THE MISSING PIECE:

ENACTMENT IN REVEALING AND REDIRECTING STUDENT PRIOR KNOWLEDGE

Can Enactment Expose Affect, Illuminate Mental Models,

and

Improve Assessment and Learning?

by

ALISON MCKIM

Submitted in partial fulfillment of the requirements

For the degree of Master of Arts

Department of Cognitive Science

CASE WESTERN RESERVE UNIVERSITY

May, 2015
CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF GRADUATE STUDIES

We hereby approve the thesis of

Alison McKim

candidate for the degree of MA in Cognitive Linguistics*.

Committee Chair

Fey Parrill

Committee Member

Vera Tobin

Committee Member

Mark Turner

Date of Defense

3/18/2015

*We also certify that written approval has been obtained

for any proprietary material contained therein
Dedications

I would like to express gratitude to my mentor and friend, Jim Zull. From the first moment I opened his books on experiential learning, I knew I had found a kindred spirit. Our discussions during this project have been a constant source of clarity and joyful understanding. His philosophy on the biology of learning has inspired me and will continually direct my future work.

I give heartfelt thanks to Fey Parrill, whose research and teaching have deeply influenced me. As my professor, she consistently exemplified cognitively compatible teaching practices in a way that captured my attention and admiration. As my advisor, she provided unfailing support, invaluable guidance in writing and research, and endless encouragement.

Special thanks and love go to my children, Schyler, Siâna and Kirian, for their patience and support throughout this entire project. They were always there at the end of the long days, listening and cheering me on. They have made this project a joy. I feel we accomplished it together.

For friendship, support, and painstaking care in helping with the final edit, I give a huge round of applause to Sarah Szweda and Mandeep Gill.

Finally, my deepest gratitude goes to my mom, Jean McKim, for always encouraging me and being so proud of my accomplishments. I could not have even begun to do this without her support.
List of Tables

Table 1: Statement of Hypotheses----------------------------------------------- 13

Table 2: Posner’s Approach toward Conceptual Change ------------------------ 25

Table 3: Implied Relationships --------------------------------------------- 31

Table 4: Group Response: Why do you think we water plants? --------------- 35

Table 5: Group Response: How does water get into the plant? --------------- 35

Table 6: Group Response: How does water get out of the plant? ----------- 36

Table 7: Group Response: What makes water move through the plant? ------ 36

Table 8: Individual Response: Why do you think we water plants? -------- 39

Table 9: Individual Response: How does water get into the plant? ------- 40

Table 10: Individual Response: What makes water move through the plant? - 40

Table 11: Individual Response: How does the water get out of the plant? -- 40
List of Figures

Figure 1: Tower of Hanoi Puzzle----------------------------------------------- 20

Figure 2: Gesture and Affect in Group Responses to Questions---------------- 37

Figure 3: Student Drawings of Water Transpiration-------------------------- 39

Figure 4: Enactment in Assessment Reveals Affect through Facial Expressions--- 45

Figure 5: Watering the Plant----------------------------------------------------- 65
Affect: 1) an observable expression of emotion. 2) non-conscious experience of intensity. 3) the body’s way of preparing itself for action in a given circumstance by adding a dimension of intensity to the quality of an experience.

Assessment: gathering information on students’ prior knowledge, skills and attitudes toward a subject.

Conception: a learner’s internal representation of an event or subject; see mental model.

Embodied cognition: the philosophy that human cognition and consciousness can only be understood in terms of the physical body and the world with which the body interacts.

Embodied simulation: for the purposes of this paper, the term embodied simulation is interchangeable with mental simulation: mentally reenacting sensory experiences.

Embodiment: mental simulation of physical events.

Emotional reinstatement: enactment that involves recalling an emotional situation by reenacting a face to retrieve emotions that were experienced during the event.

Enactment: physical emulation of an event; any self-performed representational action expressed in the form of meaningful gestures, full body action as in role playing, or recalled facial expressions.

Memory encoding: storing sensory information in short- or long-term memory; this describes any learning event.
Memory recall: re-accessing events or information from memory; also memory retrieval.

Memory retrieval: see memory recall

Memory decay: information stored in memory becomes less available for retrieval as time passes.

Mental model: this is what a person uses to explain to themselves how things work in the world; it is a mental representation made up of information about the surrounding world, the relationships between its parts, and a person’s own intuitive perception about how these things work together; related to conception, prior knowledge.

Mental rotation: the ability to move and turn mental simulations of two and three-dimensional objects as they are visually represented in the human mind.

Mental simulation: mentally reenacting sensory experiences; see embodied simulation.

Prior knowledge: a student’s preexisting attitudes, experiences, and knowledge; related to conception, mental model.

Spatially-organized: information mentally organized in order of space or location.

Water transpiration: moisture carried through plants from roots to leaves, becoming vapor that is released into the atmosphere.
Viewpoint in enactment:

**Character viewpoint:** performing actions from the first-person view, as if one is playing the role of the character.

**Observer viewpoint:** performing actions from the third-person view, as if one is observing and describing the character’s actions.
The Missing Piece: Enactment in Revealing and Redirecting Student Prior Knowledge

*Can Enactment Expose Affect, Illuminate Mental Models,*

*and Improve Assessment and Learning?*

*By*

ALISON MCKIM

Abstract

Research in cognitive science demonstrates that enactment is beneficial for encoding new information and retrieving prior knowledge. This study highlights the reciprocal relationship between enactment and prior knowledge as it benefits both teachers and learners. This thesis argues that enactment can be used to gain insight into students’ prior knowledge in a way that verbal assessment may not. This thesis also argues that an enacted lesson informed by student prior knowledge will lead to greater learning than an enacted lesson not informed by prior knowledge. Sample lessons of both conditions are included. Results of this study have implications in the fields of education and educational research. This introductory study provides a basis for future studies involving but not limited to the topics of enactment and affect, enactment in learning and enactment in assessing prior knowledge.
Chapter 1: Motivation for this Study

As a student of cognitive science, I have had an enduring love affair with cognition, emotion, and physical experience. These topics hold such an irresistible fascination for me that no matter what I study, I always manage to turn it into a new vantage point from which I can peer at embodiment and emotion. Emotion and physical experience are embedded in every aspect of cognition; they are in our bodies, our language and our learning. They really are inescapable, and the more we can learn to embrace them as researchers, teachers, and human beings, the more we can reap the cognitive benefits that they make available to us.

We are physical and emotional beings. Emotion and physical experience operate hand-in-hand. In the realms of dance, performing arts, and visual art, this partnership is highly valued. Yet in intellectual settings, the interconnection between emotional and physical experience is not often recognized or appreciated as a doorway leading into cognition. At best, they are permitted as a novelty in learning settings; at worst, they are treated as something frivolous, a waste of time for serious learners.

Throughout history, people have successfully passed down important information physically and emotionally, using dramatic narrative and enactment. These have always been our primary modes of teaching. Only in recent history have physically enacted, emotional methods of teaching been set aside in favor of verbal and textual instruction.

When I have taught elementary age students, I have observed wonderful results using experiential, enacted lessons. Students were emotionally engaged during the lessons, had a high rate of fact retention, and were able to retrieve detailed memories of
the lesson, even years later. Unfortunately, I have also had the experience of operating in educational settings where enactment and physical experience were paid lip service, but were neither understood nor implemented. Overall, my experience using role-playing and gesture in teaching has produced very successful results, but at times I have been perplexed when the lessons I prepared did not seem to connect with the students in the way I had expected. The enactments I had carefully planned seemed to be missing the mark with the students, without a clear explanation why.

I have observed that I am not alone in this experience. Within the growing body of research on teaching and enactment, studies show that other researchers have had the same perplexing experience as I have; at times their enacted lessons produced expected results, but at other times they inexplicably missed their target. They did not produce the expected student engagement, learning, or recall.

