor the details of the learning products are well understood. Furthermore, we believed that an individual's knowledge construction is not entirely predictable, discreet, or productive of a single outcome that can be fully defined before or as a result of such experiences. We sought to find evidence to test these beliefs, for which purpose a collective case study was deemed to be appropriate (Stake, 1995). Students were selected for intensive case study involving investigation of their knowledge transformations resulting from a free-choice science center visit, subsequent classroom-based postvisit activities (PVAs), and other personal experiences that the students had at home and in their discretionary time. As part of the data collection strategies, these students completed concept maps representing their understandings of topic domains, and were interviewed three times during the research: (a) before their Sciencentre experiences, (b) after their Sciencentre experiences, and (c) after their participation in classroom-based PVAs relevant to their Sciencentre experiences. All students in the class participated in all activities associated with the visit to the Sciencentre. Twelve students were selected for more intensive study (Anderson, 1999), and of these Andrew, Josie, and Hazel provide a convenient focus for discussion of the utility of the human constructivist model of learning in this report.

Participants in the study were 28 students (15 female) in Year 7 at a state elementary school in Brisbane, Australia. The school is situated in a relatively affluent suburb, in attractive though limited grounds, and is well resourced. The teacher was a young man with somewhat more interest in and knowledge of science than most of his colleagues in the school. Prominent in the classroom were numerous computers, posters, and other evidence of students' work in various subjects displayed on walls or suspended from the ceiling. There was a range of simple apparatus to support the teaching of topics included in the elementary science syllabus. One of us (D.A.) coordinated the study, liaising closely with the teacher and Sciencentre staff concerning students' experiences at both sites. There were three phases of the study: Phase A, the previsit period, during which students' prior knowledge about electricity and magnetism was investigated; Phase B, the Sciencentre visit, including previsit orientation to the Sciencentre, actual visit, and a brief follow-up session; and Phase C, postvisit lessons involving in-class completion of several practical activities explicitly linked to specific Sciencentre exhibits relating to electricity and magnetism. Students' knowledge about electricity and magnetism was also investigated at the conclusion of the second and third phases, with particular attention being paid to changes that occurred in each phase.

Phase A: Previsit

All phases of the study used concept maps and semistructured interviews to probe students' knowledge. Therefore, an important part of the previsit phase was to teach students to draw concept maps in the manner suggested by Gunstone and White (1992). A training session was conducted for this purpose, in which students were shown and discussed several simple concept maps (which were referred to as mind maps) and then worked together in pairs to produce their own maps of food webs, a topic with which they were familiar. Subsequently, they constructed individual concept maps about electricity and magnetism, having been provided with a large sheet of paper and numerous small pieces of paper on which to write concepts to be included. When they were satisfied with the number and placement of these concept labels, students pasted them onto the large sheet of paper and added connecting arrows and linking statements in the usual fashion. After careful examination of these maps and discussions with the teacher, we selected the 12 students for more intensive study. These students were selected partly because their concept maps provided us with a range of structure, scientific conceptions, and alternate conceptions. Other selection criteria included the teacher's recommendation that the students would be prepared to communicate effectively with us and our desire to ensure a roughly equal representation of girls and boys. At 4–5 days after they drew their first concept maps about electricity and magnetism, these 12 students were interviewed about their knowledge of electricity and magnetism. The concept maps provided a focus for the interviews and opportunities for the students to elaborate details of the maps and to add new concepts and/or linkages as they saw fit.

Phase B: Sciencentre Visit

Consistent with advice provided by several researchers (Anderson & Lucas, 1997; Anderson, 1994; Gennaro, 1981; Kubota & Olstad, 1991; Orion & Hofstein, 1994), students were prepared for the Sciencentre visit on the preceding day by means of a 30-minute presentation. The presentation included color slides of the Sciencentre layout, the schedule of activities for the visit, the types of exhibit to be encountered, and the fact that some would be specially identified as exhibits that all students should visit. Labels identified each exhibit and indicated the focus as follows: electric motor, generating electricity, electricity from a magnet, hand battery, Curie point, and making a magnet. Students were advised that the particular gallery that housed the electricity and magnetism exhibits would be under video surveillance and that several research assistants would be observing students in that gallery. They were neither shown slides nor given information about specific exhibits.

In terms of McManus's (1992, p. 164) description of science museum types, the Sciencentre would be classified as a third-generation museum that presents ideas instead of objects in a decontextualized scattering of interactive exhibits, which can be thought of as stations for the exploration of ideas. The exhibits in the Sciencentre galleries portrayed a diversity of science topics: light, sound, mechanics, and electricity and magnetism. Most exhibits, including the electricity and magnetism units, were standalone, hands-on, and phenomenon based, with few if any contextual links to real-world applications of the scientific principles which they were intended to demonstrate. Although these exhibits were not designed with human constructivism as a referent, their lack of context later proved to be advantageous to the research. The students brought their own real-world contexts to the Sciencentre experience, and evidence of students' attempts to construct knowledge by relating prior knowledge to their experiences of the exhibits was obtained.

