A MODEL FOR DYNAMIC TRANSFER OF LEARNING

Based on contemporary views of transfer of learning, we proposed a model to characterize transfer of learning as it occurs dynamically in an interview. Our model addresses several cognitive and epistemological issues that are relevant to transfer of learning. In light of contemporary transfer models, we have demonstrated how our model can help identify and characterize transfer as it occurs in an interview. We describe instances in which students transfer their learning spontaneously in an interview as well as those in which transfer is promoted by scaffolding provided by the interviewer.

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Introduction

Transfer of learning is often (e.g. Reed, 1993; Singley & Anderson, 1989) defined as applying what one has learned in one situation to a different situation. Most of the research on transfer of learning has focused on whether students who had learned a problem solving strategy in a given context were able to apply this strategy to other contexts (e.g. Reed *et al*., 1974).. However, the results of these and other similar transfer studies demonstrate that transfer, when measured this way, is rather rare. However, almost all of us know from everyday experience that we seldom invent a procedure or strategy each time in a new situation, rather we automatically transfer what we have learned in one situation to another. To reconcile the apparent contradiction some researchers have reconsidered the ways to characterize transfer (e.g. Bransford & Schwartz, 1999; Greeno *et al*., 1993; Lobato, 1996, 2003). In this paper we discuss our model of transfer that is based on these contemporary perspectives and has its underpinnings in cognitive psychology. We describe how our model can help characterize in vivo transfer as it occurs in an interview and its implications for research and instruction.

Theoretical Underpinnings

Lobato's (2003) "Actor-Oriented Model of Transfer" has its origin in the ideas of "perceived similarities" by Hoffding (1892) and "situated cognition" by Lave & Wenger (1991). The model relies on "personal creations of relations of similarity" by the learner, between the learning and transfer contexts, rather than similarities perceived by the researcher. Lobato's model builds on the socio-cultural aspects of transfer (Greeno *et al*., 1993). These ideas go beyond thinking of transfer as occurring entirely in a student's mind and begin to look at how the external factors such as interactions with the

environment, peers or the teacher can affect the transfer of learning. Greeno *et al.* (1993) focus on activities that the learner performs in the learning context. The learner interacts and becomes "attuned to the affordances" of the learning contexts of its "potential states of affairs," and brings the knowledge of these aspects of the learning context into the transfer context. Bransford and Schwartz (1999) promote a perspective of transfer as "preparation for future learning." They assess transfer based on students' ability to learn to solve problems with scaffolding rather than 'cold' i.e. without any hints or prior preparation. Students are given opportunities to reconstruct their learning in the transfer context in the same way as they did in the learning context.

All of the above perspectives share at least three common themes. First, they look at transfer from the students' perspectives rather than a pre-defined researcher's perspective. Second, they describe transfer as the dynamic construction of knowledge in the target scenario, rather than applying what they have learned previously. Finally, they go beyond looking at transfer from a purely cognitive perspective and include socio-cultural aspects in their discussion. Our model of transfer described above includes all of these contemporary perspectives in its discussion.

A Model for Dynamic Transfer – The Building Blocks

Interviews are a useful tool to gauge the dynamics of transfer of learning and provide insights into how students apply and reconstruct knowledge and experiences gained elsewhere as they respond to a question. An interviewer may attend to a particular aspect of a student's response at the expense of others or may unwittingly cue the student. The assumption that student knowledge remains static while it is probed in an interview ignores the dynamic in situ transfer and construction of knowledge by students.

We propose a model to characterize students' transfer in an interview. Our model utilizes the overarching structure of a two-level framework proposed by Redish, (2003) (Figure 1) which in turn is based on fundamental neuro-cognitive theories. The lower level includes associations between knowledge elements, which are "relations of similarity" in Lobato's (1996, 2003) Actor-Oriented Model. The upper level includes executive control that enhances (turns on) or suppresses (turns off) the associations between these knowledge elements based on a learner's epistemologies and expectations. Various elements of our model are described below.