A good friend and I were having a conversation one day about the importance of being aware of students’ prior knowledge in lesson planning. She was reminding me that students are not blank slates – that whether they have been taught about a concept in school or not, they will usually have formed some sort of mental model on their own, made up of their own experiences of how the world works. I experienced a light bulb moment, suddenly realizing that I had never actively assessed my students’ knowledge before developing enacted lessons – I had always based my plans purely on my perception of what the students knew about a topic. I knew my students well enough to get it right most of the time, but how much more effective could my lessons have been, had I taken the time to assess their understanding of a concept before planning enactments? That moment of realization has led me to pursue this topic for my thesis.
Studying the role that prior knowledge plays in enacted teaching can potentially provide useful and practically applicable information for researchers and educators. But as I explored the relationship between prior knowledge and enacted teaching, I began to realize that it is a two-way street.

First, using enactment during assessment appears to be an effective tool for revealing students’ prior knowledge. In fact, it seems that *enactment* might be more effective in revealing the students’ misconceptions than conventional *written* and *verbal* assessment alone. Second, assessing the students’ prior knowledge can help teachers and researchers design better, more well-informed enacted lessons. Both of these predictions have useful applications, so for this thesis, I decided to take on both sides of the coin.

This thesis explores the reciprocal relationship between enactment and prior knowledge as it benefits both teachers and learners. The first chapter talks about the surprising results of using enactment to reveal students’ prior knowledge. The second chapter talks about the value of using students’ prior knowledge to develop better informed enacted lessons.

<table>
<thead>
<tr>
<th>Statement of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Using enactment in assessment will reveal student conceptions in a way that verbal assessments alone cannot.</td>
</tr>
<tr>
<td>2. Enacted lessons that are informed by student conceptions will be more effective at correcting and redirecting inaccuracies than enacted lessons that have not been informed by student conceptions.</td>
</tr>
</tbody>
</table>

Table 1: Statement of Hypotheses
Chapter 2:

Summary of Research on Enactment, Prior Knowledge and Learning

This chapter begins by clarifying the differences between *embodiment* and *enactment*, and defining their specific roles in cognition. A summary of current research on enactment is provided. Studies on enactment as it relates to memory, learning, mental models, student conception and prior knowledge are included to provide support for the idea that enactment informed by prior knowledge can enhance lesson plans. Literature on the topic of prior knowledge is reviewed, and methods of assessing prior knowledge are discussed. This is included to provide support for the claim that enactment is a useful tool for assessing students’ prior knowledge. Connections are drawn between learning, enactment and prior knowledge, setting the stage for Chapter 3, which discusses how to access prior knowledge and how to use it effectively to design better enacted lesson plans.

What is Embodiment?

The philosophy of *embodied cognition* says that human cognition and consciousness can only be understood in terms of the physical body and the physical world with which the body interacts (Varela & Shear, 1999). In cognitive science, *embodiment* is most often defined as mental simulation of physical events. All human understanding of the world begins with physical events – actual concrete, sensory experiences. Physical events are stored as mental representations, complete with sensorimotor detail. These mental representations are part of the foundation of meaning-making. While an event is occurring, areas of the visual, auditory and sensorimotor cortex are stimulated. Sensory stimuli are then recorded and stored as memories with
physical traces. When a memory is accessed through speaking, hearing or thinking about it, the very same sensory areas that were stimulated during the original event are re-activated. These areas in the brain are designed to work double-duty – their purpose is not only to take in sensory experiences, but also to re-enact sensory experiences. The phenomenon of mentally simulating sensory experiences is called embodied simulation (also known as mental simulation). When a listener hears a sentence about kicking or chewing, for example, motor areas of the brain associated with those particular tasks become engaged (Pulvermuller & Fadiga, 2010). Processing language about seeing stimulates visual regions of the brain (Stanfield & Zwaan, 2001) just as processing language about hearing stimulates auditory simulation (Winter & Bergan, 2012).

Embodied neural areas are not only activated during language production; evidence from brain imaging, behavioral experimentation and neurophysical lesion studies also show that embodied simulation occurs during language comprehension (Bergan, 2012). Research shows evidence for embodied simulation not only during language production and comprehension but also during gesture production and comprehension (Bergan & Marghetis, 2000).

**What is Enactment?**

This thesis is about enactment. While embodiment refers to mental simulation of an event, enactment is defined as physical emulation of an event. Enactment is any self-performed representational action (Macedonia, 2011). It can be expressed in the form of meaningful gestures, full-body actions (as in role playing), or even recalled facial expressions. Enactment visibly reveals embodied cognition. It is a distinctly felt form of embodied cognition, and these stored feelings contribute to the sensorimotor information
that accompanies mental simulation (Hostetter & Alibali, 2008). Embodiment and enactment are the mental and physical expressions of embodied cognition.

**Enactment and Memory Encoding**

Enactment helps learners to translate new information into mental representations with a physical element. The modalities by which we experience an event become the channels by which we store it. By engaging sensory and motor areas of the brain, enactment included during a learning experience can increase the modalities by which the information is encoded. It will be stored not just as a sensory event but also as a physical event. Research has shown that if new information is learned with an accompanying gesture, re-enacting that gesture will aid in retrieving detailed memory of the information (Barsalou, 1999). For this reason, much research has been done on the value of enactment upon memory encoding and retrieval. Purposefully gesturing during encoding has been proven to have a positive effect upon long- and short-term recall (Allen, 1999; Cook, Mitchell & Goldin-Meadow, 2008; Cook, Yip & Goldin-Meadow, 2010). Enacting an event by using the full body may enhance memory storage (Noice & Noice, 2001). Tests show that even the anticipation of acting something out results in better recall (Glenberg, Gutierrez, Levin, Japuntich & Kaschak, 2004).

**Enactment and Mental Models**

Enactment facilitates deep comprehension by contributing a physical element to students’ mental models. Students build mental models by combining new information with their own unique prior knowledge (Johnson-Laird, 1983, 2006; Kaup, Kelter & Habel, 1999). Research has concluded that better mental models result in stronger
recollections and more correct inferences drawn from new information (Cutica, 2014; Bransford, Barclay & Franks, 1972; Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991; Johnson, Laird & Stevenson, 1970). A student must have a coherent mental model in order to successfully comprehend new concepts. This is especially important when new information is presented in a manner that lacks physical context, such as text or discourse (Cutica, 2014; Glenberg, Kruley & Langston, 1994; Graesser, Millis & Zwaan, 1997; McNamara, Miller & Bransord, 1991; Zwaan, Magliano & Graesser, 1995; Zwaan & Radvansky, 1998). Mental models are spatially organized. Enactment is also spatially oriented, which is why it is such a valuable tool for translating new information from text/discourse sources into mental models (Knauff & Johnson-Laird, 2002).

**Enactment and Education**

Considerable research has been done on the value of enactment in education. Studies show enactment helps students build mental models of concrete and abstract concepts such as space, time and emotion (Gibbs, 2006; Lakoff & Johnson, 1980). Research has shown that enactment is beneficial to students for learning and remembering a wide variety of tasks (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007; Goldin-Meadow, Cook, & Mitchell, 2009). Studies have explored the effect of enactment on mental rotation tasks (Goldin-Meadow, Levine, Zinchenko, Yip, Hemari & Factor, 2012), math concepts (Goldin-Meadow, Kim, & Singer, 1999), conservation of quantity (Ping & Goldin-Meadow, 2008), learning lists of words (Cohen, 1989; Frick-Horbury, 2002), and learning lists of phrases (Cohen, 1989; Feyereisen, 2006, 2009; Mangels & Heinberg, 2006; von Essen, 2005). Recent research has also been done on the
effects of enactment in learning science concepts (Cutica, 2014) and foreign languages (Kelly, 2009; Macedonia, 2011).

Cutica (2014) explored the beneficial effects of enactment on memory for text-based learning. Children were asked to read and study scientific texts under two conditions: a) gesturally enacting information from the text, or b) keeping their hands still. They were then asked to recall as much information as they could. Children were able to retain more correct information and draw more discourse-based inferences as a result of the gesturing condition than the hands-still condition.