During the Sciencentre visit, students spent about 40 minutes in a gallery featuring exhibits related to sound and mechanics before moving to the electricity and magnetism gallery, where they remained for about 30 minutes. This gallery also included exhibits related to light and color. The visit concluded with a 30-minute presentation to the entire class by Sciencentre staff and included some general references to electricity and magnetism. The day after the Sciencentre visit, students completed a second concept map about electricity and magnetism, following the same procedure as described previously. The 12 students were interviewed 2 or 3 days after constructing these concept maps.

Phase C: Postvisit

One week after the Sciencentre visit, students participated in two sessions of PVAs. The first involved students working in pairs to select 2 of the 6 target exhibits they found interesting, describe their own involvement with these exhibits, and provide an explanation of how they believed the exhibits worked. The aims of this activity were to have students review their Sciencentre visit and provoke them to construct and reconstruct understanding of the concepts and principles involved in the exhibits. The second session engaged students in open-ended practical activities that had obvious similarities to two of the Sciencentre exhibits. One involved moving a magnet near a coil of copper wire attached to a microammeter; the other consisted of making an electromagnet by inserting an iron bar into a solenoid and passing a direct current through the solenoid. Students experimented with both sets of apparatus and other materials conveniently at hand, such as paper clips, pencils, and erasers.

Students constructed their third and final concept maps on the day after these PVAs. The 12 selected students were interviewed for the last time 1–4 days after completing the concept maps. During these interviews, they were asked to reflect on the entire experience and what they had learned about electricity and magnetism; interviewers referred to all three of the concept maps at appropriate times in the interview and asked students to comment on differences they recognized. Students were encouraged to modify or extend their third concept map during the interview, as was the case on earlier occasions.

Analysis

From each interview and student-generated concept map, a list of student concepts was compiled into a Concept Profile Inventory (CPI) (Erickson, 1979). The CPIs contained fundamental categories into which students' concepts were sorted to form an overall previsit CPI, a postvisit CPI, and a postactivity CPI for each of the 12 selected students. The fundamental categories emerged from the analysis of the interview transcripts and inspection of the student-generated concept maps, including modifications made by the students during the course of the interviews.

Data from Phase A for all 12 students were analyzed before those from Phases B and C because we wished to document and interpret students' knowledge and understanding of electricity and magnetism unbiased by data from subsequent phases. Data analysis involved several steps, commencing with data relating to one student.

1. A list of the concepts about electricity and magnetism that we believed the student possessed was generated from an intense examination of the original concept map generated by the student and the transcript of the interview conducted with the student.
2. Relevant prior experiences and events to which the student referred while explaining or elaborating concepts were recorded in annotations on the student's concept map and on the interview transcript.
3. Based on the outcomes of Steps 1 and 2, tentative categories for the student's concepts about electricity and magnetism were generated.
4. Steps 1–3 were repeated for all other selected students in turn, with the tentative categories being progressively expanded and modified to accommodate all concepts identified. Four categories were eventually formed: Properties of Magnets; Earth's Magnetic Field, Compasses, and Applications; Properties of Electricity; and Types of Electricity.
5. The categories identified provided the structure for CPIs that were generated for each student. At the completion of data analysis for Phase A, a CPI had been generated for each of the 12 selected students. In addition, a consolidated CPI was compiled to include all concepts and generate a common labeling system and terminology for every concept included. For example, the concept "Magnets can attract certain types of metal" was labeled 1.3A—the third listed concept in the first category, Properties of Magnets, in Phase A of the study.
6. Steps 1–5 were repeated in the analysis of data from Phases B and C, respectively. The concept categories generated in Phase A proved to be generally able to accommodate additional concepts. In the process of generation of CPIs for each student for Phases B and C, only those concepts that we judged to differ from those identified in earlier phases were included so as to reduce the complexity of the CPIs. For example, a new concept may have emerged in Phase C, or a concept identified in Phase A may have been changed when identified in Phase B.

When data from all three phases had been analyzed, we had generated three CPIs for each of the 12 students. By referring to these CPIs, interview transcripts, students' concept maps, and our own field notes, we investigated ways in which students' knowledge had been transformed across the three phases of the study. Seven categories of knowledge transformation resulted from our investigation: addition, emergence, progressive differentiation, disassociation, recontextualization, merging, and development of personal theories. Although the naming of some of these categories is reminiscent of Ausubelian theory, the categories emerged from the three sets of CPIs of all 12 focus students involved in the Billabong study and were not predetermined.

Mintzes and Wandersee (1998, p. 47) described human constructivism as "a view of meaning making that encompasses both a theory of learning and an epistemology of knowledge building." More recently we have come to recognize the analytical and explanatory potential of the human constructivist perspective to inform our research of learning in informal settings. In the following section we illustrate this by reference to the Billabong study results.

Three students were purposefully selected because they effectively illustrate the seven knowledge transformation categories that emerged from the Billabong study and how we understand them from a human constructivist perspective. Not only were we able to identify and describe exemplars of knowledge transformations, but our methods allowed us to gain insights into the effects of the interrelated experiences of each student. Other students could also have been chosen from the 12 focus students for the purpose of the following discussion, although space restrictions preclude us from doing so in this article.

