CHAPTER FOUR

Incorporating Motivation into a Theoretical Framework for Knowledge Transfer

Timothy J. Nokes *and* Daniel M. Belenky

Contents

Abstract

Knowledge transfer is critical to successfully solving novel problems and performing new tasks. Several theories have been proposed to account for how, when, and why transfer occurs. These include both classical cognitive theories such as identical rules, analogy, and schemas, as well as more recent views such as situated transfer and preparation for future learning. Although much progress has been made in understanding specific aspects of transfer phenomena, important challenges remain in developing a framework that can account for both transfer successes and failures. Surprisingly, few of these approaches have integrated motivational constructs into their theories to address these challenges. In this chapter, we propose a theoretical framework that builds on the classical cognitive approaches and incorporates aspects of competence motivation. In the first part of the chapter we review the classical and alternative views of transfer and discuss their successes and limitations. We then describe our transfer framework that begins to address some of the issues and questions that are raised by

Psychology of Learning and Motivation, Volume 55

ISSN 0079-7421, DOI 10.1016/B978-0-12-387691-1.00004-1

the alternative views. In the second part, we describe how our proposed framework can incorporate aspects of competence motivation—specifically, students' achievement goals. We then describe an initial test of the framework and the implications for both psychological theory and educational practice.

1. Introduction

Solving a problem on a math final. Driving a rental car in a foreign city. Filling out tax forms after a recent move. Planning a backpacking trip. What do all of these activities have in common? *Knowledge transfer.* In each case prior knowledge and experience is used to attempt to solve a new problem or perform a new task. Success depends on a myriad of factors including the amount and type of prior relevant experience, our goals and expectations for success, our level of engagement and persistence, how important it is to succeed, and the perceived difficulty of the task or problem. In some cases success may be achieved with little effort while in others it may require much effort and persistence. In some situations we want to succeed because we want to demonstrate our abilities, or because we are trying to overcome a challenge. In each situation, transfer is determined by the interaction between our past knowledge and experience, the structure and demands of the task, and our motivations for success.

Having a deep understanding of how people transfer their knowledge from one situation to another is critical for both psychological theory and educational practice. A psychological theory of transfer must weave together research on learning, knowledge representation, memory, and problem solving in a principled and coherent way to make predictions for how and when we use our prior knowledge to perform new tasks and solve new problems. Such a theory has obvious implications for education and, for many educational theorists and practitioners, facilitating successful knowledge transfer *is* the critical goal of education (see Packer, 2001 for a historical analysis).

Although much progress has been made in the past 100 years of research on this topic, important challenges remain ahead. There are questions as to how to best account for the wide array of transfer phenomena observed in the literature, including the transfer of procedural skills versus declarative concepts and the transfer of simple versus complex knowledge representations. How do we account for near transfer to similar contexts versus far transfer across contexts and domains, and should these two types of transfer be accounted for by a single theory? How do we account for both transfer successes and failures? Can we construct a general theoretical framework that provides answers to all of these questions?

Much previous work has addressed these challenges from a cognitive perspective as being related to the application conditions of prior knowledge and the specific cognitive processes used to transfer that knowledge (see Barnett & Ceci, 2002; Gick & Holyoak, 1987 for reviews). This work has focused on the underlying knowledge representations and cognitive mechanisms including rules (Singley & Anderson, 1989), analogies (Gentner, 1983; Gick & Holyoak, 1983), schemas (Thorndyke, 1984), and declarative to procedural transfer processes (Anderson, 1987; Ohlsson, 1996). Other research has met these challenges by rejecting the classical cognitive view and proposing alternative perspectives such as situated transfer (Greeno, 1998; Lave, 1988), and preparation for future learning (PFL) (Schwartz & Bransford, 1998). Interestingly, the majority of this work has not included motivational constructs as central factors in their theories to address these challenges (but see Lave & Wenger, 1991).

This absence of motivational factors is not for a lack of research on motivation; as any review of the motivational literature is quick to turn up, there are many potentially relevant theoretical constructs such as intrinsic motivation (Malone, 1981), achievement goals (Elliot & Dweck, 2005), interest (Hidi & Renninger, 2006), task value (Eccles & Wigfield, 2002), affect (Blanchette & Richards, 2010), arousal (Eysenck, 1976), self-efficacy (Bandura, 1997), attributions (Weiner, 1985), the need for cognitive closure (Kruglanski & Webster, 1996), to name a few. Perhaps it is precisely for this reason that these constructs have not been explored and integrated into classical transfer theories; there are simply too many possibilities, making the task of integrating too daunting and unwieldy. Or perhaps this lack of integration reflects more traditional research divisions between cognitive, social, and educational psychology. Whatever the reason, we aim to address this issue in this chapter.

Our goals for this chapter are twofold, and so we divide the chapter into two corresponding parts. In the first part, we give an overview of three classical cognitive theories of transfer and two more recent approaches and discuss their successes and limitations. We then describe our theoretical framework that builds and extends the classical work and begins to address some of the issues and questions raised by the alternative perspectives. In the second part, we describe how theoretical constructs from competence motivation research—specifically, achievement goals—can be incorporated into this framework.

We see this work as an attempt to bridge prior transfer research in the learning and cognitive sciences to research on competence theory as examined in social and educational psychology. This bridging should benefit cognitive theory by incorporating the analysis of individual differences that have largely been ignored in past work and may play a key role in understanding transfer successes and failures. It should also benefit motivational theory by relating motivational constructs to fine-grained cognitive processes of learning and transfer. In the second part, we will describe some initial work testing aspects of this framework and offer some future directions. We end the chapter with the implications for psychological theory and educational practice.

2. Knowledge Transfer

A robust theory of transfer must be able to explain when, why, and how people use prior knowledge to solve new problems and perform new tasks. In this section, we briefly describe three classic cognitive transfer theories and two more recent approaches that have ventured answers to these questions. The purpose is not to provide an in-depth review of each theory, but instead to provide a background and context for our theoretical framework. We then describe how our framework incorporates the classical mechanisms and addresses some of the issues and questions raised by the alternative approaches.

2.1. Classical cognitivist approaches

One of the earliest theories of transfer is the theory of identical elements originally proposed by E. L. Thorndike (Thorndike & Woodworth, 1901). According to this theory, the amount of transfer between any two tasks is determined by the number of shared stimulus elements between those tasks—the more elements in common, the more transfer expected. J. R. Anderson and M. Singley have since given the theory a modern cognitive reconceptualization by recasting the identical task elements as *mental representations* in the form of IF-THEN production rules (Singley & Anderson, 1989). Like the original Thorndikean hypothesis, the amount of transfer is determined by the proportion of rules learned from one situation or task that applies to another. For example, if you have learned the addition rule: IF I am trying to find the sum of 2 + 2, and I know the relevant addition fact, THEN retrieve that fact and output the sum. You could of course use this rule to solve new instances of that same problem, 2 + 2 = ?. You could also use the rule to help solve the subcomponents of more complex problems such as 2 + 2 + 6, where you would first use the 2 + 2 rule before using or creating another rule to add the 6. This type of transfer is often described as vertical transfer in that the simple rule is being applied to solve a subcomponent of a more complex problem (Royer, 1979).

Identical rules are hypothesized to apply automatically, with little cognitive processing, when the application conditions of the rule are satisfied (Anderson & Lebiere, 1998; Anderson et al., 2004). They are also hypothesized to be goal-specific, and only applicable to scenarios in which the same goals are in play (Singley & Anderson, 1989). Given these representation and processing features the theory does well in predicting and explaining procedural transfer to very similar or identical contexts (e.g., Anderson, Conrad, & Corbett, 1989; Kieras & Bovair, 1986; Singley & Anderson, 1989). However, it does not explain how people can transfer knowledge to very different contexts or take advantage of that knowledge to accomplish different goals (Pennington, Nicolich, & Rahm, 1995).