**Enactment and Language Learning**

Behavioral research shows that in language learning, speakers naturally connect words to meaning through iconic gestures (gestures that produce a physical representation of an action, object or idea) (Barsalou, 2008; Bates & Dick, 2002; Kelly, Iverson, Terranova, Niego, Hopkins, & Goldsmith, 2002). Studies have shown that enactment through gesture plays a significant role in language production and comprehension for all ages, from the earliest stages of development (Baldwin, 1991; Tomasello, 1998; Yu, Ballard, & Aslin, 2005; Morford & Goldin-Meadow (1992) through adulthood (Beattie & Shovelton, 1999; Cassell, McNeill & McCullough, 1999; Feyereisen, 2006; Goldin-Meadow, 2003; Kelly, Barr, Church, & Lynch, 1999). Gesture provides clarifying information when speaking about new concepts. Gesture research has shown that participants understood more detailed information when a speaker produced meaningful gestures along with speech (Kelly, Barr, Church & Lynch, 1999).
Recent research has shown that enactment using meaningful gestures can play an important role in learning language in the classroom (Kelly, 2009; Macedonia, 2011). In one study language learners were exposed to new words (Japanese verbs) under four different conditions: speech only, repeated speech, speech plus incongruent gesture, and speech plus congruent gesture. Testing showed the highest results for recall were produced by the speech plus congruent gesture condition, while the speech plus incongruent gesture condition produced the worst results. Verbal or textual teaching plus congruent gesture allowed learners to hear new words and see them embodied at the same time, resulting in stronger mental models (Kelly, 2009).

Another study on foreign language-learning revealed that enactment enhances memory not only for concrete words but also for abstract words. Learners achieved better recall for abstract words that had been enacted with meaningful gestures than for words presented without any gestures. Gestural enactment shapes language production and language comprehension, whether the gesture is produced by the speaker or the listener (Rogers, 1978).

**Enactment and Mental Simulation**

Enactment can be used to help learners “see” their own mental simulations so they are able use them in problem solving (Bergan & Marghetis, 2000). In one study, gesture production was used to recall sensorimotor information about the weight of several objects. Participants used enactment to turn mental simulations of weight into visible, physically felt gestures. They used this information to solve a puzzle that required moving imagined items of different weights in a specific order. The gestures they enacted
enabled them to physically sense the feeling of precise weights (Beilock & Goldin-Meadow, 2010). Embodied simulation prompts gesture; that is, thinking about a concept can elicit physical action related to the concept. Conversely, observing one’s own physical enactment can reshape and change one’s own mental model of a concept. Enacting gestures in this way has been observed to improve participant’s performance on mental rotation tasks (de Ruiter, 2000; Kita, 2000; Goldin-Meadow, Levine, Zinchenko, Yip & Factor, 2012).

**Enactment in Memory Retrieval**

Research over the past three decades has shown that in a learning environment encoding through enactment has many advantages over visual or auditory encoding alone. Studies have shown that teaching with enactment produces better recall and retrieval of encoded information, greater accuracy and quantity of detail, and slower rate of decay of memories (Macedonia, 2011; Engelkamp & Krumnacker, 1980; Zimmer, Helstrup & Engelkamp, 2000). Research involving brain imaging has demonstrated that if a self-performed action accompanies a word, it will be represented neurally with a motor component (Eschen, Freeman, Dietrich, Martin, Ellis, Martin & Kliegel 2007; Macedonia, Muller, & Friederici, 2011; Masumoto, Yamaguchi, Sutani, Tsuneto, Fujita & Tonoike, 2006; Nilsson, 2000). Adding enactment to a learning experience causes it to be encoded with multiple modalities. This deepens and enriches mental and physical

Researchers have used a variety of different strategies to encourage their participants, often school-age children, to engage in memory retrieval by using gestures and body movement. In a study by Stevanovi & Salmon (2005), children participated in an event and were asked to recall it two weeks later. They described the event under one of four given conditions: a) gesture modeled – teacher showed them gesturing in her example, but did not verbally instruct them to gesture or not, b) gesture allowed – children were given permission to gesture if they wanted to, c) gesture not-allowed, and d) gesture instructed. Those operating under the gesture-instructed condition were able to retrieve much more detailed information than those instructed not to gesture. These results indicate that instructing children to purposefully gesture when describing a past event elicits greater memory retrieval (Stevanovi & Salmon, 2005). Gesture also elicits more detailed memory recall for emotional events. In a study by Wesson and Salmon (2001), children were asked to describe a situation in which when they had felt happy, sad or mad. They were asked to express their feeling in one of three ways: a) verbally, b) verbally and by drawing or c) verbally and by enactment. Children who expressed themselves only verbally often gave very brief accounts of their experiences, which may not have accurately portrayed the amount of information they had encoded about the events. The children who expressed themselves through drawing or enactment provided more descriptive information than the verbal-only group. These results indicate that embodiment during recall enhances memory retrieval and detail in narrative (Wesson & Salmon, 2001).
In a study by Liwag and Stein (1995), children were asked to recall an emotional situation by making a face to show how they had felt during the event. This kind of enactment is known as *emotional reinstatement*. When the children in the study practiced emotional reinstatement as directed, they not only recalled their own facial expressions, but were able to act out the event in detail, portraying body movements and facial expressions of themselves and others present during the event. By enacting facial expressions, children were able to retrieve memories of other physical actions and details about the event, leading to greater recall of the emotional experience. This shows how enactment can allow mental models to be expressed as detailed, enacted narrative (Liwag & Stein, 1995).

**Enactment and Student Conceptions**

Enactment can be useful for revealing students’ mental models of concepts. It is also a valuable tool for *correcting* and *redirecting* prior knowledge that is inaccurately represented in memory. Enacting an event can change how information is stored in memory. Each time an event is “replayed” through enactment, it is updated in memory to include the latest sensory and motor information. Memories containing incorrect facts can potentially be re-opened and redirected by adding correct information guided by enactment (Nader & Ledoux, 1999).

Because of its potential to correct and redirect inaccurate student conceptions, enactment is a valuable tool for teaching. This role of enactment in redirecting conceptions holds tremendous untapped potential in the field of education. Students come to the learning experience with preconceptions about how things in the world work, based
on their embodied and enacted experiences. The gestures and actions students use to describe a scientific subject often reveal how their embodied conceptions differ from the scientific point of view. Understanding students’ prior knowledge is invaluable in planning lessons, enacted and otherwise. Inaccurate student conceptions can be redirected and overwritten using accurate enactments. But to be effective, teachers need to gain access to students’ embodied prior knowledge.

**What is Prior Knowledge?**

Prior knowledge is what the student brings to the table in a learning experience. Students’ embodied and emotional experience (Pintrich, Marx & Boyle, 1993; Zembylas, 2005; Zull, 2002: 91-132), combined with what they have learned about a topic from external sources (Treagust & Duit, 2008; Acar, Sesen & Ince, 2010), forms their mental model (conception) of an event or subject (Glynn & Duit, 1995). In the field of educational research, conception is defined as “the learner’s internal representation constructed from the external representation of entities constructed by other people such as teachers, textbook authors or software designers (Treagust & Duit, 2008).” This definition forms the foundation of much of the current educational research on prior knowledge. Embodied cognition adds to that definition the understanding that the learner’s internal representations about the world are grounded in embodied experience. A more complete explanation would say that a student’s physical experience in their specific body and environment, combined with what they learn from external sources, forms their conception, the basis of their prior knowledge (Lakoff & Johnson, 1999:16-23; Gibbs, 2006:12-13; Damasio, 1999:169-194; Zull 2002: 2-9).
**Why is Prior Knowledge Important?**

Prior knowledge forms the framework upon which students attach new ideas. If the framework a student brings to class is inaccurate, it can lead to confusion and difficulty in incorporating new information (Carey & Gelman, 1991). It is important for teachers to become informed of their students’ conceptions. If incorrect conceptions are not addressed, students may appear to “learn” new material by memorizing facts about a subject, but outside of the classroom they will revert to their original conceptions about the subject (Donovan & Bransford, 1999; Zull, 2002: 92-93). Minstrell (1989: 130-131) compares student misconceptions to tangled strands of yarn, advising that it is the job of a teacher not to disregard, but rather to acknowledge the tangled conceptions, and to help students untangle and redirect them along a more scientific path.