A Human Constructivist Perspective on the Billabong Study

Extracts from CPIs prepared for Andrew, Josie, and Hazel in all three phases of the study are presented as Figures 2–4, respectively. The complete CPIs are much more detailed[2] (Anderson, 1999) but for clarity only some concepts for which transformation between phases can be demonstrated by the data are included. These transformations are labeled on the right side of Figures 2–4:

1. Addition of new concepts
2. Emergence of existing concepts not revealed in an earlier phase, which had been retrieved from memory as a result of subsequent experiences
3. Progressive differentiation of concepts identified in an earlier phase
4. Disassociation of concepts identified in an earlier phase
5. Recontexualization of previously held concepts in the light of the PVA, Sciencentre, and past experiences
6. Merging of separate conceptions
7. Personal theory development evidenced in the form of contextual knowledge.

These categories are in accord with several of the knowledge construction processes of human constructivism, three being essentially equivalent (Table 1). Although the other four categories are not described by proponents of human constructivism, we regard them as being entirely consistent with that view of learning. For instance, we regard disassociation and recontextualization as closely related to progressive differentiation. Although emergence and personal theory building, knowledge transformation categories derived from Anderson's (1999) study, appear to have no direct equivalent in the human constructivist view of learning, we think that they are consistent with it and that they may be particularly related to the experience of learning in an informal environment such as the Sciencentre.

Addition

Evidence of concepts in Phases B and C that were not apparent in a previous phase of the study was available in relation to Andrew, Josie, and Hazel. Some concepts were apparently new to students, and we categorized such knowledge transformations as addition during analysis of the Billabong study data. From a human constructivist perspective, addition would be described as subsumption, or as having occurred by the process of subsumption.

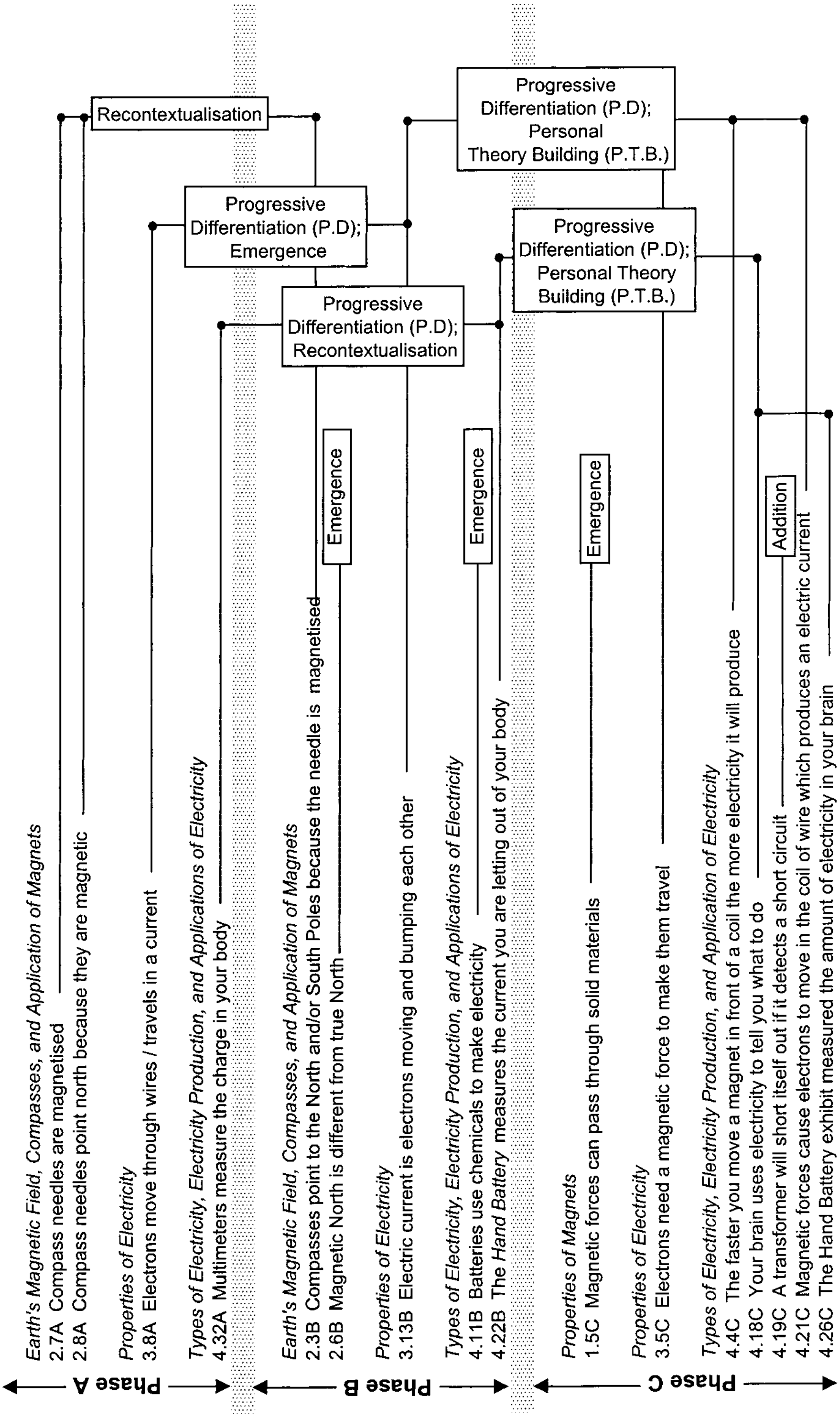

Figure 2. Extract from Andrew's Concept Profile Inventory with examples of knowledge transformations

