Handbook of Design Research Methods in Education
Innovations in Science, Technology, Engineering, and Mathematics Learning and Teaching
Anthony E. Kelly, Richard A. Lesh, John Y. Baek

Research Methods for Alternative Approaches to Transfer

Joanne Lobato
Published online on: 19 Jun 2008

Accessed on: 05 Sep 2023

Full terms and conditions of use: https://www.routledgehandbooks.com/legal-notices/terms

This Document PDF may be used for research, teaching and private study purposes. Any substantial or systematic reproductions, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The publisher shall not be liable for an loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.
Part 3

Modeling Student Learning During Design Research
9 Research Methods for Alternative Approaches to Transfer

Implications for Design Experiments

Joanne Lobato
San Diego State University

Introduction

Prevailing theories and methods of measuring transfer work well for studying full-blown expertise, but they represent too blunt an instrument for studying the smaller changes in learning that lead to the development of expertise. New theories and measures of transfer are required.

(Bransford & Schwartz, 1999: 24)

A central and enduring goal of education is to provide learning experiences that are useful beyond the specific conditions of initial learning. Issues of the generalization of learning are particularly important in design experiments. For example, in design experiments, researchers typically use a complex artifact (often a computer software tool) and then are interested in how learners’ interactions with the artifact will influence their attempts to solve problems without the artifact. Furthermore, the generation of these creative and innovative artifacts is often aimed at helping students to develop robust understandings that will generalize to decision making and problem solving outside the classroom. Finally, information about the specific ways in which students are generalizing what they have learned in local iteration (x) of a design experiment can inform the action of redesign as the design experiment progresses to iteration (x + 1).

However, researchers’ progress in understanding and supporting the generalization of learning has been limited because of methodological and theoretical problems with the transfer construct. Numerous critiques of transfer (Beach, 1999; Carraher & Schliemann, 2002; Greeno, 1997; Lave, 1988; Packer, 2001) have contributed to a growing acknowledgment that “there is little agreement in the scholarly community about the nature of transfer, the extent to which it occurs, and the nature of its underlying mechanisms” (Barnett & Ceci, 2002: 612).

Theoretical Perspectives on the Transfer of Learning and Design Experiments in Education

In a previous paper, I argued that the theoretical assumptions underlying a researcher’s model of transfer affect how a design experiment in education evolves (Lobato, 2003). For example, whether one takes what MacKay (1969) calls an observer’s (expert’s) or an actor’s (learner’s) perspective toward transfer affects information that is available to researchers as they make design decisions. Specifically, in the classical transfer approach, transfer is said to occur when subjects perform correctly on tasks that are structurally similar to initial learning tasks from an expert’s point of view. (By the
classical transfer approach, I refer to the common elements theories that have dominated the twentieth century, from Thorndike’s [1906] emphasis on identical elements in the physical environment to the mainstream cognitive accounts of identical or overlapping mental schemes [e.g., Anderson et al., 1995].)

The classical approach underestimates the amount of generalization of learning that occurs, in part because generalizations that result in incorrect performance are not counted as evidence of transfer. Moreover, transfer experiments typically reveal whether or not transfer occurs and do not tend to identify the specific generalizations that students form, especially when those generalizations are non-normative or result in incorrect performance. As a result, attempts to revise the curriculum without the benefit of data regarding the many and specific ways in which students have generalized their learning experiences may lead to a decision to align the instruction more closely with the transfer tasks. This can lead to gains on transfer measures due to a training effect rather than to significant shifts in the nature of students’ generalization of learning (details are provided in Lobato, 2003).

In contrast, researchers operating from an actor-oriented transfer perspective (Lobato, 2003, 2007; Lobato & Siebert, 2002) seek to understand the processes by which people generalize their learning experiences, regardless of whether the personal relations of similarity that people form across situations lead to correct performance. Although mathematical correctness should not be ignored or de-emphasized as an instructional goal, limiting the definition of generalization to that of correct formal descriptions supports fewer insights into what students themselves construe as general (Ellis, under review). More importantly, the actor-oriented approach provides a way to link individual students’ generalizations to the features of instructional environments that afford these generalizations (Lobato et al., 2003). Additionally, these relationships are articulated with sufficient detail to inform revisions in curriculum materials and pedagogical approaches during iterative cycles of instructional design (Lobato, 2003). In sum, one’s theoretical assumptions regarding the transfer of learning (e.g., whether the observer’s or the actor’s perspective is privileged) affect how a design experiment evolves.