Prior knowledge and student conception have become increasingly important topics of research in recent decades (Wandersee, Mintzes & Novak, 1994). As early as 1962, Ausubel stated that prior experience was the single most important factor influencing learning (Ivie, 1998). In 1982, Posner echoed that conviction when he developed a classical approach for studying conceptual change. His approach begins by confronting students with their misconceptions. Posner believes confrontation will cause the students to feel dissatisfied about their misconceptions, which will motivate them toward conceptual change. Once they have been confronted, they must be presented with accurate conceptions that fit three criteria in order to motivate change:
Intelligible | New conceptions must be sensible, non-contradictory, and make sense to the student.
---|---
Plausible | The student must consider the conceptions to be believable
Fruitful | The conceptions must be useful in helping the student solve problems or find direction in new research.

Table 2: Posner’s approach toward conceptual change

These criteria have been used in many studies to determine students’ conceptions and understand what motivates conceptual change (Hewson & Hennessey, 1992; Tsiu & Treagust, 2007). However, confrontation alone does not always bring about change – conceptions are often deeply held, personal beliefs that are resistant to change (Treagust, 2008). Simply being confronted with their misconceptions may not be enough to motivate students to change their internal representations. A more effective route for redirecting concepts would be to present correct information and allow student to take responsibility for changing their own conceptions.

The impact of emotion on conceptual change has become a recent topic of interest in research, though it has received limited attention. Researchers studying this topic view emotional affect as an important element in motivating interest and leading to conceptual change (Pintrich, Marx & Boyle, 1993, van der Veer & Valsiner, 1991). According to Zembylas (2005), cognitive and emotional dimensions must both be considered with equal status as variables influencing conceptual change.
Current Findings on Student Conceptions

Considerable research has been done on student conceptions. Numerous well-documented studies have explored how students form conceptions and how this prior knowledge impacts how they learn new material (Duit, 2007; Treagust & Duit, 2008). Studies have explored student’s mental models of science-related processes, including physics, astronomy, mechanics, acids, evolution, radiation, and metacognition (Riesch & Westphal, 1975; Boyes & Stanisstreet, 1994; Neumann & Hopf, 2012; Eikelhof, Klaassen & Lijnse, 1990; Millar, Jarnail & Singh, 1996; Millar, Klaasen & Eikelhof, 1990; Rego & Peralta, 2006; Duit, 2007). Studies have revealed some common external factors that contribute to incorrect conceptions. In some cases, confusion and unclear conceptions were the result of premature introduction of science terminology (Rego & Peralta, 2006). When students could not distinguish between new and unfamiliar terms, they developed unclear mental representations of concepts (Riesch & Westpahl, 1975; Boyes & Stanisstreet, 1994). In other cases, incorrect online media representations led students to develop incorrect conceptions (Eikelhof et al., 1990; Millar, Jarnail & Singh, 1996; Millar, Klaassen & Eikelhof, 1990). One study traced student misconceptions about science topics back to scientifically incorrect internet sources that students had used for research (Acar, Sesen & Ince, 2010). Another study revealed that student misconceptions are sometimes passed down by teachers. Students and teachers assessed in this study were found to share common inaccuracies in their conceptions. (Duit, 2007; Libarkin, Anil, Crockett & Sadler, 2011).
What Methods have been used to Assess Students’ Prior Knowledge?

Researchers and teachers have employed a variety of methods to gain access to student conceptions. Studies often combined several of the following methods to gather data:

1. Written: Students answer a questionnaire about their understanding and emotional response to the subject (Boyes & Stanisstreet, 1994; Libarkin, Anil, Crockett & Sadler, 2011; Rego & Peralta, 2006).

2. Personal interview: Researchers follow up on the answers to the written questionnaire with an in-depth interview (Libarkin, Anil, Crockett & Sadler, 2011). During the interview, students may be shown pictures and then encouraged to talk freely about the topic, revealing their understanding of the subject.

3. Panel discussion: Students discuss the subject as a group (Libarkin et al., 2011). This can be a valuable method, as social and group factors have been shown to have a positive influence toward motivating interest and conceptual change (Solomon, 1987; Dykstra, Boyle & Monarch, 1992).

4. Drawing: Students are invited to draw a picture of their conceptions. Studies have shown commonalities within different age groups in the way they represent conceptions through drawing (Neumann & Hopf, 2012).

Here is an example of questions used in one study (Neumann & Hopf, 2012) that can easily be adapted to fit other studies:
• What words come to your mind when you hear the word ___?
• What feelings and emotions come up when you hear the word ___?
• I am going to show you pictures of different objects. Which object do you associate with the term ___?
• I am going to list some specific types of ___. Please tell me whether or not you have heard of them, and in what context you have heard of them.
• You read in a magazine or online that ___. Do you think this could be true?

The Missing Piece: Incorporating Enactment into Assessment of Prior Knowledge

The list above includes written, spoken, group, and drawing methods of assessing prior knowledge. What is missing entirely is an enacted approach. Even though research shows that enactment increases capacity for detailed memory retrieval and enables recall of prior knowledge (Wesson & Salmon, 2001; Liwag & Stein, 1995), it is not being used to assess prior knowledge in any studies I could see. Yet it would not be difficult to incorporate an element of enactment into one of the above methods, adding it into the personal interview or the group discussion. Students could simply be asked to gesture or act out a concept, and to show with their body how they feel about it. Adding enactment to assessment would provide an exciting new way to visibly reveal students’ emotions about subjects being discussed. Enactment could provide information about prior knowledge in a way that written and verbal interviews cannot.
Summary

For years, researchers have believed that prior knowledge is an important factor influencing learning. Studies have investigated student conception in a wide variety of different subjects, many times focusing on science concepts. Knowing what students know is very important, but how do we get at that knowledge? Until now, data for studying prior knowledge has been gathered mostly through non-emotional, non-physical methods, such as group discussion, written and verbal interviews (Treagust, 2008).

This thesis argues that using enactment in assessment will reveal student conceptions in a way that verbal assessments alone cannot. My study has two goals:

1. To use enactment to assess students’ prior knowledge
2. To take what is revealed about their prior knowledge and use it to develop an enacted lesson that can correct and redirect their misconceptions.

The next chapter will discuss how enactment reveals students’ prior knowledge through affect. The data analysis and results of an enacted assessment will be presented. The final chapter will use data from this study to develop an enacted lesson plan that is informed by student conception. The informed lesson plan will be contrasted with a lesson plan that is not informed by prior knowledge. I will finish with conclusions of this study and its possible future applications.
Chapter 3: Using Enactment to Assess Student Prior Knowledge

This chapter includes a discussion of methods for assessing prior knowledge, techniques for developing enacted assessments, and results of the actual assessment done for this study.

Methods

The methods used for gathering information in this study were drawn from previous studies on student conception. These methods were selected to provide multimodal channels of expression through which student conceptions may be made visible. Elements of assessment include:

- independent group discussion of written questions
- drawing
- personal interview
- narrating and enacting concepts

Participants

Three boys, aged 11, participated in this study. Two of the participants are twin brothers. All three participants grew up in the same school system.

Techniques used for developing assessment

1. A concrete example (plant and water) was made available. At the beginning of the assessment, students were asked to water the plant. This was intended to prime their creative thinking and problem solving about the concepts being discussed.
2. The questions in the assessment were few and designed to be simple.
3. Phrases like “why do you think” and “what are your ideas about how this works” were included to encourage students to reveal their own personal conceptions, rather than simply saying what they think they are “supposed” to say. The purpose of the assessment was to make the students’ thinking visible to themselves and the researcher – not to ask them to perform a task or repeat facts about a subject (Donovan & Bransford, 1999:15).

4. During the assessment, familiar terms were used to introduce and discuss concepts. Scientific terminology was avoided because students were still developing an early understanding of the concept. Studies have indicated that terminology introduced before students have built an accurate conception can cause confusion (Neumann & Hopf, 2012; Eikelhopf et al., 1990; Millar & Jarnail Singh, 1996; Millar, 1990). After students have formed a clear conception, then terminology will be relevant and useful (Zull 2002: 158-159).