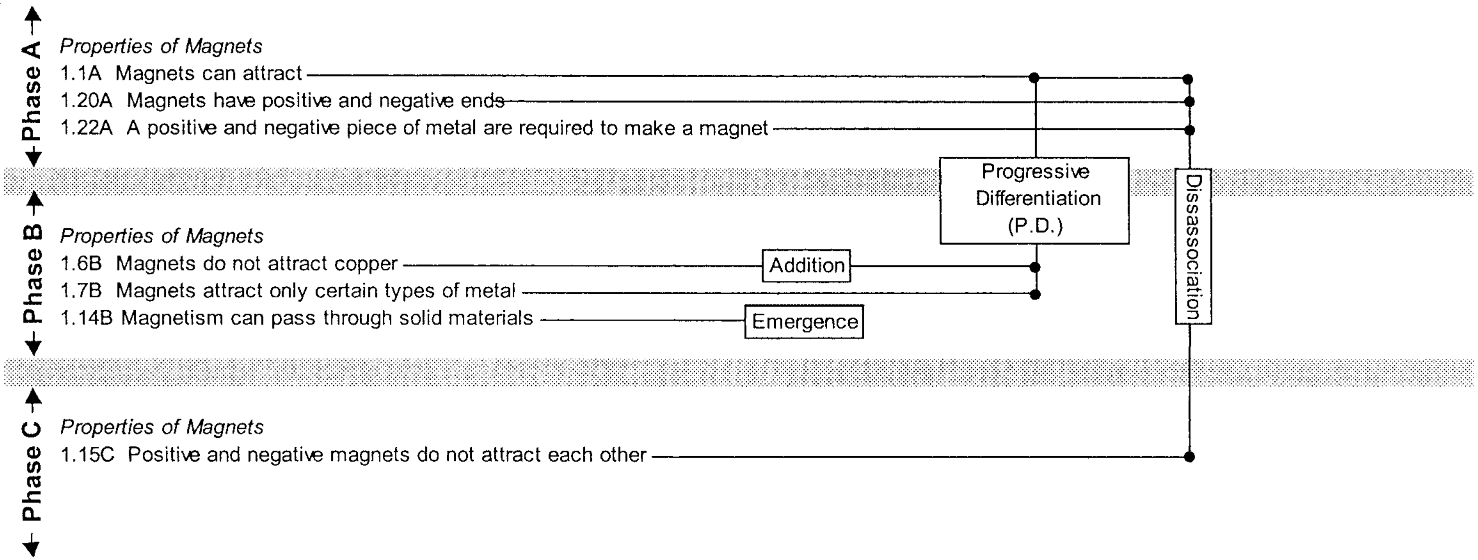

Figure 3. Extract from Josie's Concept Profile Inventory with examples of knowledge transformations

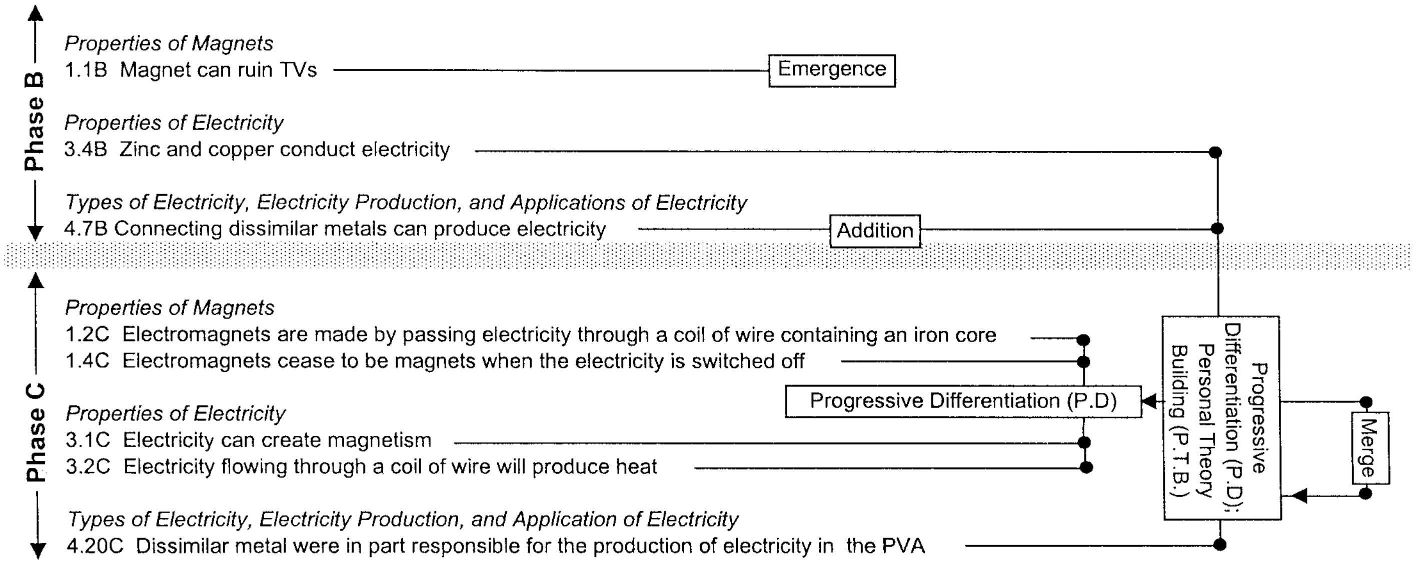

Figure 4. Extract from Hazel's Concept Profile Inventory with examples of knowledge transformations