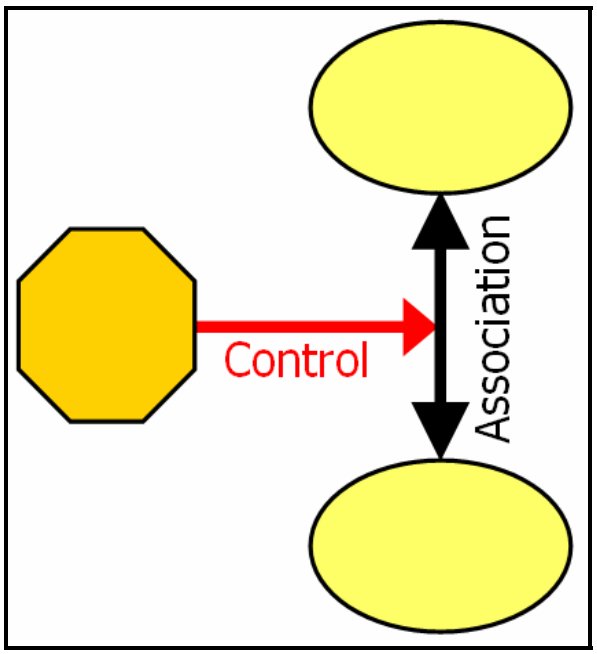

Figure 1: Redish's (2003) "two-level" framework of associations and control

External Inputs answer the question: "What prompts transfer?" An external input is information provided by the interviewer. It also includes other materials, e.g. text, pictures, demos, videos, etc. used in the interview. External inputs can play a key role in influencing transfer of knowledge. They can prime the student to focus on certain aspects of a problem situation at the expense of others. They may provide verbal and non-verbal feedback that prompts the student to think in a particular way, thereby facilitating either positive or negative transfer. Taking the external input into consideration is consistent with Greeno et al. (1993) and Lobato's (1996, 2003) view that "transfer is distributed across mental, material, social and cultural planes." Interaction with the interviewer is an example of this social interaction, which may cue students to access various knowledge elements or tools in their reasoning.

Tools answer the question: "What transfers?" In our model almost any object or idea, concrete or abstract, real or imaginary, can be a tool. We categorize tools in the following ways for our discussion of transfer.

'Source' Tools are pre-existing knowledge or experiences from a prior context such as real-life experience, classroom instruction, popular media or even previous interview questions (Gray, 2004). Source tools include a learner's dormant knowledge that is activated to make sense of new situations.

'Target' Tools are attributes of the 'target' situation that the learner uses to "know with" (Bransford & Schwartz, 1999; Broudy, 1977). They define the target context in the learner's mind. Target tools are presented via external inputs however not all inputs are tools. Rather the learner 'reads out' information that she considers relevant (diSessa, 1998) and uses this read out information as a tool. Target tools may include surface

features, deep structure, affordances or states of affairs (Greeno et al., 1993) that a learner attends to.

'Epistemic Meta-Tools' are epistemic resources ("knowledge is propagated" or "knowledge is fabricated") that a student activates to exercise executive control over workbench processes. Unlike the target tool, the epistemic meta-tool may be activated from a learner's long term memory through priming by the external input. Hammer and Elby (2001) describe two kinds of personal epistemological modes – "knowledge as propagated stuff" and "knowledge as fabricated stuff." A student's personal epistemic resources affect the types of cognitive tools they use. Thus, epistemic resources are "meta-tools" or higher-level tools that control the use of lower-level (cognitive) tools that the student uses. We have found in our research that epistemic meta-tools are not necessarily binary in nature, i.e. a student is not necessarily in either the "knowledge is propagated" state or the "knowledge is fabricated" state. Rather, a student could be in a combination of these two states in such a way that it is difficult to glean from the interview as to which state is being activated. An instance of this situation is discussed in the example below.