5. Questions were designed to be non-leading. Word choice involving verbs, prepositions, and directional wording was given careful consideration to avoid imposing misleading agent/patient relationships in conception.

   Examples of implied relationships:

<table>
<thead>
<tr>
<th>How does a plant take in water?</th>
<th>Agent: plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does water get into a plant?</td>
<td>Agent: water</td>
</tr>
<tr>
<td>What makes water move into a plant?</td>
<td>Agent: plant, water, or an outside force</td>
</tr>
</tbody>
</table>

Table 3: Implied relationships
Verbs, prepositions and directional words determine how the student embodies (mentally simulates) and enacts (physically emulates) their understanding of the relationship between the plant and the water. Word choice in questions may inadvertently impose a particular viewpoint. Neutral terms are used when possible in order to stimulate and reveal the student’s own thinking about agent/patient relationships in the concept.

6. A drawing component was included to help students spatially organize their thoughts as a reference to encourage detailed narrative and enactment during the individual interviews.

The Assessment

Part One: Group Discussion and Drawing

Students began the assessment sitting together at a table. The following items were on the table: a plant, three cups of water, drawing materials, and a piece of paper containing the following discussion questions and instructions:

- Please water the plant.

1. Discuss your ideas about the following questions together:

   - Why do you think we water plants?
   - How does the water get into the plant?
   - How does the water get out of the plant?
   - What makes the water move through the plant?
2. Draw a picture of how you think this may work.

Students were asked to read the directions and take a few minutes to discuss the questions among themselves. The discussion was recorded.

**Part Two: Individual Interviews**

After the group discussion, students were taken individually into a separate room to be interviewed. During the interview, students were repeatedly encouraged to respond to questions by “acting it out” and “showing” what they meant with their bodies. Interviews were recorded. The following statements and questions were included in both the group and individual discussions:

- I would like to know what you think about plants and water and how they work together.
- I would like you to tell me with words and also show me with actions – show me what is happening by acting it out, show me with your hands.

1. Show me and tell me what is happening in your drawing?
2. Why do you think we water plants?
3. How does the water get into the plant?
4. How does the water get out of the plant?
5. What makes the water move through the plant?
Data Analysis

In analyzing the videos of the group and individual interviews, I was looking for the following information:

- What did the students’ words and actions reveal about their conceptions of the relationship between the plant and the water? What did actions reveal about student conceptions that words did not?
- What did the students’ words and actions reveal about their emotional affect toward the different questions? What did actions reveal about their emotional affect that words did not?
- What are the common misconceptions and gaps in the students’ knowledge? What student misconceptions and gaps did action reveal that words did not?

The data analysis provided supporting evidence that using enactment in assessment can reveal student conceptions in a way that verbal/written assessment alone cannot.
Group Discussion Questions and Responses:

Directive: Please water the plant.

- Students watered the plant with little discussion, but as they answered the following questions, the plant on the table became the physical reference and focal point of their discussion and enactments.

Directive: Discuss your ideas about the following questions together:

1. Why do you think we water plants?

   Student response:
   
<table>
<thead>
<tr>
<th>Verbal</th>
<th>to help it live, grow, make it blossom, provide nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>gestures followed path of water and enacted blossoming of plant</td>
</tr>
<tr>
<td>Affect</td>
<td>similar words and gestures indicated confidence in answers and showed group was in agreement and mental alignment</td>
</tr>
</tbody>
</table>

   Table 4: Group response: Why do you think we water plants?

2. How does the water get into the plant?

   Student response:
   
<table>
<thead>
<tr>
<th>Verbal</th>
<th>suction through stem to leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>sucking sounds and small pulling movements directed toward the root area of the plant on the table.</td>
</tr>
<tr>
<td>Affect</td>
<td>confident, agreement in gestures and speech</td>
</tr>
</tbody>
</table>

   Table 5: Group response: How does water get into the plant?
3. How does the water get out of the plant?

Student response:

<table>
<thead>
<tr>
<th>Verbal</th>
<th>Evaporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>small pinching/pulling movement directed toward leaves</td>
</tr>
<tr>
<td>Affect</td>
<td>confident, agreement in gestures and speech</td>
</tr>
</tbody>
</table>

Table 6: Group response: How does water get out of the plant?

4. What makes the water move through the plant?

Student response:

<table>
<thead>
<tr>
<th>Verbal</th>
<th>students made vague half-sentences about the stem, the sun, water rising.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>students all suddenly began producing multiple upward pointing gestures; it seemed like they were searching for an answer, and aligning gestures gave them confidence in their answers. rising, rippling fingers enacted evaporation.</td>
</tr>
<tr>
<td>Affect</td>
<td>less confident, revealed by slight frowns, pauses, looking at plant, searching gestures.</td>
</tr>
</tbody>
</table>

Table 7: Group response: What makes water move through the plant?

Directive: Draw a picture of how you think this may work.

The drawing component was included to provide an opportunity for students to graphically organize their thoughts. It was used as a reference to encourage narrative and enactment during the individual interviews.
**Summary of Group Discussion**

Working as a group seemed to give the students confidence, although the conclusions they reached together were not always correct. Students aligned their verbal conceptions and increasingly echoed each other’s gestures as they shared ideas and agreed on conclusions. Difficult questions resulted in higher gesture production. Enactment was focused toward the plant, and came from an observer point of view, as opposed to actually taking on the role of the plant or the water.

<table>
<thead>
<tr>
<th>How does water get into plants?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing gesture toward roots seemed accurate, but sucking sounds in enactment indicated inaccurate conception.</td>
</tr>
<tr>
<td>Affect: strong, confident</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How does water get out of the plants?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulling gesture to enact water coming out through leaves was accurate.</td>
</tr>
<tr>
<td>Affect: strong, confident</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How does water get out of plants? (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising, rippling gesture indicated accurate embodied conception of evaporation.</td>
</tr>
<tr>
<td>Affect: strong, confident</td>
</tr>
</tbody>
</table>
How does the water move through plants?
Group produced multiple common upward-pointing gestures, but lacked words to describe the concept verbally.

This indicated a gap in knowledge.

What is the force that makes the water move through plants?
Group produced vague, limp gestures.

Affect was weak, indicating less confidence of knowledge.

Figure 2: Gesture and Affect in group responses to questions about water and plants.

**Individual Interview Questions and Combined Student Responses**

**Interviewer:** *I would like to know what you think about plants and water and how they work together. I would like you to tell me about that with words and also show me with actions – act it out, show me with your hands – what is happening?*

**Questions:**

1. Show me and tell me what is happening in your drawing?

In some cases, the drawing was a useful tool to help the student to produce detailed, enacted narrative. Mainly deictic gesture was produced, following path of water as it travels through plant. Rippling fingers enacted how water becomes vapor.
Student drawings give the appearance of a strong understanding of how water moves through plants, yet additional enacted testing revealed areas of misconception. This is evidence that in conventional assessment, students are able to conceal areas in which they lack understanding.

1. Why do you think we water plants?

Student responses:

<table>
<thead>
<tr>
<th>Verbal</th>
<th>they would die without water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>None</td>
</tr>
<tr>
<td>Affect</td>
<td>confident</td>
</tr>
</tbody>
</table>

Table 8: Individual response: Why do you think we water plants?
2. How does the water get into the plant?
Student responses:

<table>
<thead>
<tr>
<th>Verbal</th>
<th>by the roots/suction/ roots suck up the water from the soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>my feet are the roots (suction sound), suction gestures with spread fingers, pulling gestures with arms and body, full body drawing water up from ground to over head</td>
</tr>
<tr>
<td>Affect</td>
<td>confident</td>
</tr>
</tbody>
</table>

Table 9: Individual response: How does water get into the plant?