Table 1
Relationships between categories of knowledge transformation derived from the Billabong study and knowledge construction processes described by human constructivism

Categories of Knowledge Transformation from Billabong Study	Knowledge Construction Processes Described by Human Constructivism
Addition	Subsumption
Emergence	Not described
Progressive differentiation	Progressive differentiation
Disassociation	Not described
Recontextualization	Not described
Merging	Integrative reconciliation
Development of personal theories	Not described

An example of addition included in Andrew's CPI (Figure 2) is "4.19C, A transformer will short itself out if it detects a short circuit."

> Interviewer (Int.): Postvisit activities . . . mind maps . . . and how your knowledge has changed . . . first of all, what do you remember about the activities?
>
> A: The—what we did?
>
> Int.: The experiments.
>
> A: Well, we made the electromagnet with the coil and the rod and the, um, the, the, um, yeah, the transformer. And one thing I can remember is the transformer kept shorting.
>
> Int.: Why was it doing that?
>
> A: Because the circuit was sort of completed and it sort of, yeah, fuses.

Emergence

When concepts were identified that may have been stored in the student's memory but not discussed during previous concept mapping or interviews, we categorized the process as emergence. The distinction between emergence and addition of such concepts depended on whether there was evidence provided by the student that he or she was aware of the concept previously, but had not included it on a concept map or mentioned it during an earlier interview. In the case of emergence, we suggest that the existing concepts may have become more relevant or more readily retrievable from memory as a result of some intervening experience or combination of experiences. These experiences could have been associated with the visit to the Sciencentre and the related PVAs, the individual student's participation in concept mapping and interviews associated with the research, or from a myriad of other activities. Hazel's CPI (Figure 4) indicates the emergence of a new concept, Concept 1.1B, Magnets can ruin TVs. The following excerpt provided evidence for this being emergence resulting from interaction with an exhibit at the Sciencentre and a subsequent conversation with her teacher rather than evidence of addition. (Mr. Wallace is a pseudonym.)

> Int.: You've got here [on your concept map], "Magnets ruin TVs." Tell me about that.
>
> H: Yeah. They had a TV [at the Sciencentre] and it can also go on computers, um, the TV. And whenever you put the magnet near it, different colors would come. And that happened on not just that one but on any TV if you stick it there on the screen. The same with the

> computers. Mr. Wallace told us about, um . . . if you had one of the old computers, someone put a magnet on the screen and no matter what they could do, there was—until the computer guy, um, there was always a sort of a gray mark there. (Postvisit Interview)
>
> After the postvisit activity:
>
> Int.: Let's look at your previous mind map. Let's look at all three at once. The way I've labeled these is A, B, and C. Take a look at these two to start with and tell me some differences between these two—the changes in your knowledge.
>
> H: Um, television. I knew about that [the effect of a magnet on a computer monitor] but I didn't know that magnets could ruin TVs [as well as] computers. (Postactivity Interview)

Progressive Differentiation

From a human constructivist perspective, progressive differentiation is a process of gradual clarification of concept meanings (Mintzes et al., 1997). This is equivalent to the category of knowledge transformation that we recognized in the Billabong study and which we also labeled progressive differentiation. Several instances of progressive differentiation are recorded in Figures 2–4. For example, Josie's understanding that "magnets can attract" (Concept 1.1A) had been clarified by "magnets do not attract copper" (Concept 1.6B) and "magnets only attract certain types of metal" (Concept 1.7B) when she was interviewed after the Sciencentre visit (Figure 3). During the visit, Josie had interacted with an exhibit called Magnetic Materials at which many different sorts of materials could be tested to see if they were affected by a bar magnet.

Progressive differentiation is also evident in Figure 2. Initially, Andrew stated that "multimeters measure the charge in your body" (Concept 4.32A). During the visit to the Sciencentre, Andrew spent some time interacting with the Hand Battery exhibit, which included a multimeter in a simple circuit that visitors were invited to complete by placing their hands on two dissimilar metal plates. In this case, a small reading registered on the multimeter indicating the flow of a small current. Alternatively, visitors could complete the circuit by placing their hands on two plates made from the same metal, in which case no current flowed in the multimeter. Andrew's clarified understanding was expressed in terms of current (whether electric or magnetic was unresolved) emerging from his body. The following excerpts are from the pre- and postvisit interviews in which Andrew first describes his experiences with multimeters some time in the past (previsit interview) and later provides an interpretation of the Hand Battery exhibit (postvisit interview):

> Int.: You've got this idea here that that multimeters measure the charge in your body [Concept 4.32A]?
>
> A: My dad's got a multimeter with all these—with the three. Yeah. I played around with that one day.
>
> Int.: You did?
>
> A: Yeah. Measuring the charge in me and my dad and Chris, my brother.
>
> Int.: Did you have charges in you?
>
> A: Yeah, but not much. (Previsit Interview)
>
> A [Interviewer shows a picture of the Hand Battery exhibit to Andrew]: Oh, they're the hand batteries.