A second classic cognitive approach to transfer is analogy. An analogy is the use of prior exemplar knowledge to solve a new problem or perform a new task (Gentner, 1983, 1989; Gick & Holyoak, 1980, 1983). Gentner (1999) defines analogy as having the following five components: (1) *retrieval*—recalling a prior (source) example or situation based on some similarity to the current context, (2) *mapping*—aligning the objects and relations of the source example and target problem, (3) *inference*—generating an inference based on that mapping for the current context, (4) *re-representation*—searching for new alignment and mapping if the initial mapping failed to result in an adequate solution, and (5) *learning and abstraction*—creating a new representation by abstracting over relations.

Analogy provides a good account for near transfer of prior examples to very similar contexts for novices (see Reeves & Weisberg, 1994 for a review of the empirical findings). Unlike the identical rules theory, the retrieval and application of an example using analogy is not goal dependent and thus frees the example to be used in different ways depending on the application context. Analogy can also account for more rare, across-domain transfer when the specific features do not match but the structural or higher-order relations do (Gentner, 1983, 1989). However, such transfer either requires enough experience in the domain to create an abstract representation that includes structural features of the problem (e.g., Novick, 1988), or the use of abstraction or re-representation processes (e.g., Hummel & Holyoak, 2003), both of which require additional cognitive processing either at the acquisition or application phases (see Forbus, Gentner, & Law, 1995; Holyoak, Novick, & Melz, 1994; Hummel & Holyoak, 2003, for computational models).

A third classic cognitive approach is schema theory (Marshall, 1995; Schank & Abelson, 1977; Thorndyke, 1984). This approach highlights the content and structure of the knowledge representation as the critical factor underlying knowledge transfer. Schemas are knowledge structures that consist of a description of the prototypical features and application conditions of the concept, principle, or skill. Compared to the rules approach, schema representations tend to include abstract features that are true of many examples of the concept, whereas rules include specific features of particular examples or situations. This mechanism can therefore facilitate far transfer to new contexts and across domains because the structural features of the knowledge representation are not tied to any particular instance or context. Although this knowledge structure supports far transfer, it also requires much cognitive processing to interpret how the abstract declarative knowledge should be applied to the new context (Nokes, 2009; Nokes & Ohlsson, 2005). This process of interpreting the declarative knowledge of the schema into a set of procedural actions is called declarative to procedural transfer. Two computational models that illustrate this process are knowledge compilation (Anderson, 1987; Neves & Anderson, 1981) and constraint violation (Ohlsson, 1996; Ohlsson & Rees, 1991), and both require much computational processing to translate abstract declarative knowledge into procedural actions.

Each of these approaches has received independent empirical evidence and can account for some key aspects of transfer phenomena. Common to each view is a focus on the scope of transfer afforded, how knowledge is represented, the cognitive processes for applying the knowledge, and the degree of cognitive processing required. Table 1 provides a summary of the representational and processing characteristics of each approach.

When transfer does not occur as expected it is typically explained as a failure in satisfying the application conditions for the mechanism or a disruption of the cognitive processes involved. Research that has shown transfer failures where transfer was intuitively expected, such as across isomorphic problem structures (i.e., Bassok, 1990), has led to the further development and refinement of these theories. Critically, none of these approaches has incorporated motivational constructs as major components of the theory. We believe that motivations may play a particularly important role in explaining both the transfer failures and successes. We build upon this classic work and articulate a theoretical framework in which the classical mechanisms naturally emerge from sense-making and satisficing processes enacted during transfer. The framework provides a solid foundation to incorporate motivational constructs, specifically competence motivation, into the theory. However, before describing the framework in detail we briefly describe alternative views to the classical cognitive approaches.

2.2. Alternative views

The alternative views were motivated in part by the paradox that although transfer appears to be a ubiquitous aspect of everyday life it proved elusive and difficult to observe in the psychological laboratory (see Bransford & Schwartz, 1999; Lobato, 2006 for reviews). These failures to observe

Table 1 Cognitivist Classical Approaches to Transfer

Approach	Scope of transfer	Knowledge	Transfer process	Efficiency
Identical rules	Very near; applies in situations that match similar application conditions and goals	Production rules	Applied automatically if application conditions of the rule match the current context	High efficiency, applied automatically
Analogy	Near for both novice and expert; far for experts	Exemplars	(1) Retrieve an example, (2) align and map to the current context, (3) generate inference, (4) re-represent, and (5) learn	Moderate efficiency; more similar task representations will result in faster alignment and mapping
Schema	Near to far	Facts, principles, and constraints	Declarative to procedural: knowledge compilation; constraint violation	Low efficiency, requires much cognitive resources and is error prone

transfer in the laboratory raised important questions about the definition, assumptions, and processes of the classical approaches (Lave, 1988; Lobato, 2006). In this section, we briefly describe two of the alternative views including situative transfer and PFL.

The situative perspective postulates that knowledge transfer is deeply interwoven into the individual's activity in the world (Greeno, 1997, 1998; Lave, 1988; Rogoff, 2003; see Gruber, Law, Mandl, & Renkl, 1995 for a review). Transfer is dependent on a set of interrelations between the individual and the environment and it is this set of interrelations that determines the likelihood of transfer (Greeno, 2006). Transfer is described as "patterns of participation" and it is the replication of this pattern that determines transfer to future contexts. Research programs that employ this view examine how the environment affords particular ways of participating in authentic activities (Brown, Collins, & Duguid, 1989). This view shifts the focus from the cognition of the individual to how the individual acts in the world.

In contrast to the classical theories, this view begins to incorporate aspects of motivation into transfer theory by focusing on how individuals participate in legitimate, authentic practices in a community (Lave & Wenger, 1991). With this focus on self-identity and participation in community practices there is great potential to link to work in the social and educational sciences on self-concept, attributions, as well as work on group processes. Similar to this view, we see motivational processes as critical to the transfer story and important to include in a general theory of transfer. Our proposal differs from this in that we focus on a different aspect of motivation, namely, competence motivation and achievement goals, and instead of rejecting the classical mechanisms of transfer, we build upon these mechanisms by incorporating them into our framework.

The second alternative view of transfer is PFL. Here transfer is not viewed as the static transportation of knowledge components from one task or situation to another but instead as the use of prior knowledge and experiences to *learn* from new resources and information that then can affect subsequent performance (Bransford & Schwartz, 1999; Schwartz & Bransford, 1998; Schwartz, Bransford, & Sears, 2005). This view has criticized the classical approach as focusing too narrowly on transfer as a form of sequestered problem solving, with no consideration of additional resources that the initial learning may have prepared people to use more effectively. The authors argue that this limits the types of transfer that one can observe and creates a setting that is not very naturalistic or representative of transfer in daily life.

This view differentiates between transferring knowledge "into" situations versus transferring knowledge "out of" situations. Transferring "into" focuses on how prior knowledge affects the interpretation, encoding, and learning of new information, whereas transferring "out of" focuses on how prior knowledge can be used to solve new problems and perform new tasks (i.e., the classical view). This definition broadens the theoretical conceptualization of transfer and has contributed to the discovery of previously hidden transfer phenomena (Schwartz & Bransford, 1998; Schwartz & Martin, 2004). However, like the classical mechanisms, this approach does not incorporate motivational constructs into the theory.