Transfer Methods and Design Experiments

In this chapter, I extend the argument that transfer theories can influence design decisions by attending to the research methods employed in various transfer perspectives. Classical models of transfer rely on experimental methods for measuring transfer, whereas the actor-oriented transfer approach relies upon ethnographic methods. These different methodological approaches affect the nature of the information that one can obtain and consequently affect design decisions. Furthermore, several alternative approaches to transfer have emerged in recent years, yet little has been written comparing the approaches, especially in terms of the methods employed. In Part One of this chapter, I articulate the methodological approach of five transfer perspectives—the classical approach, the actor-oriented approach, and three other alternative perspectives—by arguing that transfer methods and transfer theories are related reflexively. For example, I demonstrate how the methods used in a transfer perspective reflect theoretical assumptions about the studies underlying phenomena measured by transfer, and, in turn, how the nature of one’s research questions about transfer is related to the type of methods utilized.

Once the foundations have been laid for articulating the general methodological approach of various transfer perspectives and the relationship of these methodological approaches to theoretical assumptions about transfer, I turn to the development of
specific transfer methods. Although the methods used in the classical transfer approach are well established, the methods used to document most of the alternative transfer perspectives are emerging. In Part Two, I present two specific techniques that evolved in the course of our efforts to document actor-oriented transfer in a variety of mathematics education studies: (a) a method for identifying instances of actor-oriented transfer in classroom settings, and (b) a method for capturing the socially situated nature of actor-oriented transfer.

**Purpose**

This chapter has two purposes: (a) to demonstrate the reflexive relationship between transfer theory and methods by contrasting the general methodological approaches and accompanying theoretical assumptions of five transfer perspectives, and (b) to present two specific methods that have emerged during our efforts to develop an alternative approach to the transfer of learning. I then use the arguments from both parts of the chapter to reflect on the implications for design experiments. The chapter concludes with a brief discussion of how actor-oriented transfer might be combined with other transfer approaches at different stages in a multistage model of design research.

**Part One: Relationships Between Theory and Methods in Transfer Models**

In Part One, I argue that the relationship between the research methods employed to measure transfer and the theoretical assumptions regarding transfer is reflexive. I demonstrate how research methods influence the definition of transfer within a transfer perspective, and, reflexively, how a shift in one’s definition of transfer influences the methods one employs to measure transfer. I then illustrate how reflexive relationships also exist between research methods and other dimensions of transfer models.

The relationships between theory and methods will be explicated by comparing and contrasting five theoretical perspectives on transfer. Although the main focus is between the classical transfer model and the actor-oriented transfer perspective, three additional alternative transfer perspectives will be discussed: transfer as preparation for future learning (Bransford & Schwartz, 1999; Schwartz & Martin, 2004; Schwartz et al., 2005), the affordance and constraints approach (Greeno, 1997; Greeno et al., 1993, 1996), and transfer as consequential transitions (Beach, 1999, 2003). The purpose of comparing perspectives is not to pit one against another in order to arrive at a “best” view. Rather, it is to illustrate how one’s theoretical and methodological approach to transfer affects both the amount and the nature of the transfer that one sees. As a result of describing what is gained and lost by adopting a particular perspective, we can advance later the argument that different transfer perspectives are useful for different stages of a multistage design experiment (see the Discussion section for details).

**How Research Methods Influence Transfer Definitions**

In a classical approach, transfer is defined as the application of knowledge learned in one situation to another situation (National Research Council, 2000). From the actor-oriented perspective, transfer is defined as the generalization of learning, which also can be understood as the influence of a learner’s prior activities on his or her activity in novel situations (Lobato, 2003, 2007). These definitions seem similar until one looks more closely at the methods employed in each approach. In fact, there are instances in
which researchers operating from a classical perspective describe transfer as the influence of prior learning experiences on attempts to solve problems in new situations (e.g., see Marini & Genereux, 1995; Reed et al., 1974). However, in this section, I argue that researchers from a classical transfer perspective treat transfer methodologically as the formation of particular, highly valued generalizations, rather than as the generalization of learning more broadly, and that this difference is significant.