> Int.: What happened there?
>
> A: Um, you put your hands on the pieces of metal and the, the electric current, the magnetic current in you registered on the multimeter thing.
>
> Int.: Right. The current within you?
>
> A: Yeah.

Additional evidence of progressive differentiation apparently linked to Andrew's reading of a science book and participating in the PVAs was evoked during the final interview. At that time, Andrew understood that "the Hand Battery exhibit measured the amount of electricity in your brain" (Concept 4.26C).

> Int.: You've got this relation here between electricity and brain [Interviewer is referring to Andrew's postactivity concept map]. I don't think that's on any other previous maps of yours.
>
> A: No.
>
> Int.: That's new. Tell me about that.
>
> A: Well, when I was looking for something for my science project which we're doing soon, I saw something about—to do with that copper plate and aluminium plate that's measuring the current . . .
>
> Int.: At the Sciencentre?
>
> A: Yeah, in the Sciencentre. Well, I sort of got the explanation for that from one of those science experiment books.
>
> Int.: And what is the explanation?
>
> A: Well, your brain sends a very small electric current along your nervous system to tell your body what to do, and yeah.
>
> Int.: So how's that relate to that experiment at the Centre?
>
> A: And then, um, the electricity that it's sending, it jumps to the aluminium and copper plates and then it's measured on the multimeter. (Final Interview)

It is evident from these data that Andrew had constructed additional understanding of his original concept of electrical charge in his body (Concepts 4.32A and 4.22B), resulting in Concepts 4.18C and 4.26C. This type of analysis of learning, consistent with human constructivism, highlights how a visit to the Sciencentre and several related postvisit experiences led to changed understanding for Andrew, albeit understanding not in agreement with the accepted scientific view.

Disassociation

The foregoing example revealed how Andrew constructed knowledge that was inconsistent with canonical science. We encountered several examples during the Billabong study of students commencing with erroneous knowledge, which was brought into question and transformed by the students' experiences in the Sciencentre or during related activities. Josie's initial understanding of the properties of magnets included the claim that "magnets have positive and negative ends'' (Concept 1.20A) and that ''a positive and negative piece of metal are required to make a magnet'' (Concept 1.22A) (Figure 3). She also knew that ''magnets can attract'' (other magnets) (Concept 1.1A). However, after the lessons in which Josie completed the PVAs, it was evident that her knowledge had undergone a transformation. The link between magnets and mutual attraction had been broken, or the previously associated concepts had been disassociated in Josie's knowledge structure.

> J: I figured that negative and positive [magnets] actually, they don't want to go together.
>
> Int.: Mmm . . .
>
> J: And then I was saying here [on my postactivity concept map] that they're opposite but I didn't know that they, like, I thought, like, if you put, like, a brick or something there [between the two magnets] and then you put positive and negative they'd want to, like, um, attract, but they don't and I figured that out.
>
> Int.: All right, so explain to me once again what you mean by this. You say negative and positive are opposites and positive is a different type of magnet and negative is a different type of magnet, so we've got positive magnets and negative magnets, is that right?
>
> J: Yep, and they don't want to attract, I thought that they did want to, like because they were two different types they would want to go together.
>
> Int.: Right.
>
> J: And, but, they don't because, um, well, they attract paperclips but they don't attract each other.
>
> Int.: Right, so if I have negative magnet and a positive magnet, they won't attract one another?
>
> J: No.
>
> Int.: Okay, are there any sorts of magnets that do attract one another?
>
> J: I don't know. I don't think so.
>
> Int.: You don't think so? What about, what about magnets which push one another away? Are there any sorts of magnets which do that?
>
> J: Yep, there's one that you showed us in the experiments. You were going like that [Josie mimics the action of moving a magnet close to another magnet] and then one would go the other way.
>
> Int.: Mmm . . .
>
> J: There was a force.
>
> Int.: Right. Are they two magnets?
>
> J: Yeah, I think so.
>
> Int.: Right, so there's some magnets which do push one another away?
>
> J: Yeah. (Final Interview)

Although human constructivism does not specifically identify a process equivalent to what we have labeled disassociation, we recognize that it is inherent in some instances of progressive differentiation. In our view, evidence of disassociation occurring in such circumstances is of considerable importance. This is because it emphasizes the dynamic nature of the learning process in which students are engaged and makes it easier for us to appreciate how intended and unintended learning outcomes may eventuate in the processes of knowledge construction by individuals.

Recontextualization

One of the most obvious features of a class visit to a location such as the Sciencentre is that the context in which students encounter and discuss objects and phenomena differs greatly from the more formal context of a typical school classroom. When the changed context resulted in modification of a student's knowledge of a previously identified concept without significant clarification of meaning, we described the knowledge transformation as recontextualization rather than progressive differentiation. For example, Andrew's initial understanding that "compass needles are magnetized" (Concept 2.7A) and "compass needles point north because they are magnetic" (Concept 2.8A) was transformed to "compasses point to the North and/or South poles because the needle is magnetized" (Concept 2.3B) (Figure 2). We do not interpret this as indicating significant clarification of meaning for Andrew. However, because his experience in the Sciencentre included making a magnet, we suggest that his understanding concerning the properties of a compass had been recontextualized.