Although situative and PFL approaches are often discussed as competitors to the classical cognitivist approaches, we believe they are complementary, providing an important focus on components critical to a general theory of transfer but lacking in the specific cognitive processes. We believe that progress in understanding transfer depends on bridging the classical cognitive approaches with these alternative approaches. To move toward this goal, we describe a sense-making framework of knowledge transfer, which consists of cognitive processes that determine when the transfer cycle begins and ends. This framework incorporates interrelations between the learner and the environment, and draws on the classical cognitive mechanisms, which naturally emerge. We believe that this framework can also incorporate motivational constructs that may help to further bridge the classical approach with these alternative views.

2.3. Multiple mechanisms and sense-making transfer framework

Our theoretical framework builds on our prior work on transfer as sense-making and dynamic shifting between multiple mechanisms (Nokes, 2004, 2005, 2009; Nokes, Mestre, & Brookes, submitted) and Mestre and his collaborators' work on coordination processes in transfer (Dufresne, Mestre, Thaden-Koch, Gerace, & Leonard, 2005; Thaden-Koch, Dufresne, & Mestre, 2006). The framework consists of two stages: constructing a representation of context and generating a solution. Each stage is explicitly targeted to account for novice transfer behavior. The construction of context stage consists of generating the frame and activating prior knowledge, and the solution generation stage consists of knowledge application and solution evaluation. These different stages are driven by sense-making and satisficing processes in which one evaluates whether the current representation or problem solving approach "makes sense" and is moving the solver closer to the solution. Figure 1 shows an illustration of the transfer cycle in this framework.

2.3.1. Sense-Making and Satisficing

Sense-making is the act of coordinating an individual's goals and expectations with his or her current understanding of the problem or task and then resolving possible discrepancies. It is an evaluation process that takes place during each stage of the transfer cycle. We hypothesize that sense-making takes place in accordance with H. A. Simon's (1956, 1996) notion of *satisficing*, which is the idea that people will use a solution that suffices to accomplish the goal, even though that solution may not be the most optimal or efficient for the task. Simon (1956) famously described this type of reasoning as "bounded rationality." We take this notion and apply it to transfer. We hypothesize that people satisfice when both constructing a representation and generating a solution, and that these processes determine when the transfer cycle begins and ends.

Applying these ideas to transfer shifts attention from a sole focus on the application conditions of the prior knowledge to determining the cognitive

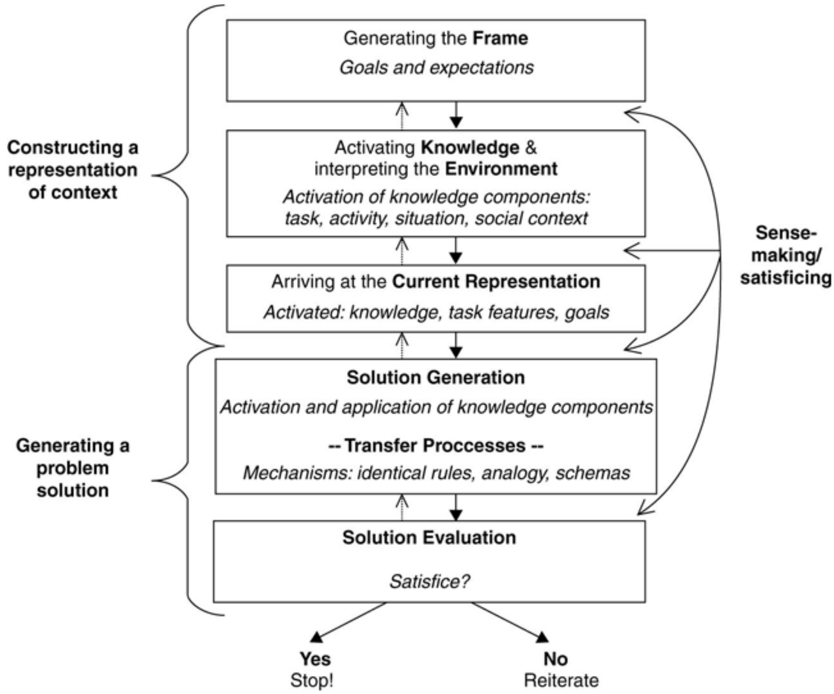

Figure 1 Sense-making transfer cycle adapted from Nokes, Mestre, & Brookes, submitted.

and motivational constraints on the transfer scenario. It also highlights the importance of determining what factors influence a person's *satisficing criteria*. For example, if a person's goal is to understand the solution, then we might expect different kinds of transfer processes than those for a person who simply wants to obtain a correct answer. Specifically, in the former case we might expect a mastery-oriented individual who is concerned with understanding a task to show more engagement and a higher likelihood of generating a deep, relational analogy than a performance-oriented individual who is satisfied with a less optimal surface feature solution. Next we describe the framework in more detail, beginning with constructing a representation of context before discussing solution generation.

2.3.2. Representation of Context

2.3.2.1. Frames The first component necessary for the construction of context is the generation of the frame. Consistent with other work in the learning sciences, we define a *frame* as an individual's representation of what is being asked or expected of her (Hammer, Elby, Scherr, & Redish, 2005; Redish, 2004; Scherr & Hammer, 2009). For example, a student may frame a physics laboratory group activity as an opportunity to learn more about the underlying physics concepts whereas another student may frame that very same activity as a opportunity to show what she knows and demonstrate her ability to solve physics problems to her classmates and teacher. The first student frames it as an opportunity to develop understanding and the second frames it as an opportunity to perform for others. The frame is often implicit and can be described as answering the question: "What sort of activity is going on here?" We hypothesize that frames are formed as the result of an interaction between a person's goals, expectations, and perception of the target task. We hypothesize that the frame will have a large impact on the satisficing criteria adopted for a particular transfer situation. In the above example, the first student's frame may lead to a deep engagement in the activity and a quest to understand the physics, resulting in collaboration with her classmates; whereas in the latter case, the student's frame may lead to a focus on individual performance and ability, resulting in little collaboration.

2.3.2.2. Knowledge and Environment The second component for the construction of context is the activation of prior knowledge. Consistent with other work in the cognitive and learning sciences, we postulate that knowledge is represented as *knowledge components*. We adopt the classical view that knowledge components include different types of knowledge representations including rules, examples, declarative facts, strategies, principles, and constraints (e.g., Koedinger, Perfetti, Corbett, & the PSLC, 2010). These components get activated in response to perceived cues from the environment and the generated frame. Consistent with classical cognitive theories we view knowledge activation as dependent on memory mechanisms, such as spreading activation, that is, the idea that concepts are related to one another in a semantic network, and activation of one concept activates related concepts as a function of the strength of the relation (Collins & Quillian, 1969). The types of knowledge components activated during this stage depend on perceptions of the cues in the environment. This includes both the physical environment, such as the structure and type of task (e.g., a word problem or an algebraic expression), as well as the social environment including the other individuals present and the social context (e.g., an in-school activity vs. a family function). The environment will provide constraints (e.g., time limitations) and affordances (e.g., books, the internet) that will impact the activation of prior knowledge components.

In sum, the construction of context is highly dynamic, activated by individuals' motivations, prior experiences and knowledge, and the features of the physical and social environment. The context contributes to the sense-making and satisficing processes used throughout the transfer process.

2.3.3. Generating a Solution

2.3.3.1. Transfer Processes In the solution generation stage a person's prior knowledge is brought to bear to generate a solution or to perform some action. Here the various classical cognitive mechanisms naturally emerge from the activated prior knowledge (see Figure 1). If multiple mechanisms are activated the mechanism with the least cognitive cost will be triggered, according to the principle of cognitive economy (Nokes, 2009).