Researchers operating from a classical transfer model typically present subjects with a sequence of tasks. The subjects are taught a solution, response, or principle in an initial learning task (Task A). Then, the subjects perform a transfer task (Task B). Tasks A and B share some structural features (e.g., a common solution strategy) but have different surface forms (e.g., different contexts for word problems). The performance of the experimental group is compared with that of a control group, which receives no practice on Task A, but starts directly with Task B. If the performance of the experimental group on Task B is better than that of the control group, there is positive transfer from Task A to Task B; if it is worse, there is negative transfer. A variety of formulas have been used historically to calculate the amount of transfer, but the simplest is Gagné’s raw score formula, which is the difference between the score of the experimental group and the control group on transfer Task B.

When performance improves, the researcher using a classical transfer approach infers that the subjects have generalized some aspect of the learning experience to the transfer tasks. Researchers typically predetermine “what” will transfer, rather than making the “what” an object of investigation. Even when researchers do identify the particular knowledge that has transferred (e.g., the particular mappings that people construct between base and target solutions and problems), they typically rely on models of expert performance (e.g., see Gentner, 1989) and that knowledge is examined only for subjects who have performed correctly on the transfer tasks.

In contrast, evidence for transfer from an actor-oriented perspective is found by scrutinizing a given activity for any indication of influence from previous activities and by examining how people construe situations as similar using ethnographic methods, rather than relying upon statistical measures based on improved performance. As a result, the actor-oriented transfer perspective responds to diSessa and Wagner’s (2005) position that transfer theories should describe knowledge, not merely successful or unsuccessful performance.

Operating from an actor-oriented view of transfer can result in the gathering of significantly different information about students’ generalizing processes than is possible from the classical transfer perspective. For example, as part of a design experiment aimed at helping high-school algebra students develop conceptual understanding of slope and linear functions, Lobato (1996) performed two contrasting analyses—from classical and actor-oriented transfer perspectives—on the same set of data. Using classical transfer measures, the level of transfer was poor (40 percent to a playground slide task and 33 percent to a roof task), despite high performance on tasks encountered in the experimental curriculum, such as finding the slope of staircases (87 percent correct) and lines (80 percent correct). The results for the larger population of 139 students were similar to the results for the 15 students in the interview sample.

On the other hand, every interview participant demonstrated evidence of transfer from the actor-oriented perspective. A typical response to a transfer task is provided in Figure 9.1. Jarek recalled correctly the slope formula as “rise divided by run” but selected incorrectly the length of the platform as the run. In the actor-oriented transfer perspective, the general analytic approach for establishing evidence of transfer is to look for relations of similarity that learners construct between transfer and learning.
situations. The first step in this process is to examine the nature of the instructional experiences in order to see how they could be influencing the learner’s perception of the new situation. In this case, the instructional activities related to slope had been dominated by explorations of real staircases, a computer microworld with dynamic staircases, and the use of mathematical “stairs” to determine the slope of a line and other objects. With this in mind, the data were re-analyzed by looking for ways in which these experiences with staircases may have influenced the students’ comprehension of the transfer situations. Specifically, Jarek’s work on the slide task is consistent with a “stairstep” relation of similarity. Jarek’s choices for rise and run suggest that he was looking for a stairstep in the slide setting (e.g., something that appears to have visually-connected “up” and “over” components and affords climbing in an imagined state of affairs), which he found on the right side of the slide apparatus (see Figure 9.1). The platform as the run may have held particular appeal for Jarek because it is the only “tread” or “over” affordance present in the diagram. (A correct run, on the other hand, needs to be constructed with the use of an auxiliary line.)

In sum, according to the classical measure of transfer, the students in the study showed little evidence of generalizing their learning experiences. In contrast, the analysis from the actor-oriented perspective illuminated how each of the learners generalized their learning experiences by showing how the new situations were connected with the thinker’s conception of previous situations even though the relations of similarity were unexpected and nonstandard.