3. What makes the water move through the plant?
Student responses:

<table>
<thead>
<tr>
<th>Verbal</th>
<th>(pauses, uncertainty, questioning intonation) Other things inside the stem maybe? Dirt? I don’t know. Um, uh, like, little... (unfinished thought).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>dramatic pulling, squeezing motion to fill in verbal gaps</td>
</tr>
<tr>
<td>Affect</td>
<td>not confident. All students were either embarrassed, hesitant, unsure, shifting, head tilting, gazing into distance for answer.</td>
</tr>
</tbody>
</table>

Table 10: Individual response: What makes water move through the plant?

4. How does the water get out of the plant?
Student responses:

<table>
<thead>
<tr>
<th>Verbal</th>
<th>steam/water vapor/the sun/it travels through the roots, up the stem to the leaves and evaporates off the leaves.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacted</td>
<td>Student 1: I am the water, I pour into the plant, (acts out being poured) I am the plant, the water goes up me, (arms straight up) and to the sun (arms and fingers spread upward).</td>
</tr>
</tbody>
</table>

Student 2: (silent, arms akimbo, plenty of sucking sounds, enacts plantsucking in water until it has reached full capacity, then…) Burst! (arms suddenly fling up as if releasing water) And then it evaporates.

Student 3: *If the sun is shining on me then water comes out* (Sssss sound, with arms over head waving, pushing water out)

<table>
<thead>
<tr>
<th>Affect</th>
<th>Confident</th>
</tr>
</thead>
</table>

Table 11: Individual response: How does the water get out of the plant?

**Summary of Individual Interviews**

The individual interviews revealed the students’ uncertainty of concepts and gaps in knowledge more than the group discussion or the drawings. Students required persistent encouragement from the interviewer to enact the role of the plant or water, but when they did, it produced significant details about their conceptions and level of confidence in their answers. Enacted answers produced longer, more detailed narratives than non-enacted answers.

**Results**

The analysis of the student responses provided the following answers to my original questions:

1. What did the students’ words and actions reveal about their conceptions of the relationship between the plant and the water?
   
   - Students correctly understood that evaporation is a factor in water movement through plants, and that water moves from soil to root to stem to leaves.
What did actions reveal that words did not?

- In the group discussion, actions were used as a means of aligning of mental models. Group agreement was important and increased confidence.
- In individual interviews, enactment produced greater verbal detail, as well as exposing misconceptions and revealing gaps in knowledge and areas of uncertainty.

2. What did the students’ words and actions reveal about their emotional affect toward the different questions?

- Emotional affect toward the questions was revealed verbally by intonation. Confident answers were statements and unsure answers were questions with pauses.
- Emotional affect was revealed in action through facial expression, gesture rate, posture and gaze.

What did actions reveal that words did not?

- Acting out concepts revealed emotional affect in a way that verbal answers did not. Affect was a clear indicator of prior knowledge.
- Negative affect during enactment visibly exposed students’ lacked of confidence in their knowledge, even when their speech was convincing the interviewers and themselves that they knew the right answer. Students’ reluctance and anxiety toward enacting a conception was indicated by hesitation, facial expressions, side glances, body posture, lack of eye contact during enactment, and vague, anxiously repeated gestures.
Positive affect produced strong, confident gestures. Enactment was more effective than speech for evaluating students’ levels of confidence in their understanding. When students were uncertain of answers, their faces, hands and bodies revealed affect much more than their words.

3. What overall common misconceptions and gaps in knowledge were revealed by the assessment?

- The assessment revealed that these students had an incorrect conception that roots use suction to draw in water from the soil.

- The assessment also revealed a gap in students’ understanding of what causes the movement of water through the plant.

What did action reveal that words did not?

- The sucking sounds and sucking gestures used in describing the concept emphasized students’ inaccurate mental models.

- The gaps in knowledge were revealed less by words and more by silent pauses, uncertain gestures, increased repeated gestures, uncertain postures and facial expressions.
Results Applied to Hypotheses

<table>
<thead>
<tr>
<th>Statement of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Using enactment in assessment will reveal student conceptions in a way that verbal assessments alone cannot.</td>
</tr>
<tr>
<td>2. Enacted lessons that are informed by student conceptions will be more effective at correcting and redirecting inaccuracies than enacted lessons that have not been informed by student conceptions.</td>
</tr>
</tbody>
</table>

Table 1: Statement of Hypotheses

The results of the data were applied to the first point of the hypotheses:

1. Does enactment in assessment reveal student conceptions in a way that verbal assessments alone cannot?

Observations of this particular group of students indicated that enactment during assessment can provide information about student conceptions that may not be revealed through verbal assessment alone. During the group discussion, enactment was observed as being a means of aligning mental models, coming to agreement, and building confidence. In individual interviews, enactment exposed misconceptions, emphasized gaps in knowledge and increased detail of verbal narrative.

Enactment made students’ levels of confidence in their knowledge visible. They were less confident about enacting a conception they felt they did not know well. Acting out concepts revealed emotional affect in a way that verbal answers alone did not.
One thing I was not looking for and was surprised to discover was how enactment exposed students’ emotional affect toward topics. Emotions about different topics were revealed through enactment in ways that verbal assessment alone did not reveal. Facial expressions, posture, vocal quality (answering hesitantly, slowly, quietly, fading out, or strong and confident), and prosody during enactment were all indicators of how the students felt about their knowledge and their ability to enact the concept. Shifting, fidgeting gestures, embarrassed smiles and looking up to think or down to avoid eye contact, as well as pauses in speech and gestures were very telling of topics in which students’ felt less confident of their conceptions. This was revealed more during character viewpoint, role playing enactment during the individual interviews than observer point of view gesture in the group discussion.

<table>
<thead>
<tr>
<th>Side glance, slight cringe, raised eyebrows.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates uncertainty of knowledge.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upward gaze held, drawn eyebrows. Perplexed by inability to access a mental simulation to use as the basis of enactment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates gap in knowledge.</td>
</tr>
</tbody>
</table>
Figure 4: Enactment in Assessment Reveals Affect through Facial Expressions. Students did not produce these facial expressions during verbal and drawing portions, but as they concentrated on enactment they seemed to become less conscious of their facial expressions.

The results led me to these observations overall:

Enactment puts affect in the spotlight. Enactment is a window of insight through which students unconsciously expose their level of confidence through affect. A student’s primary motivation is to give the right answer, whether they know it or not. In an assessment, their spoken and written answers may be misleading, designed to bluff through and conceal areas of weakness. Something about enacting is very revealing – through body language, posture, and speech, students unconsciously give away a clear picture of what concepts they understand and what they are struggling with. Verbal,
written and drawing assessments do not reveal emotional affect in this way. Enacted assessment provides a way for students to see their own mental simulations played out, and actively test them against concrete examples. Enactment makes conception visible to student and teacher. The majority of educational assessments are in written form, yet research indicates this may not be the most effective way to get at student conception and emotional affect toward the topic. I propose that a future study should ask this question:

Will data support the idea that verbal assessment accompanied by enactment is more effective in revealing information about student conceptions than written assessment alone?

This information would benefit researchers, teachers and students. A proposed outline of this study is included in the conclusion of this thesis.

2. The results of the data were also applied to questions raised by the second point of the hypotheses:

What student misconceptions were revealed by this assessment? How can an enacted lesson plan use this information about the students’ prior knowledge to correct and redirect their misconceptions?

The assessment revealed the following misconceptions:

- Students enacted an inaccurate conception of roots using their own suction power to pull in water from the soil.
- Students’ enactions revealed a gap in their understanding about what causes the movement of water through the plant.
Students in this particular study portrayed plants as agents, actively sucking water from the soil. This conception is scientifically inaccurate. Water is drawn into roots and stem through osmotic exchange and transpiration; plants are neutral components in these actions. Students were also uncertain about how water moves through plants, though they had partially correct conceptions. In a role-playing setting, students naturally tend to project their own human characteristics, such as agency, onto whatever concept they are acting out. This can cause a problem with scientific concepts, where components operate by forces that do not fit into the roles of agent and patient.