2.3.3.2. Evaluation After a solution attempt has been made, the individual evaluates his or her solution to see whether the solution satisfies the intended goal, which constitutes the last stage in the transfer process. If the solution attempt satisfices, the transfer cycle for that problem is over. If not, some aspects of the transfer cycle will be reiterated. This may result in a change to the frame and the satisficing criteria ("I'm not sure this is right, but I am bored and want to stop") or a new attempt to satisfy the current goal ("Since this formula didn't work, I need to look for a different one that applies here.").

2.4. Answers to initial questions

This transfer framework provides some answers to the questions posed in the introduction. By incorporating multiple transfer mechanisms, the framework can account for both procedural and declarative transfer, as well as near and far transfer (Table 1). The framework makes testable predictions about which mechanisms will be triggered for particular types of transfer scenarios, as well as what behavioral outcomes to expect (e.g., if rules are triggered then one should expect the student to show procedural transfer with minimal cognitive processing).

This framework can also help describe mechanisms that assist in accounting for both transfer successes and failures. According to the framework, transfer failures occur because of either (1) the limited scope of the transfer mechanism or (2) an outcome of satisficing. The first type of failure is consistent with classical work but extends this view to incorporate the notion of multiple mechanisms and that particular mechanisms will have different levels of success dependent on the specifics of the transfer scenario (frames, prior knowledge, and task characteristics). An example of this type of failure is lack of transfer for a production rule to a new context in which it does not apply. The second type of failure is a misalignment of the expectations of the experimenter, teacher, or expert with the novice's satisficing criteria. An example of this type of failure occurs when a student is asked to "explain her/his answer" but instead simply restates or redescribes the answer or gives a surface response such as those common in math and physics classes when a student explains that an answer is the result of applying a particular equation without providing a justification for why they are using that equation or what it means conceptually. This suggests that future work should focus on understanding what factors affect satisficing criteria for particular situations. We believe that motivational factors will play a particularly important role in determining the satisficing criteria for specific types of transfer scenarios.

Next we describe how research in *competence motivation*, specifically students' achievement goals, can be incorporated into the framework. Although other motivational constructs may also be incorporated, we believe achievement goals in particular offer a compelling example of how research on motivational variables can serve to inform our understanding of knowledge transfer.

3. Competence Motivation and Achievement Goals

Much work in social and educational psychology has focused on human motivation, learning, and performance. A large portion of this work falls under the category of what has been called achievement motivation (e.g., Covington, 2000; Dweck, 1986; Nicholls, 1984). This work concerns the factors that affect success in obtaining achievement and encompasses research on intrinsic and extrinsic motivation, attributions, evaluation anxiety, goals, and other constructs. Elliot and Dweck (2005) have recently argued that this literature is better conceptualized as research on competence rather than achievement because competence provides a clearer, coherent, theoretical construct, and target of study.

By focusing on competence as the core of achievement motivation research, Elliot and Dweck (2005) highlight the dual aspects of human ability and success, as well as inability and failure. They argue that competence is a ubiquitous aspect of our daily lives and critical to many human pursuits in work, academic, sports, and social contexts. Furthermore, this construct naturally incorporates both approach motivations, or striving toward competence and avoidance motivations, or moving away from incompetence. We adopt this view and suggest that competence plays a particularly important role in knowledge transfer in academic settings. We examine the role of competence motivation as it is manifest in students' achievement goals.

3.1. Achievement goals and transfer

A prolific amount of research has been conducted on the topic of achievement goals in the past 20 years. Achievement goals are a person's aim in an achievement setting. The dominant framework for considering achievement goals posits two dimensions for goals: definition and valence (Elliot & McGregor, 2001; Elliot & Murayama, 2008). Definition refers to the criterion by which competence is evaluated. When it is based on an absolute standard or some internally set goal, this is considered a mastery goal. When it is based on a normative standard, this is considered a performance goal. Valence refers to the seeking out of positive outcomes (approach) or the avoidance of negative outcomes (avoidance). Combining these dimensions results in four different separable goals: mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance. This framework has been empirically validated, though discussions are still on-going about the reality and utility of the mastery-avoidance construct.

A student in an academic setting can have varying levels of each of these goals, and, as each of these goals are theoretically separate, the independent effect of each can be examined. Over many studies, certain general patterns of student behavior, affect, and achievement outcomes have emerged for each achievement goal. Performance-avoidance goals have been consistently linked with maladaptive outcomes, such as test anxiety, low self-efficacy, poor study habits, avoidance of help-seeking, procrastination, and ultimately, poorer achievement (in the form of test scores, term grades, etc.) (Elliot, McGregor, & Gable, 1999; Urdan, Ryan, Anderman, & Gheen, 2002). The findings for performance-approach goals are more mixed, and have spurred debate about their relative impact on students and achievement (see Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002; Midgley, Kaplan, & Middleton, 2001). Performance-approach goals have been linked to negative behaviors and affective variables, such as procrastination, test anxiety, and shallow processing strategies (Elliot & McGregor, 1999) as well as positive behaviors, such as persistence and effort (Elliot et al., 1999). In terms of achievement outcomes, performance-approach goals have been found to predict achievement measures, such as grades, particularly in college settings (Elliot & Church, 1997; Harackiewicz, et al., 2002). Mastery-approach goals have been related to greater use of cognitive and metacognitive strategies, such as elaboration, planning, monitoring, and help-seeking, a preference for challenge, higher levels of effort, less procrastination, greater interest, and long-term retention (e.g., Elliot & McGregor, 1999; Ford, Smith, Weissbein, Gully, & Salas, 1998; Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008; Pintrich, 1999; Somuncuoglu & Yildirim, 1999). However, there is only mixed evidence for mastery-approach goals being linked to achievement measures, such as grades.

4. Transfer Framework and Achievement Goals

Given the previous work establishing relationships between achievement goals and student behaviors, cognition, and affect, we hypothesize that students with greater adoption of mastery-approach achievement goals should show a higher probability of knowledge transfer. By incorporating these achievement goals into our transfer framework, we hope to capture variation in transfer performance that is not currently captured by the classical cognitive theories or the alternative views of situated transfer or PFL. We hope that by including these goals they will help further improve the predictions of the framework as well as provide a first step to integrating aspects of motivational and cognitive theories. Second, we hope this integration will further specify the underlying cognitive mechanisms by which achievement goals have their effects.

We view achievement goals as different kinds of cognitive *frames* the student generates for a given transfer scenario. Figure 2 illustrates how various achievement goals could be incorporated into the transfer framework and their potential effect on knowledge activation and satisficing criteria. For example, we predict that a mastery-oriented student might persist until he or she has understood the solution, whereas a performance-oriented student may satisfice after simply generating a plausible answer, whether or not s/he has a deep understanding of the solution.

As the previous section highlights, these different orientations should impact the initial learning and the knowledge acquired, which should also have implications for transfer through creating different prior knowledge that can be activated in the construction of the context. If, for example, a mastery-approach goal facilitates deep cognitive processes, persistence, and engagement, then we might expect this to lead to the acquisition of more abstract knowledge and promote far transfer through the later application of abstract declarative to procedural transfer processes. If one did not initially develop that abstract declarative knowledge, it would be impossible to use a declarative to procedural transfer mechanism. Similarly, a mastery-approach goal may make one actively seek prior knowledge to use, increasing the likelihood of making an analogy.