Merging

Merging of two or more separate conceptions to provide an explanation for a newly encountered phenomenon is predicted by the human constructivist view of learning. Some examples of this type of knowledge transformation were encountered in the Billabong study. For example, Hazel appears to have merged multiple conceptions in an attempt to construct an explanation for the production of electricity in one of the PVAs she completed in class. Before this, her experience at the Sciencentre had resulted in new knowledge about metals and the production of electricity, in particular that "connecting dissimilar metals can produce electricity" (Concept 4.7B) and that "zinc and copper conduct electricity" (Concept 3.4B) (Figure 4). These concepts evidently were progressively differentiated to become "dissimilar metals were in part responsible for the production of electricity in the PVA" (Concept 4.20C) at the time of the final interview. In addition, Hazel had two other concepts which related to magnets and the production of electricity. At the time of the final interview these concepts were that "electricity can create magnetism" (Concept 3.1C) and "electricity flowing through a coil of wire will produce heat" (Concept 3.2C). The following excerpt demonstrates how Hazel merged these separate conceptions to account for her experiences with the two PVAs. In one PVA, Hazel had moved a magnet near a coil of copper wire and noticed a slight reading on the microammeter; in the other, she had created an electromagnet by passing an electric current through a coil which had a removable iron core.

> Int.: That first activity where we were making electricity by waving the magnet in front of the coil: What was your understanding or explanation as to what was making the electricity?
>
> H: The iron and the copper and the magnets, um, I think—the magnet had something to do with it . . . um . . .
>
> Int.: The iron and the copper . . .

H: Well, the iron and the copper, it wouldn't work if the iron wasn't there and it wouldn't work if the copper wasn't there. It could also work the other way around. Hold the iron that, on there, you could put the magnet in and out and it would also produce more electricity, I think.

Int.: Were there any exhibits in the science museum that were kind of similar to that, do you recall?

H: Um . . . no, not in the actual exhibits but at the science show, and there was I think copper and zinc, copper, um, a copper and an iron. And a zinc rod and someone held the rod and someone had the other one and they were attached to a big meter. And when they touched hands, the thing would go.

Int.: You've got here on your concept map copper and iron to make electricity when a magnet is waved in front of it.

H: Uh-huh.

Int.: So if you didn't have either one of these it wouldn't work.

H: No.

Int.: So you need to have—do you think it would work with any two different sorts of metals or does it have to be copper and have to be iron?

H: Um, I think maybe zinc instead of iron.

Int.: What about if I had a copper inner core. Would that work the same?

H: A copper in what?

Int.: Instead of having that rod I put inside the coil of wire being made of iron, say, made of copper, would it have the same effect?

H: If the iron was the wire.

Int.: If the rod that I actually put inside the hollow tube was made of copper instead of iron.

H: Uh-huh, and the iron was . . .

Int.: And the wire was still copper. In other words, if it had copper inside copper, would it still work?

H: I don't know. I think I just learned today that, um, I think electricity moves faster through copper. I think it might work but it might go a little slower.

Int.: What I'm trying to figure out, do these two metals need to be different for the magnet to produce electricity? Or no? Or don't you know?

H: I don't get that question.

Int.: In other words, I've got copper wrapped around the tube. Right?

H: Yeah.

Int.: I'm putting iron inside, which is a different metal. I'm just wondering whether you know whether the two metals need to be different for this effect to be achieved.

H: I think maybe they just have to be . . .

Int.: They just have to be copper and iron.

H: Or copper and zinc.

> Int.: Okay.
>
> H: But they can't be copper and copper. (Final Interview)

Based on her merged understanding, Hazel argued strongly about the production of electricity and was adamant that a copper core within a copper coil would not produce electricity. When asked to explain the production of electricity during one of the PVAs, she wrote, "The iron and the magnet attract each other and generated electricity through the copper. You get more electricity by moving the magnet quickly because of friction." This suggests that Hazel had merged yet another concept—friction—into her increasingly interconnected understanding of electricity and magnetism. We interpret merging to be similar to the process of integrative reconciliation described by Mintzes et al. (1997, p. 420) as leading to "a more cohesive and integrated framework of knowledge." As was the case in an earlier example, the result was not consistent with canonical science.

Development of Personal Theories

The transformation of knowledge in various ways by Andrew, Josie, and Hazel, as well as the other students in the class for whom we have extensive data, is consistent with the human constructivist view of learning. Most students in the study showed evidence of the development of personal, and at time elaborate, theories of electricity and magnetism in response to their experiences in the Sciencentre, classroom, and elsewhere.

For example, Andrew had developed a detailed and scientifically appropriate explanation, in which he incorporated Concepts 3.8A, 3.13B, 3.5C, 4.4C, and 4.21C (Figure 2).