An enacted lesson that is informed by student conception would correct and redirect conceptions in the following ways:

1. Confronting /addressing students’ misconception that plants have their own suction power.
2. Redirecting misconceptions by guiding students through a new, plausible alternative enactment that accurately represents transpiration.
3. Filling in gaps with another enactment designed to build a stronger mental model of the role of evaporation in transpiration.
4. Testing new information with enacted follow-up exercises.

The next chapter will use the above information to address the second question raised by the hypothesis:

Are enacted lessons that are informed by student conceptions more effective at correcting and redirecting inaccuracies than enacted lessons that have not been informed by student conceptions?
The data that has been analyzed here will be used to create an enacted lesson that is informed by students’ prior knowledge, following the four guidelines above. This lesson plan will be contrasted with an enacted lesson plan that is not informed by student conception.
CHAPTER 4: Planning Lessons Informed by Student Prior Knowledge

This chapter compares two lesson plans: Lesson A, which is informed by student prior knowledge, and is designed to address specific inaccuracies and gaps in knowledge, and Lesson B, an enacted lesson that is not informed by prior knowledge. Lesson A and Lesson B will both attempt to answer these questions using enactment.

- Why do you think we water plants?
- How does the water get into the plant?
- How does the water get out of the plant?
- What makes the water move through the plant?

Lesson A will demonstrate how prior knowledge can enable a teacher to design a more effective lesson plan that will help students correct and redirect inaccurate conceptions.

Lesson B will demonstrate how a lesson plan that is not informed by student prior knowledge will be less effective at addressing and correcting student misconceptions.

Teaching these lesson plans is not included in the scope of this project, but could provide the basis of future study and analysis.

Preparing Lesson A: Based on Student Prior Knowledge

Lesson A demonstrates how knowledge of students’ prior knowledge enhances an enacted lesson. Students can be led to recognize their misconceptions and redirect their own new conceptions. The following guidelines were used to develop the lesson plan.
1. How can I use my understanding of the students’ prior knowledge to address and redirect their specific misconceptions using enactment?
   • This lesson addresses a gap in the students’ knowledge of evaporation. The enacted assessment revealed that the three students understood evaporation is involved in water transport in plants, but they seemed to have a weak grasp on how evaporation actually functions in this process. The lesson will demonstrate evaporation through enactment to strengthen their mental model.
   • This lesson also addresses an inaccurate conception. The enacted assessment revealed that the students shared a conception of plants as agents, capable of sucking up water. The lesson is designed to redirect this misconception with an enactment demonstrating that plants are not agents, and replacing that concept by comparing the plant to a straw, a passive conduit for water. The enactment will emphasize that the sucking power does not come from the plant, but is caused by the outside force of evaporation.

2. Options: Confront students with misconceptions, as Posner directs? Or instead, design the lesson in a way that guides students to discover their own misconceptions?
   • Posner’s approach says students need to be confronted with their misconceptions and taught how to correct them. But conceptions are often strongly held, personal beliefs, representing a student’s reality and their
personal experience of the world. Students may be unwilling to change their conception based on a teacher’s words alone.

- A different approach would provide students with correct information and opportunities for active testing, allowing students to come to the realization of their error. Research indicates when students are able to realize their error and rebuild their own mental models, they are more likely to take ownership of their knowledge about a concept (Zull, 2002: 225-243).

3. Offer new conceptions that are intelligible, plausible and fruitful.
   - This lesson will provide enactments and exercises to allow them to experience the plausibility of the new conception and actively test its fruitfulness.

4. Set the scene to draw forth their prior conceptual framework so that new ideas may be attached to it.
   - This lesson sets the scene by having students water a plant. This action provides a concrete basis for thinking about how the concept works. The assessment they recently participated in began with the same action – watering a plant. The action is repeated here with the goal of reopening those recently stirred pathways of thought.
LESSON A

Let’s explore how water moves in plants. To start out, I have a dry plant. Let’s give it some water.

Let’s think about where the water is going right now. Imagine it slowly moving from the soil into the roots of the plant, then up the stem and out of the leaves. How is that happening? What is making it move? How does it get out?

(Give the students each a glass of water with a straw. Have them suck some water through the straw.)

Describe what is making the water move through the straw.

Stand up tall now, and stretch your arms up. Imagine you are a hollow tube, a giant straw, and water is being pulled through you. Imagine it flowing through you, coming up through your feet and rushing out of your head and hands. You are not pulling the water through – something else is pulling it through you. What does it feel like? (Give some time to feel it and reflect)

Can the straw suck the water up by itself? What is the power that pulls the water through the straw?

A plant is just like that. It does not have its own sucking power. It is just like a straw having water pulled through it.

(Stick a straw into the soil beside the plant to help students continue thinking along these lines)
Let’s think for a few minutes about what might be pulling the water upward through the plant.

(Get some little mirrors and have the students breathe on them to make them foggy)

There is water vapor on the mirror. Where did it come from? Why can’t I see the water when I breathe, but I can see it on the mirror? Tiny drops of water, so tiny they are invisible. Every time we breathe, tiny water is coming out of our mouths into the air. That is evaporation.

The same kind of thing happens with plants. Plants also have tiny little holes on the bottom of their leaves. They look a lot like tiny mouths, because they can open and close. At night they close. But as soon as it is light, they open and release water vapor. They also open if it is hot, or dry. Whenever they are open, water vapor is always coming out of them, evaporating into the air. In fact, the plant only saves 5% of the water for itself. The rest comes out of the holes on the leaves and evaporates.

These tiny holes that open and close are called stomata. Let’s pretend we are stomata. Remember, when it is nighttime, they close, when it is daytime, they open and let out water vapor. When you let the water vapor out, you can make a sound (turn light off, students close mouths, turn light on, students open mouths and breathe.)

Now let’s think about the water. Water is naturally drawn to places where there is less water, moving from a wet place to a dry place. If you put a napkin into a glass of water, the water will move up out of the glass and fill the napkin. When it is daytime, and the stomata on a plant are open, water in the soil is powerfully pulled into plant roots by the force of evaporation. The plant cannot move the water; it is just like a straw that the water
is being pulled through. When the stomata close for the night, the water stops moving too.

Tiny drops of water always like to stick together. When they start moving, they grab onto each other and pull each other along in a chain. We are going to try that. Grab your friend’s hand and pull them along. Now, imagine the classroom door is one of the stomata. When I open it, you begin to move toward it, but you have to grab the drop of water next to you until you all pull each other along through the door.

But what happens to the water then when it goes through the stoma? It turns into tiny drops of vapor and released the other drops of water. As soon as you go through the door, you can release each other and float around through the air. That is evaporation.

**Active testing activities:**

- Demonstrate the wicking action of water by placing a napkin or coffee filter in a glass of water. After a little while, water will defy gravity and be pulled up into it the area of lower pressure.

- Place a leafy stalk of celery or a white carnation into a glass of colored water. Hours later the veins of the stalk or the carnation will be filled with the color showing the path of the water.
Preparing Lesson B: Not Informed by Student Prior Knowledge

Without taking student prior knowledge into consideration, as a teacher, I can only guess at where to start my enacted lesson plan. I will begin from my own ground zero, planning the lesson based on my own assumptions of what they already know, or even thinking of the students as blank slates with no personal mental model of water movement in plants. I may not cover things they are confused about, or I may over-teach things that are already understood, which is not very interesting. Without taking prior knowledge into consideration, I will not think about redirecting or correcting misconceptions; I will just be piling new knowledge onto old. Without understanding their prior knowledge, I run the risk of inadvertently reinforcing their misconceptions by enacting a concept inaccurately, or failing to strengthen an area of weak understanding.

My main motivation for including enactment will be to grab their interest, to make the lesson emotionally and intellectually relevant by adding a physical experience. These are very good things. But we sell enactment short if we go into it blindly, and may inadvertently ingrain misconceptions if we are not informed of the students’ prior knowledge.

If I do not know what students think about transpiration, I may present an enactment that endows plants with human characteristics. It may seem like a good role-playing exercise to compare a plant breathing and drinking water to a human doing those same activities. I think this will help the students, but I am inadvertently reinforcing their erroneous belief that a plant has the same capabilities as a tiny human body.
LESSON B – not informed by student prior knowledge

Today we are going to learn about how plants breathe.