In the transfer phase itself, these orientations may also play a role by affecting the satisficing criteria of the transfer task. That is, when solving a transfer problem with a mastery-approach goal, one might not be happy with simply arriving at just any solution, but may evaluate the quality ("Do I think the answer makes sense?"). In contrast, if one has a

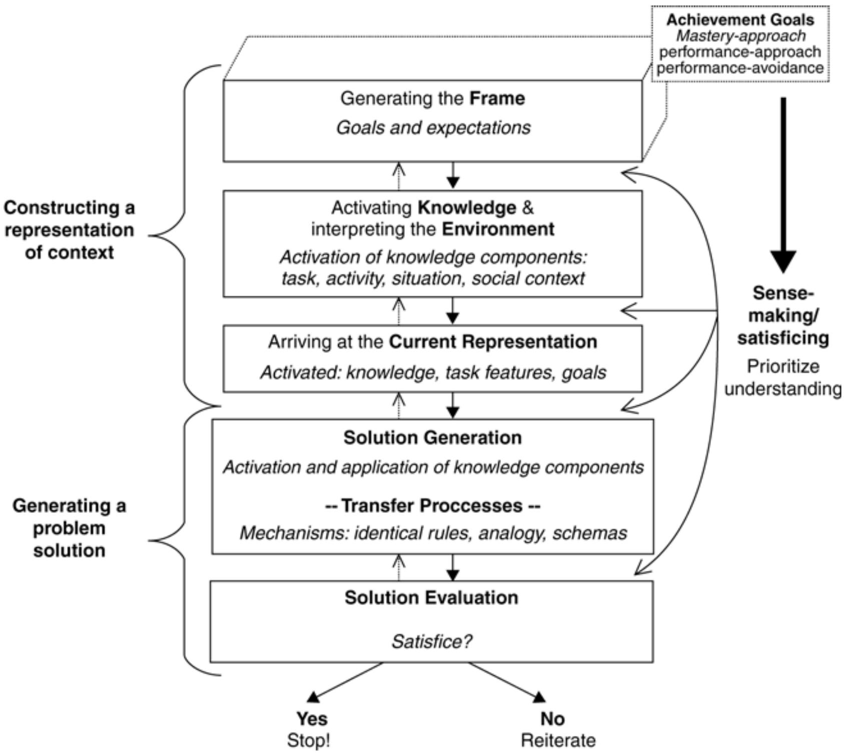

Figure 2 Sense-making framework with achievement goals incorporated. In this illustration a student generates a frame that consists of a mastery-approach achievement goal, which affects her satisficing criteria by focusing on understanding the content of the transfer task.

performance-approach goal and treats each task as a separate demonstration of ability, then one might not be expected to transfer across performances ("Do I think this is what the teacher is looking for here?").

We believe that one reason for incorporating achievement goals into classical theories of transfer is that it adds a new target at which to aim instructional interventions. That is, much of the research on the classical mechanisms has focused on the knowledge representation as the instructional target (see Barnett & Ceci, 2002; Gick & Holyoak, 1987 for reviews). We know from prior work that this has been only partially successful, and is likely not to be the whole transfer story. Even when students acquire the "correct" knowledge components (as defined by the representational scope of application) there have been cases of transfer failure (Nokes, 2009). We hypothesize that sense-making and satisficing processes are one way to account for these failures. If achievement goals affect *satisficing criteria* then one can target instruction at manipulating students' achievement goals as another route to facilitate knowledge transfer.

4.1. Testing the hypothesis

Based on this understanding of how motivation may influence transfer, some predictions are available for empirical testing. One main prediction is that having a mastery goal orientation during learning—which is geared toward the development of understanding—will ultimately lead to better transfer of that knowledge. Although there are theoretical reasons to believe this to be so (Harackiewicz, et al., 2002; Pugh & Bergin, 2006), very few empirical studies have examined this in academic domains (see Bereby-Meyer & Kaplan, 2005; Bereby-Meyer, Moran, & Unger-Aviram, 2004; Ford et al., 1998, for examples in nonacademic domains).

Another set of predictions has to do with how different academic tasks can spur different motivational goals, and what influence this can have on transfer. Specifically, research on the effect of different classroom practices and expectations has found that granting students authority, using different forms of evaluation, and offering challenges increases mastery goal adoption and interest (e.g., Ames, 1992; Ames & Archer, 1988; Malone & Lepper, 1987). As such, one would expect that more open-ended forms of instruction may increase mastery goal adoption for the task at hand. This mastery goal adoption may lead to improvements in transfer, relative to instruction that does not promote this change in goals, particularly for those students who would otherwise not adopt mastery goals on their own.

Together, this leads to the following predictions, which can be empirically tested:

- Students who are more mastery-oriented are more likely to successfully transfer knowledge from instruction to both near and far transfer contexts.
- Students who are not highly mastery-oriented to begin with will transfer better from a more exploratory, open-ended instructional technique relative to a standard direct instruction model. This benefit will be due, at least in part, to an increase in mastery goal adoption during the learning activity.

One study that has examined these possibilities has recently been conducted (Belenky & Nokes, 2009, submitted). This work was based on an earlier study by Schwartz and Martin (2004), which investigated the role of different instructional activities on subsequent ability to transfer knowledge into new learning opportunities and future problems. Belenky and Nokes (2009, submitted) added motivational measures to this paradigm, using the Achievement Goal Questionnaire (Elliot & McGregor, 2001) to assess existing mastery-approach orientation toward mathematics, as well as asking students about their goals and affect during the activities. In this study, students were given one of two types of instructional activities, tell-and-practice or invention. These activities had to do with the concept of standardization, asking students to decide which of two exceptional scores from different given data sets was more impressive. To solve this correctly requires using some conceptualization of the idea of standardizing the values.

In the tell-and-practice condition, students were shown a graphical method for divvying up the distribution to aid in deciding which of the scores was more impressive and told to use it to help them solve the problem. This could be equated with a "direct instruction" form of pedagogy, where the focus is on telling students how to solve problems, and giving them practice doing so. In the invention condition, students were given the same problem to solve, but were not given any explicit aid to solve the problem. Instead, they were instructed to try to come up with a way to solve the problem on their own. Although students struggle and fail to arrive at the correct solution, this sort of problem gives students authority and agency over solving a challenging problem. As such, this type of instruction may have benefits for mastery goal adoption, placing relatively more importance on the development of understanding than on demonstrating ability. This possibility was investigated using a short questionnaire that was administered during the learning activity.

Transfer was assessed by a question that gave students high values from two distributions. For each of these distributions, the descriptive statistics were given (i.e., mean and standard deviation). The students had to decide which of the values was more impressive. While similar to the learning activity, this problem was different in that it did not give the students the data, but rather just the descriptive statistics. As such, the exact method from the tell-and-practice condition could not be used without some adaptation. Also, the problems were constructed in such a way that more intuitive forms of reasoning would arrive at faulty conclusions (i.e., the largest value is not the most impressive, given the distributions).