> Int.: Tell me the actual details of the process of how you made the electricity in that experiment.
>
> A: Well, you got the coil; put the [c]ore—the rod iron [c]ore through the middle of it. You connected it to the multimeter [microammeter]; put the bar magnet and moved it up and down near the coil which makes the little [electrical] current.
>
> Int.: What was your understanding of how moving the magnet actually did that?
>
> A: It [the magnet] sort of moved the electrons around, like they're moving [inaudible word] the current round, and moving . . .
>
> Int.: Okay. So the magnet. Moving the magnet.
>
> A: Yeah. The electrons in the copper coil.
>
> Int.: And they made electricity.
>
> A: Yeah.
>
> Int.: And you did the part of the experiment where you just put the magnet still? And what happened?
>
> A: Yeah, and that didn't make any [electricity].
>
> Int.: Why is that?
>
> A: Because it's not moving—the magnets not moving so it can't move the electrons in it, so it sort of . . .
>
> Int.: And you did the bit where you moved it slow then fast?

> A: Yeah. Slowly it made almost nothing, and fast it made more—a lot more electricity. (Final interview)

The data support the interpretation that Andrew had developed new understanding by combining several related concepts through a series of transformations of the kind discussed in this article to form his personal theory of electrical induction. The human constructivist view of learning stresses the role of personal experiences, observations of objects and events, culture, language, and interactions with other people in learning. Some of these aspects were evident in Andrew's personal theory building. The concepts that Andrew drew on to construct his personal theory of induction were clearly formed or modified over the period of our study. Despite recognition of the importance of social interaction in learning, it is ultimately an individual achievement. Andrew's personal theory no doubt owed something to experiences, observations, and discussions shared with fellow students in the classroom and the Sciencentre, but he also drew on individual and personal experiences. For example, when asked, ''How did you know that was what electricity was, and what a current was?'' he replied ''Partly from the ABC [television] shows and stuff, and my mum was telling me about it.''

Discussion

Among the variety of conceptual frameworks available to investigate learning, we conclude that the human constructivist view of learning has much merit and utility as a framework for conceptualizing visitors' learning which is emergent from their museum experiences. This view recognizes the influence not only of prior knowledge and understanding on learning in-gallery, but also of subsequent life experiences on continuing the transformation of individuals' knowledge beyond the museum setting, at home, and in the formal environment of the classroom. The fruitfulness of this view of learning is evidenced by its capacity to link individuals' prior knowledge, museum experiences, PVAs, and other experiences to provide an account of knowledge development. Moreover, the theory has enabled us to analyze the complexity of the learning that occurs. The variety and number of knowledge transformations identified serve to illustrate this complexity. The depth and richness of learning evident in the findings are in marked contrast to much of the previous research in the field of learning in informal settings, which has been largely descriptive and devoid of theoretical foundation.

Several implications for museum staff and teachers planning and implementing learning experiences for students in informal settings may be drawn from the findings. Because we contend, from the human constructivist viewpoint, that learning is highly individualistic in nature, we believe that no two visitors will have the same prior knowledge or learning experiences in the museum. Teachers are well situated to meet the challenges and capitalize on the opportunities inherent in such differences between learners' knowledge and understandings. To exploit these opportunities, it is crucial that, as part of their planning and implementation, teachers listen to and actively seek to explore students' accounts of their responses to the museum and its exhibits. Education staffs in museums similarly enjoy unique opportunities to probe students' understanding in the rich and stimulating environment of the museum.

Many teachers are already skilled in using concept maps and directed open-ended questioning as part of their repertoire of teaching strategies. This article reveals the importance of using such strategies to identify students' prior knowledge and knowledge developed as a result of museum experiences. In doing so, teachers will be able to use the key experiences and unresolved questions of their students in ways that support student learning, and in many cases extend and enrich the school-based curriculum. If museum staff and teachers are unable to use these teaching strategies, appropriate professional development courses that emphasize strategies which probe students' knowledge and understanding as a way of adding value to informal learning experiences should be provided. Emphasis should also be placed on examining the importance and value of informal learning experiences in preservice teacher education courses.

The demonstrated value of PVAs in furthering students' construction of knowledge as a result of engagement in museum experiences should not be underestimated. It is vital that PVAs be planned and implemented using students' experiences in the museum and their prior knowledge and understanding as a platform for learning. Accordingly, teachers need to attempt to understand their students' knowledge in the domain of the museum exhibition before and emergent during the visit to develop effective PVAs that enhance students' learning.

With a few notable exceptions (Falk & Dierking, 1997; McManus, 1993; Piscitelli & Anderson, 2000; Stevenson, 1991), most studies of learning in museum settings have either examined or contextualized learning solely in the confines of visitors' experiences in the museum gallery. Such a view somewhat limits the wider scope of learning evident in the Billabong study. We have shown that learning develops in many often unexpected ways from the catalyst of museum experiences. The findings thus reinforce our view that the human constructivist theory of learning is an empowering and fruitful perspective from which educators can analyze the learning emergent from museum-based experiences. It is to this end that we encourage future research to provide more in-depth analyses of learning over longer time spans, and to capture more effectively the impact on learning of visitors' experiences subsequent to their museums visit.

Notes

[1] In this article, we use the term *museum* to include facilities such as history museums, art museums, science centers, aquariums, planetariums, and zoos.

[2] Most individual CPIs included approximately 50 concepts.

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