Workbench answers the question: "How does transfer occur?" The workbench includes mental processes that utilize inputs and tools, such as making connections between various tools. Workbench processes include reorganization and restructuring of knowledge such as assimilation and accommodation (Piaget, 1964), conceptual combination (Ward, 1997) or hybridization (Hrepic *et al.*, 2002), analogical, inductive or deductive reasoning and making decisions about the tools to activate in a given situation, i.e. "epistemic gaming" (Collins & Ferguson 1993) which Redish (2003) describes as a "coherent activity that uses …knowledge and … processes to create [new] knowledge." The notion of a workbench is consistent with the idea that transfer is a dynamic process in which relations and similarities are constructed anew in the transfer context and not merely transported from the learning context. Lobato's Actor-Oriented Model asks, "What relations of similarity are created? How are they supported by the environment?" The model of transfer by Greeno et al. hypothesizes that "a symbolic representation of structure is generated in the transfer situation based partly on information about another situation that is retrieved." Both of these are workbench processes that allude to dynamic learning, consistent with Bransford and Schwartz's view transfer as preparation for future learning. The following types of workbench processes are relevant to our discussion of transfer.

'Read-out' is the process by which a learner recognizes the relevance of certain attributes or transfer tools in the external inputs. A learner may be primed to notice some information at the expense of others based on the epistemic meta-tools that are activated at that time.

'Activation' is the process by which a learner recalls source tools or epistemic meta-tools into working memory that are dormant in long term memory.

'Association' is the process by which a learner interconnects tools in the working memory. Various types of associations are possible, e.g. inferential, causal, analogical, deductive or inductive. It is often difficult to distinguish between activation of a tool and its association with other tools. Typically when students explicate the associations that they construct, the activation is implied.

'Priming' is a higher order (meta) process by which covert meta-messages influence the way in which a learner frames the situation and activates certain epistemic meta-tools. Evidence of priming is indirectly inferred from the sources of knowledge that the learner refers to in her reasoning.

'Control' is a higher order (meta) process by which a learner enhances or suppresses associations, activations and read-out based on the epistemic meta-tools. 'Epistemic gaming' (Redish, 2003) by which a learner decides the types of knowledge is a controlling process. Like priming, evidence of executive control must be inferred indirectly from a learner's statements (e.g. "I made it up").

A Model for Dynamic Transfer – The Mechanism

Figure 2 demonstrates our model of transfer that builds on the generic structure provided by Redish (Figure 1). We model the transfer mechanism in three phases that are often indistinguishable.

Phase 1: The interviewer provides external input describing the problem scenario. Additionally, the interviewer also primes the learner through 'covert messages' to activate epistemic meta-tools

Phase 2: The activated epistemic meta-tool controls the process by which the learner weighs the relevance and reads-out certain pieces of input information to be used as a target tool in the reasoning process.

Phase 3: The epistemic meta-tool activates source tools from long-term memory. If the 'knowledge is propagated stuff' epistemic meta-tool is activated in phase 2, the learner is more likely to utilize knowledge acquired through formal instruction. If the 'knowledge as fabricated stuff' epistemic meta-tool is activated, the learner is more likely to use self-constructed knowledge. The learner establishes associations or relationships between the source and target tools. The association process described here is typically explicated by the student, while the activation process is implicit.

Therefore, in our model, transfer is a dynamic creation of associations between target tools read out from the external inputs and source tools activated from long term memory. Readout, activation and associations are mediated through higher-order control by epistemic meta-tools, which are in turn activated through priming by covert meta-messages in the external input.

We acknowledge that our model of transfer includes the role of the working memory in ways that may not be consistent with existing knowledge about the limitations of working memory. One such limitation is the maximum number of items that we can attend to simultaneously in our working memory. Another limitation pertains to the maximum duration for which one can hold information in the working memory without continuous rehearsal. Our model is silent about these limitations because we use the term 'working memory' rather loosely. Further research may be needed to refine this model to be more consistent with existing notions of the working memory as used in cognitive science.

Phase 4 (not in Figure 2): Two possibilities exist in this phase. First, in the short term, the source-target tool association prompts metacognitive reflection and self-regulation (Flavell, 1987) causing the learner to rethink the problem. Second, if the source-target tool association is strongly established to yield a new tool (comprising the two interlinked tools), that is committed to long term memory. This new tool may be activated as a single cognitive entity in the future, akin to Hammer et al's model (this volume) of coherent activation of coordinated resources. A learner's repeated association of the same tools in different contexts creates in her mind a co-ordination class described by diSessa (1998).