Additionally, half of each condition received a worked example embedded in the test, which introduced and demonstrated how to use a formula to calculate a standardized score (i.e., [Given value−Mean]/Standard Deviation). No explicit mention was made of how this could be used in relation to the earlier problems or to potential future uses. This worked example was always presented at least two problems prior to the transfer item. If students noticed that this formula could be used in the transfer problem, this would be evidence for initial learning that had

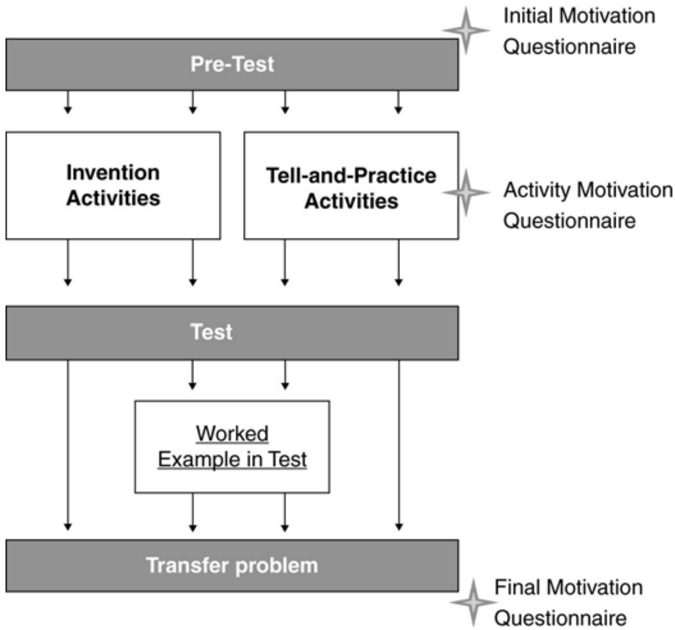

Figure 3 Overview of the experimental design from Belenky and Nokes, 2009, submitted.

prepared the students for future learning of the similar concepts. Students who did not receive this worked example had difficulty solving the transfer problem (11%), but interesting results emerged among those who did receive the worked example. See Figure 3 for an overview of the experimental design.

Among those who received the worked example, the students who were more mastery-oriented at the beginning of the study were more likely to transfer, collapsing across the type of instruction they received. Figure 4 shows the regression model predictions for the likelihood of transfer as a function of students' preexisting mastery orientation scores. For each unit change of the mastery-approach orientation score the odds of successfully solving the transfer problem increase by 29%. This is evidence for the first prediction, that mastery goal orientations can lead students to engage in a way that promotes transfer, as predicted by the sense-making transfer framework.

Evidence for the second prediction required seeing a benefit for invention activities over tell-and-practice for those students who entered lower in mastery orientation. This prediction was also supported. For the tell-and-practice group, the effect mirrored the one seen in Figure 4; the higher one's mastery-approach scores, the higher the likelihood of

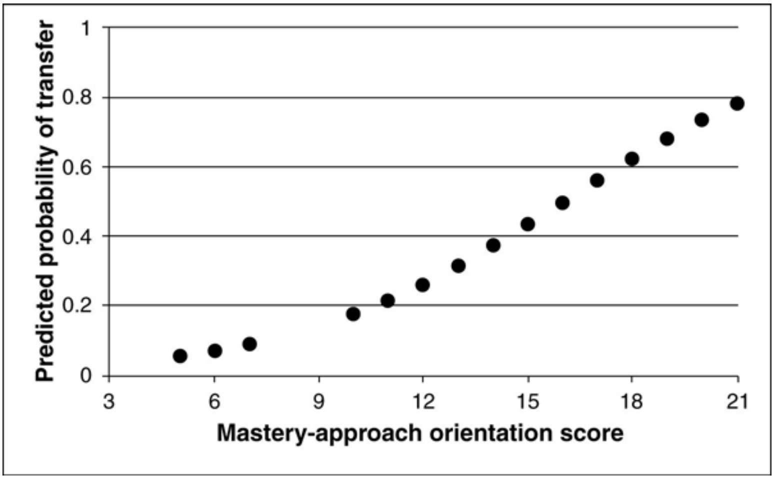

Figure 4 Predicted probability of transfer for those who received a worked example collapsed across condition. Based on data from Belenky and Nokes, 2009, submitted.

successfully transferring. Those low in mastery-approach orientations were unlikely to successfully transfer. However, for the invention group, the relationship between existing mastery-approach orientations and likelihood of transfer was attenuated. Figure 5 shows the regression model predictions of the likelihood of transfer as a function of mastery-orientation score and instructional condition. Students who invented were likely

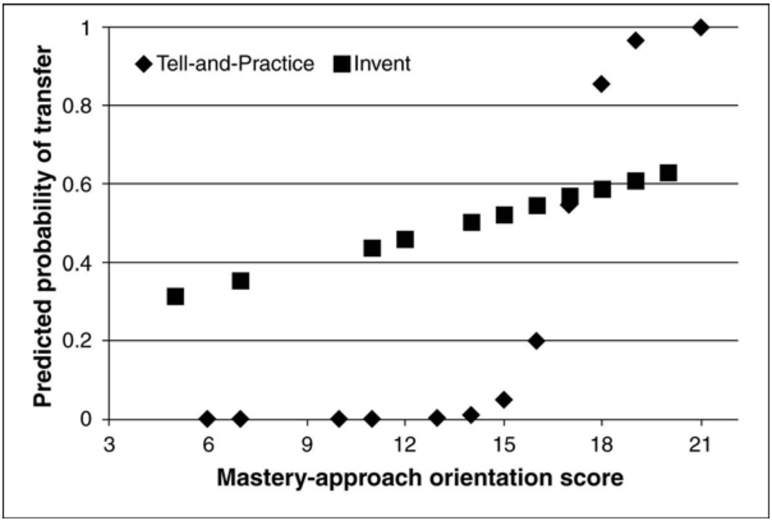

Figure 5 Predicted probability of transfer among those who received a worked example, split by instructional condition. Adapted from Belenky and Nokes, 2009, submitted.

to transfer regardless of whether they were high or low in their initial mastery goal orientations. This effect could be due exclusively to different types of cognitive engagement required by invention activities, rather than having anything to do with a change in mastery goal adoption during the task. However, responses on the questionnaire collected during the learning activities provide evidence against such an argument. The invention activity led to more mastery-related affect and goal responses than did the tell-and-practice, with invention students reporting higher levels of concern for understanding, correctness, and quality of their procedure, as well as feelings of challenge.

This pattern of evidence suggests that the invention form of instruction, which is more open-ended and places greater emphasis on student agency and exploration, influences the adoption of mastery-related goals for a given task. This effect seems particularly beneficial for those lower in mastery orientation to begin with, who, in a more traditional, tell-and-practice form of learning activity, are less likely to transfer. Although only indirect evidence, we believe this leads to more "sense-making" during the learning phase, resulting in more useful prior knowledge to bring to bear on the worked example and subsequent transfer problem. We also believe that the mastery goals may have changed the satisficing criteria on the transfer problem from "Come up with an answer" to something closer to "Come up with a mathematically valid answer," something that was clearly labeled in the instructions but may have been interpreted differently by each student, depending on the frame they generated. This shift could account for the higher likelihood of transfer for those with mastery-approach goals.

To summarize, there is evidence that higher levels of existing mastery-approach goal orientations increase the likelihood of successful transfer. For students lower in these goal orientations, invention activities improve the likelihood of successful transfer. This effect may be due, at least in part, to this type of activity facilitating the adoption of mastery-related goals and affect within the learning environment.

5. Conclusion

Transfer is a ubiquitous phenomenon in the real-world and occurs in many situations across many different kinds of tasks. Sometimes we use a prior example to help us solve a new problem; other times, we solve a new problem by applying a general principle. The proposed transfer framework accounts for this variety of transfer phenomena by including multiple transfer mechanisms, each with a different scope of application and efficiency. One aspect that has been missing from prior cognitive theories of transfer is the inclusion of motivational constructs. When a person is solving a new problem, they have particular goals, and these goals will influence the ways in which that person attempts to transfer, and what types of performances they consider adequate.

This framework has two main stages that a novice engages in when attempting to transfer: constructing a representation of the context and generating a solution. Both of these stages are governed by sense-making and satisficing processes, which are used in evaluating each stage. The construction of context involves generation of the frame and relevant prior knowledge, and the frame affects the satisficing criteria for a given transfer scenario. Specifically, we have hypothesized how achievement goals, a form of competence motivation, may play a role in the frame generation and the satisficing process. For example, having a mastery-approach orientation may result in setting a satisficing criterion that requires deep understanding of the solution, which leads to more successful transfer on a novel problem.