Everybody stand up. Take a long, deep breath in and raise your arms up over your head. Can you feel the air filling up your lungs? Now slowly breathe out and lower your arms. Let’s do that one more time.

Here is a plant. Did you know that plants breathe too?

What are the parts that we use for breathing? (lungs, mouth)

But plants have different bodies than we do. They do not have any lungs. Instead, they have tiny, tiny holes all over the back of their leaves that look just like little mouths. These little mouths are called stomata.

When it is daytime, they open up to breathe and look like this (everybody open your mouth).

When it is dark, they close like this, and stop breathing (let’s do that too).

We breathe in and out.

But plants only breathe out.

This plant looks thirsty. I am going to give it a drink. What happens now? How does the plant drink the water?

(Have students drink some water through straws.) We can think of the plant like a straw, with the roots sucking up the water.
Imagine you are thirsty plants. I will pretend to pour some water on you, and you can show me what a plant does. What does it sound like?

When the plants suck in the water, it goes all the way up the stem. Stand up tall, reach up your arms and imagine how that feels.

The plant sucks the water in through its roots.

Then when it breathes out through the tiny holes, the water gets pulled right up the stems. It turns into vapor and goes out the holes. As you know, that is evaporation.

Let’s all make a sound like we are sucking the water in through our roots. Now let’s open our mouths wide and breathe the water out.
Problems with enacted Lesson B:

This lesson is not all bad. It is active, fun and engaging, which is important in learning. It also teaches some scientific concepts. But adding student prior knowledge will greatly improve the content and scientific accuracy.

Specific problems with this lesson:

- It strengthens the student misconception that a plant has agency, breathing and sucking in water like humans.
- It does not address the gaps in student knowledge by providing an enactment to clarify how evaporation actually works to move the water through the plant.
- It does not attempt to build on the strength of what the students already know.
Conclusions

I entered into this project with one conception of enactment – I have gained a richer understanding of the possibilities it offers. I had always used enactment in education primarily because it is engaging for the students, helping them understand concepts and remember them by acting them out. Through this study, I have discovered these additional benefits of using enactment in education:

1. Enacted lessons informed by students’ prior knowledge can reshape inaccurate mental models and bring them into alignment with scientific models. Thinking about how enacted lessons can be improved by shaping them to fit students’ prior knowledge opens a whole new world of possibilities. We store our conceptions spatially as mental models. The idea of using body movement to re-shape our mental models seems natural and logical. Enactment seems like a more direct route to conceptual change than writing over inaccurate conceptions with words. Physical action is a direct way to reshape mental action.

2. Enactment reveals not only student misconceptions, but also teacher misconceptions. Previous findings have revealed that student misconceptions sometime stem from teacher misconceptions. I experienced this while working on this project. As I analyzed the data, watching the students enact their misconceptions and gaps in knowledge, I realized that the enacted lesson I had been originally been planning to teach them would support some of their inaccuracies.
3. Enactment during assessment reveals emotional affect. The results of this study show that enactment can play an important role in assessment by revealing student affect. Affect was revealed more during the enacted portions of assessments than during verbal or drawing portions. This suggests that enactment may also reveal affect more than written assessments. That prediction was not examined in this thesis, but would be an interesting topic for a future study. These results could have a far-reaching impact in education and research, since student assessments done in these fields are primarily written or verbal; to my knowledge they do not benefit from an enacted element.

   Students can hide their gaps of knowledge and misconceptions more easily during conventional non-enacted assessment. Enactment makes affect visible, revealing how students really feel about the subject. Students’ lack of confidence and overcompensation are visibly revealed during enactment through posture, gesture, facial expressions, and other physical actions.

4. This study could be a foundation for future research. Here are some conditions to consider for future studies:

   **Condition One**

   One future study would be a practical application of Lessons A and B provided in this thesis. It would ask the same question presented in this thesis, but actually test it by teaching the lessons and analyzing the results.

   - Does an enacted lesson informed by prior knowledge help correct and redirect student conception more than one not informed by prior knowledge?
A group of participants would have their prior knowledge on water transpiration assessed verbally and with enactment using the assessment materials provided in this study. Their prior knowledge would be used to develop Lesson A, with enactments designed to address their specific misconceptions and gaps in knowledge.

Students would be divided into two groups. Group one would be taught Lesson A, the other half would be taught Lesson B, not informed by prior knowledge.

Following instruction, students would take part in another assessment to determine their understanding of the concepts. This data would be used to answer these questions:

- Did any of the students redirect their enactments of the conception as a result of the lesson? Which group?
- Did any of them perform more accurate physical representations? Which group?
- Did the students who were taught the informed lesson correct their enacted conception?
- Did either group reveal a positive change in emotional affect when questioned about the subject, such as better posture, eye contact, answer in statements rather than questions, and enact fewer searching glances?
Condition Two

Another interesting direction would be to adjust the study to include research on teacher conception. Observing how the students enact conceptions is very useful for instructors to reconsider their own mental models and pinpoint any inaccuracies they may have before they pass them on. The study will ask this question:

- Does observing student enactment of a concept provide a useful method for teachers to re-evaluate their own mental models and adjust them to improve accuracy of instruction?

Methods:

Have teachers plan an enacted lesson based on their own knowledge. Then have the teachers observe students during enacted assessments of the concept. Have them rewrite the enacted lesson based on these observations.

Interview the teacher:

Through the process of studying student enactment, did you become aware of any personal conceptions on the subject that were inaccurate?
**Condition Three**

Another study would observe differences between students who are confronted with their incorrect conceptions, as directed in Posner’s approach (1982) as opposed to those who are given the freedom to come to their own conclusions and reshape their own mental models. The study would ask this question:

- Will students who are primed to discover their own inaccurate conceptions be more effective at correcting them than students who are confronted with their error by an external source?

This is discussed in the section on prior knowledge in Chapter 2 of this study. I predict that students who are presented with correct conclusions and allowed to test and compare them to their misconceptions will exhibit greater independent thinking skills than those who are confronted with their errors and presented with a new conception by an external source.

**Condition Four**

I would be most interested in the results of this idea for a study which I suggested in the results section of Chapter 3. This study would explore the efficacy of written vs. enacted + verbal assessment in revealing affect and prior knowledge. The majority of educational assessments are in written form. Research indicates that enactment may be a more effective way to get at student conception and emotional affect. I propose that a future study should ask this question:
Will data support the idea that verbal assessment accompanied by enactment is more effective in revealing information about student conceptions than written assessment alone?

This information would benefit researchers, teachers and students. A proposed outline of this study is included in the conclusion of this thesis.

The study would follow the same outline as the one in this paper:

Participants would be split into two groups. Group One would be given a written only assessment, students in Group Two would be given the same questions and asked to respond in individual interviews with enactment accompanied by speech. Responses would be observed and evaluated for level of understanding of concepts. I predict that enacted/verbal assessments will expose misconceptions and gaps in knowledge that students are effectively able to conceal in their written answers.

In conclusion, there are many directions that research on this topic could take. Enactment is an important field of study for research and education. Its value in encoding and retrieval are well documented. With hope, the new function presented in this study, enactment in testing and redirecting student prior knowledge, will see fruitful application in future studies and practical implementation.

Figure 5: Watering the Plant
Appendix

Question sheets used for group and individual assessments:

**Group questions (read aloud by students):**

Please water the plant. Talk together and try to figure out answers to these questions:

1. Why do you think we water plants?
2. How does the water get into the plant?
3. How does the water get out of the plant?
4. What makes the water move through the plant?
5. Draw a picture of how you think it works

**Individual questions (asked verbally):**

1. I would like to know what you think about plants and water and how they work together.
2. I would like you to tell me about that with words and also show me with actions – act it out, show me with your hands – what is happening?
   - Show me and tell me what is happening in your drawing?
   - Why do you think we water plants?
   - How does the water get into the plant?
   - How does the water get out of the plant?
3. What makes the water move through the plant? Act it out with your whole body.
Bibliography


http://dx.doi.org/10.1002/acp.706