We adopt a 'value neutral' stance toward the scientific correctness of the associations described above and focus rather on the underlying factors. This knowledge of the intuitive associations, whether correct or incorrect, can help us design curriculum and instruction that promotes transfer.

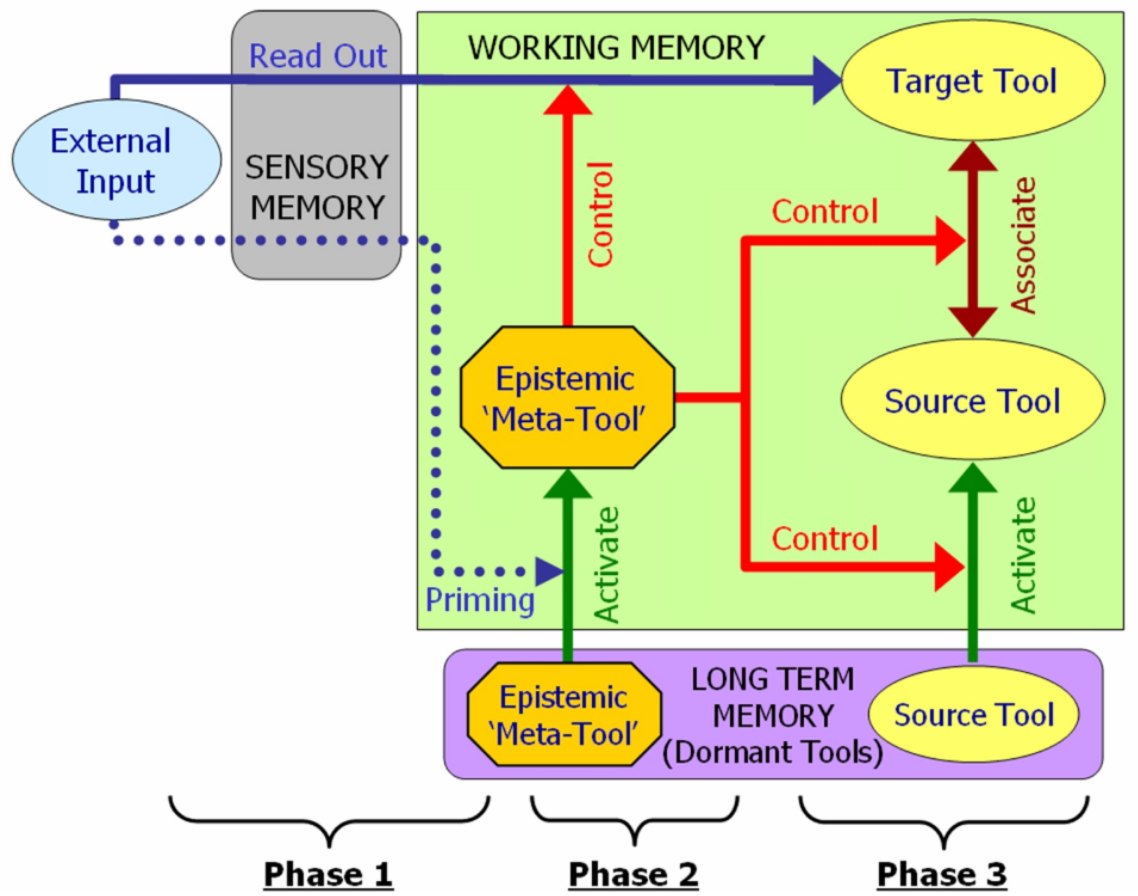

Figure 2: The mechanism of transfer proposed in our model

Applying Our Transfer Model – An Example

We demonstrate our model with data collected by other researchers (Wittmann & Scherr, 2002) who investigated the effect of a student's epistemological mode on her reasoning in an interview about current and conductivity. The student was asked what "category" [conductor or insulator] Styrofoam fell into. She stated that it was insulating. When asked why, she said she had "memorized it!" When asked to explain the property of Styrofoam that might lead to its insulating behavior, she referred to the "little density thing" and added that she did not "really know." When prompted that Styrofoam was "not terribly dense" she restated that she did not "really know" but added that "something inhibits the electrons from moving quickly." Asked to explain her reasoning, she talked about electrons bound to the lattice, but when asked to elaborate she stated, "I have no idea! That's organic chemistry!" As the authors point out, the student in this segment appears to rely on the epistemic mode that "knowledge is propagated" from authority (organic chemistry) and must be committed to memory. She appears to read out the 'density' attribute (target tool) of the Styrofoam and associate with her memorized knowledge about electrons (source tool).

In a subsequent segment the interviewer specifically asks the student to provide "*any* explanation" that she can find. The student begins to elaborate her reasoning: "… the electrons are bound to these molecules and it takes certain energies to tear them away." She is asked what tears them away and responds that she "assumes … just the battery…the power supply." As the authors explain, the prompt to provide "*any* explanation" appears to switch the student into the "knowledge is fabricated stuff" epistemic mode as indicative of the choice of her word "assume." She associates her ideas of electrons being "bound to molecules" and needing "energies to tear them away," both of which are previously acquired source tools with the battery or power supply in the target context. Another viable interpretation for this apparent change in the epistemic state of the student is that a student is in fact not completely in either the "knowledge is fabricated" state or the "knowledge is propagated" state at any time. In a sense she is always in a combination of the two states. Depending upon the context, she uses elements of both states as she selects the cognitive tools to construct her reasoning.