This possibility—that mastery-approach goals are more likely to lead to successful transfer—is a research question that has received relatively little empirical study (Pugh & Bergin, 2006). The results of a study in which existing mastery-approach goals led to an increased likelihood of transfer was presented (Belenky & Nokes, 2009, submitted). In addition, the results supported the claim that certain types of instruction (more open-ended, "discovery"-type) led to adoption of mastery-approach goals in that instructional activity. For those students who entered the study lower in such goal orientations, the adoption of mastery-approach goals spurred by the instruction led to an increased likelihood of transfer, relative to those lower in mastery-approach orientations who completed a more standard "direct-instruction" style learning activity.

Although promising, this is only preliminary evidence. Future research should continue to explore this interplay between achievement goals and transfer. In particular, a focus on satisficing criteria may be a fruitful enterprise. Perhaps performance-approach goals, with a focus on demonstrations of competence over development, will create situations in which a fluent use of an existing production rule counts as the satisficing criterion, regardless of whether that production rule actually solves the given problem (i.e., plug and chug). Future work is also necessary to disentangle the effect of these goals on learning from the effect of these goals being present at the time of transfer, something Belenky and Nokes (2009, submitted) did not address (but see Bereby-Meyer & Kaplan, 2005).

Transfer is important to understand for both theories of cognition and for educational practice. Students who are unable to transfer their knowledge to assessments are at a disadvantage for success both inside and outside the classroom. To craft instruction that facilitates transfer, we need to fully understand how it works and the factors that affect it. We believe that the integration of existing theories of transfer with individual difference variables, such as motivation, will be a powerful basis for future studies that will aid our theoretical understanding and our ability to create practical educational interventions.

ACKNOWLEDGMENTS

This work was supported by Grant SBE0354420 from the National Science Foundation, Pittsburgh Science of Learning Center (http://www.learnlab.org) and Grant R305B070085 from the Department of Education, Institute of Education Sciences. No endorsement should be inferred. We would like to thank Brian Ross and Jose Mestre for their many helpful comments and suggestions on the paper.

REFERENCES

Ames, C. (1992). Classrooms: Goals, structures, and student motivations. *Journal of Educational Psychology, 84*(3), 261–271.

Ames, C., & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivation processes. *Journal of Educational Psychology, 80*(3), 260–267.

Anderson, J. R. (1987). Skill acquisition: Compilation of weak-method problem solutions. *Psychological Review, 94*, 192–210.

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of mind. *Psychological Review, 111*(4), 1036–1060.

Anderson, J. R., Conrad, F. G., & Corbett, A. T. (1989). Skill acquisition and the LISP Tutor. *Cognitive Science, 13*, 467–506.

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought.* Mahwah, NJ: Lawrence Erlbaum.

Bandura, A. (1997). *Self-efficacy: The exercise of self-control.* New York: Freeman.

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin, 128*(4), 612–637.

Bassok, M. (1990). Transfer of domain-specific problem-solving procedures. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 522–533.

Belenky, D. M., & Nokes, T. J. (2009). Motivation and transfer: The role of achievement goals in preparation for future learning. *Proceedings of the Thirty-First Annual Conference of the Cognitive Science Society* (pp. 1163–1168). Netherlands: Amsterdam, Cognitive Science Society.

Belenky, D. M., & Nokes, T. J. (submitted). Motivation and transfer: The role of mastery-approach goals in preparation for future learning. *Journal of the Learning Sciences.*

Bereby-Meyer, Y., & Kaplan, A. (2005). Motivational influences on transfer of problem-solving strategies. *Contemporary Educational Psychology, 30*, 1–22.

Bereby-Meyer, Y., Moran, S., & Unger-Aviram, E. (2004). When performance goals deter performance: Transfer of skills in integrative negotiation. *Journal of Organizational Behavior and Human Decision Processes, 93*, 142–154.

Blanchette, I., & Richards, A. (2010). The influence of affect on higher level cognition: A review of research on interpretation, judgement, decision making, and reasoning. *Cognition and Emotion, 24*, 561–595.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education*, *24*, 61–100.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*, 32–42.

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, *8*(2), 240–247.

Covington, M. V. (2000). Goal theory, motivation, and school achievement: An integrative review. *Annual Review of Psychology*, *51*, 171–200.

Dufresne, R., Mestre, J., Thaden-Koch, T., Gerace, W., & Leonard, W. (2005). Knowledge representation and coordination in the transfer process. In J. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 155–215). Greenwich, CT: Information Age Publishing.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, *41*, 1040–1048.

Eccles, J. S., & Wigfield, A. (2002). *Development of achievement motivation*. San Diego, CA: Academic Press.

Elliot, A. J., & Church, M. A. (1997). A hierarchical model of approach and avoidance achievement motivation. *Journal of Personality and Social Psychology*, *72*, 218–232.

Elliot, A. J. & Dweck, C. S. (Eds.) (2005). Competence and motivation: Competence as the core of achievement motivation. In *Handbook of competence and motivation* (pp. 3-14). New York, NY: The Guilford Press.

Elliot, A. J., & McGregor, H. A. (1999). Test anxiety and the hierarchical model of approach and avoidance achievement motivation. *Journal of Personality and Social Psychology*, *76*, 628–644.

Elliot, A. J., & McGregor, H. A. (2001). A 2 × 2 achievement goal framework. *Journal of Personality and Social Psychology*, *80*(3), 501–519.

Elliot, A. J., McGregor, H. A., & Gable, S. L. (1999). Achievement goals, study strategies, and exam performance: A mediational analysis. *Journal of Educational Psychology*, *91*, 549–563.

Elliot, A. J., & Murayama, K. (2008). On the measurement of achievement goals: Critique, illustration, and application. *Journal of Educational Psychology*, *100*, 613–628.

Eysenck, M. W. (1976). Arousal, learning, and memory. *Psychological Bulletin*, *83*, 389–404.

Forbus, K. D., Gentner, D., & Law, K. (1995). MAC/FAC: A model of similarity-based retrieval. *Cognitive Science*, *19*, 141–205.

Ford, K. J., Smith, E. M., Weissbein, D. A., Gully, S. M., & Salas, S. (1998). Relationships of goal orientation, metacognitive activity, and practice strategies with learning outcomes and transfer. *Journal of Applied Psychology*, *83*(2), 218–233.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, 7, 155–170.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou, and A. Ortony, (Eds.), *Similarity and analogical reasoning* (pp. 199–241). London: Cambridge University Press.

Gentner, D. (1999). Analogy. In R. A. Wilson, and F. C. Keil, (Eds.), *The MIT encyclopedia of the cognitive sciences* (pp. 17–20). Cambridge, MA: MIT Press.

Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology*, *12*, 306–355.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology*, *15*, 1–38.

Gick, M. L., & Holyoak, K. J. (1987). The cognitive basis of knowledge transfer. In S. M. Cormier, and J. D. Hagman, (Eds.), *Transfer of learning: Contemporary research and applications* (pp. 9–46). Orlando, FL: Academic Press.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher*, *26* (1), 5–17.
Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist*, *53*, 5–26.
Greeno, J. G. (2006). Authoritative, accountable, positioning and connected general knowing: Progressive themes in understanding transfer. *The Journal of the Learning Sciences*, *15*, 537–547.
Gruber, H., Law, L., Mandl, H., & Renkl, A. (1995). Situated learning and transfer. In P. Reimann, and H. Spada, (Eds.), *Learning in humans and machines: Towards an interdisciplinary learning science* (pp. 168–188). Oxford, UK: Pergamon Press.
Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 89–119). Greenwich, CT: Information Age Publishers.
Harackiewicz, J. M., Barron, K. E., Pintrich, P. R., Elliot, A. J., & Thrash, T. M. (2002). Revision of achievement goal theory: Necessary and illuminating. *Journal of Educational Psychology*, *94*, 638–645.
Harackiewicz, J. M., Durik, A. M., Barron, K. E., Linnenbrink-Garcia, L., & Tauer, J. M. (2008). The role of achievement goals in the development of interest: Reciprocal relations between achievement goals, interest, and performance. *Journal of Educational Psychology*, *100*(1), 105–122.
Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*, 111–127.
Holyoak, K. J., Novick, L. R., & Melz, E. R. (1994). Component processes in analogical transfer: Mapping, pattern completion, and adaptation. In K. J. Holyoak, and J. A. Barden, (Eds.), *Advances in connectionist and neural computation theory volume 2: Analogical connections* (pp. 113–180). Norwood, NJ: Ablex Publishing Company.
Hummel, J. E., & Holyoak, K. J. (2003). A symbolic-connectionist theory of relational inference and generalization. *Psychological Review*, *110*, 220–264.
Kieras, D. E., & Bovair, S. (1986). The acquisition of procedures from text: A production system analysis of transfer of training. *Journal of Memory and Language*, *25*, 507–524.
Koedinger, K. R., Corbett, A. T., Perfetti, C. & the PSLC. (2010). The Knowledge-Learning-Instruction (KLI) Framework: Toward Bridging the Science-Practice Chasm to Enhance Robust Student Learning. Technical Report: CMU-HCII-10-102. Carnegie Mellon University.
Kruglanski, A. W., & Webster, D. M. (1996). Motivated closing of the mind: "Seizing" and "freezing.". *Psychological Review*, *103*(2), 263–283.
Lave, J. (1988). *Cognition in practice.* Cambridge, MA: Cambridge University Press.
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge, UK: Cambridge University Press.
Lobato, J. (2006). Alternative perspectives on the transfer of learning: History, issues, and challenges for future research. *The Journal of the Learning Sciences*, *15*, 431–449.
Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, *4*, 333–369.
Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivation for learning. R. E. Snow, and M. J. Farr, (Eds.), *Aptitude, Learning and Instruction III: Conative and Affective Process Analyses.* Hillsdale, NJ: Erlbaum.
Marshall, S. P. (1995). *Schemas in problem solving.* Cambridge, UK: Cambridge University Press.
Midgley, C., Kaplan, A., & Middleton, M. (2001). Performance-approach goals: Good for what, for whom, under what circumstances, and at what cost? *Journal of Educational Psychology*, *93*, 77–86.

Neves, D. M., & Anderson, J. R. (1981). Knowledge compilation: Mechanisms for the automatization of cognitive skills. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition* Hillsdale, NJ: Lawrence Erlbaum.

Nicholls, J. G. (1984). Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance. *Psychological Review*, *91*, 328–346.

Nokes, T. J. (2004). Testing three theories of knowledge transfer. In D. Gentner., K. Forbus, and T. Regier, (Eds.), *Proceedings of the Twenty-Sixth Annual Conference of the Cognitive Science Society* (pp. 1029–1034). Mahaw, NJ: Erlbaum.

Nokes, T. J. (2005). An investigation into adaptive shifting in knowledge transfer. In B. Bara., L. Barsalou, and M. Bucciarelli, (Eds.), *Proceedings of the Twenty-Seventh Annual Conference of the Cognitive Science Society* (pp. 1660–1665). Erlbaum: Mahaw, NJ.

Nokes, T. J. (2009). Mechanisms of knowledge transfer. *Thinking & Reasoning*, *15*, 1–36.

Nokes, T. J., Mestre, J., & Brookes, D. (submitted). Sense-making as transfer. *Educational Psychologist*.

Nokes, T. J., & Ohlsson, S. (2005). Comparing multiple paths to mastery: What is learned? *Cognitive Science*, *29*, 769–796.

Novick, L. R. (1988). Analogical transfer, problem similarity, and expertise. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*(3), 510–520.

Ohlsson, S. (1996). Learning from performance errors. *Psychological Review*, *103*(2), 241–262.

Ohlsson, S., & Rees, E. (1991). The function of conceptual understanding in the learning of arithmetic procedures. *Cognition and Instruction*, *8*, 103–179.

Packer, M. (2001). The problem of transfer, and the sociocultural critique of schooling. *The Journal of the Learning Sciences*, *10*(4), 493–514.

Pennington, N., Nicolich, R., & Rahm, J. (1995). Transfer of training between cognitive subskills: Is knowledge use specific? *Cognitive Psychology*, *28*, 175–224.

Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research*, *31*(6), 459–470.

Pugh, K. J., & Bergin, D. A. (2006). Motivational influences on transfer. *Educational Psychologist*, *41*(3), 147–160.

Redish, E. F. (2004). A theoretical framework for physics education research: Modeling student thinking. In E. Redish, and M. Vicentini, (Eds.), *Proceedings of the Enrico Fermi Summer School, Course CLVI* Italian Physical Society.

Reeves, L. M., & Weisberg, W. R. (1994). The role of content and abstract information in analogical transfer. *Psychological Bulletin*, *115*, 381–400.

Rogoff, B. (2003). *The cultural nature of human development.* New York: Oxford University Press.

Royer, J. M. (1979). Theories of the transfer of learning. *Educational Psychologist*, *14*, 53–69.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures.* Hillsdale, NJ: Lawrence Erlbaum.

Scherr, R. E., & Hammer, D. (2009). Student behavior and epistemological framing: Examples from collaborative active-learning activities in physics. *Cognition and Instruction*, *27*(2), 147–174.

Schwartz, D. L., & Bransford, J. D. (1998). A time for telling. *Cognition and Instruction*, *16*, 475–522.

Schwartz, D. L., Bransford, J. D., & Sears, D. (2005). Efficiency and innovation in transfer. In J. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 1–51). Greenwich, CT: Information Age Publishers.

Schwartz, D. L., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction*, *22*, 129–184.

Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review*, *63*, 129–138.
Simon, H. A. (1996). *The sciences of the artificial.* Cambridge, MA: The MIT Press.
Singley, M. K., & Anderson, J. R. (1989). *The transfer of cognitive skill.* Cambridge, MA: Harvard University Press.
Somuncuoglu, Y., & Yildirim, A. (1999). Relationship between achievement goal orientations and use of learning strategies. *Journal of Educational Research*, *92*(5), 267–277.
Thaden-Koch, T., Dufresne, R., & Mestre, J. (2006). Coordination of knowledge in judging animated motion. *Physical Review E – Special Topics – Physics Education Research*, *2*, 020107 11 pages.
Thorndike, E. L., & Woodworth, R. S. (1901). The influence of improvement in one mental function upon the efficiency of other functions. *Psychological Review*, *8*, 247–261.
Thorndyke, P. (1984). Applications of schema theory in cognitive research. In J. Anderson, and S. Kosslyn, (Eds.), *Tutorials in learning and memory: Essays in honor of Gordon Bower* (pp. 167–192). San Francisco, CA: W.H. Freeman & Company.
Urdan, T., Ryan, A. M., Anderman, E. M., & Gheen, M. H. (2002). Goals, goal structures, and avoidance behaviors. In C. Midgley (Ed.), *Goals, goal structures, and patterns of adaptive learning* (pp. 55–83). Mahwah, NJ: Erlbaum.
Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review*, *92*, 548–573.