In this episode, the phrasing of the question appears to have primed the student into different epistemic modes. Initially she was asked what category (conductor or insulator) Styrofoam fell into. We speculate that asking her to use pre-constructed categories with scientific sounding labels may have activated her "knowledge is propagated" epistemic meta-tool. Later, asking her to provide "any explanation" she could find activated the "knowledge is fabricated" epistemic meta-tool. That a student's epistemic mode is not stable is consistent with the idea that transfer exists across multiple planes – intellectual, material and social (Lobato, 1996). Interaction with the interviewer primes the student into an epistemic mode, which in turn controls the activation of certain source tools and their association with target tools in the transfer context.

Summary and Instructional Implications

Based on the contemporary views of transfer (e.g. Lobato, 1996; Bransford & Schwartz, 1999; Greeno, *et al.*, 1993), we have constructed a model to characterize dynamic transfer of learning in an interview. Our model is based on the premise that students construct their responses to interview questions dynamically and often make things up on the spot. Our model is also consistent with Redish's (2003) two-level theoretical framework of associations and activations controlled by a learner's epistemic mode. We identify transfer as activation of associations between tools in the source (learning) and target (transfer) contexts. Epistemic resources are 'meta-tools' that control which associations a learner activates. For instance, a learner may selectively activate associations between the target scenario and classroom knowledge and ignore her everyday experiences because her epistemic resource directs her to see knowledge as propagated from authority and not created by her based on her everyday experience. Based on the external input, including meta-messages from the interviewer, a learner may be primed into a particular epistemic mode. The view of transfer as a process of epistemologically controlled activation of associations between source (learning) tools and target (transfer) tools is useful in characterizing dynamic transfer in an interview.

The clinical interview is useful in observing how students construct and transfer their knowledge dynamically. However, its goal of 'measuring' while not changing the knowledge state of the learner limits the amount of scaffolding that the researcher can provide to the learner. Therefore, although it may tell us the learner's prior knowledge state, the clinical interview often reveals little about how the learner will construct and transfer knowledge in a true instructional setting, when external inputs are provided. The teaching interview or teaching experiment (Steffe *et al*, 2000) affords the researcher the opportunity to investigate dynamic transfer and knowledge construction. The interviewer engages the learners in ways similar to a teacher in a small group instructional setting, often providing scaffolding such as hints, cues, hands-on learning, peer instruction, Socratic dialog, etc. All of these interactions provide a rich repertoire of tools akin to those in a true instructional setting. Therefore, our model has implications for designing effective curriculum and instruction to promote the transfer of learning.

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