In light of the contrasting methodological treatments of transfer, the definitional differences between the two approaches become more apparent. In the classical approach, transfer is characterized more accurately as the application from one setting to another of a predetermined set of knowledge from the researcher’s or expert’s point of view. In the actor-oriented perspective, transfer is treated broadly as the influence of a learner’s prior activities on his or her activity in novel situations, which entails any ways in which learning generalizes (as opposed to that learning being restricted to the initial context of learning). The actor-oriented transfer approach has focused primarily on the process of “similarity-making,” but, in some accounts, we have analyzed also the roles of discerning differences (Lobato et al., 2005) and modifying situations (Lobato & Siebert, 2002). The most striking difference between the two transfer approaches is the acceptance in the actor-oriented perspective of students’ idiosyncratic and even (mathematically) incorrect relations of similarity as evidence of transfer. In short, in the actor-oriented approach, transfer is taken to be the generalization of learning, whereas, in the classical approach, transfer is the formation of particular, highly valued generalizations.
How Transfer Definitions Affect Research Methods

Just as research methods result in a refinement of transfer definitions, the particular definition of transfer determines, in part, which methods are appropriate. This point is illustrated briefly with the affordances and constraints approach to transfer (Greeno, 1997; Greeno & The Middle School Mathematics through Application Project Groups, 1998; Greeno et al., 1993, 1996).

The affordances and constraints perspective emerged in response to critiques that the classical transfer model accounts inadequately for the structuring of material artifacts or the sociocultural environment (Laboratory of Comparative Human Cognition, 1983; Lave, 1988; Pea, 1989; Rogoff & Gardner, 1984). Greeno et al. (1993) redefined transfer as the extent to which participating in an activity in one situation influences one’s ability to participate in another activity in a different situation. Transfer is not an invariant property of the individual but, rather, an ability to interact with things and people in various ways. By redefining transfer in this manner, Greeno et al. were seeking to remove it from the sole domain of the cognitive structures of the individual and distribute it across people, artifacts, and situations.

As a result, new methodological tools were needed to account for transfer as an interaction between agents and material resources. Greeno et al. (1993) provided general analytical tools in the form of affordances and constraints. They argued that for transfer to be possible, there must be some affordances (the support for particular activities created by relevant properties of the things and materials in the situation) and/or constraints (regularities) in the learning situation that are invariant under the transformation that changes the learning situation into the transfer situation and that the learner must become attuned to these invariants. The extended examples provided by Greeno et al. illustrate the methodological approach of combining an analysis of affordances and constraints in particular situations with an ethnographic account of people’s activity in those situations. Other researchers have developed additional methodological tools that are consistent with the affordances/constraints approach to transfer (Hickey & Pellegrino, 2005; Hickey et al., 2003). In sum, by creating a definition of transfer that is compatible with a situated view of knowing, different methodological tools needed to be developed, thus illustrating how transfer theory can influence research methods.

Relationships Among Methods and Other Dimensions of Transfer Theory

A model of the transfer of learning involves much more than its definition. Other dimensions are equally important, such as the type of research questions that can be investigated productively by operating within a particular perspective, the nature and location of the transfer processes, assumptions about the transfer tasks, conceptions of abstraction, and so on. In this section, I examine the relationships between research methods and two of these dimensions—the research questions and the location of transfer processes.

How the Nature of the Research Question is Related to the Methods

I examine how research questions are related to research methods by comparing the ethnographic methods employed in the actor-oriented transfer perspective with the experimental methods used in the preparation for future learning approach (Bransford & Schwartz, 1999; Schwartz & Martin, 2004; Schwartz et al., 2005).
The preparation for future learning approach responds to the critique that the classical transfer approach ignores the real-world conditions that people can often exploit, such as soliciting help from colleagues, seeking additional learning resources, and having opportunities to obtain feedback. Classical tests of transfer involve what Bransford and Schwartz (1999) call “sequestered problem solving,” meaning that students work in environments where they have no “contaminating” information sources other than what they have learned previously. In contrast, the preparation for future learning approach examines how various instructional treatments prepare students to benefit from a learning opportunity.

The preparation for future learning approach demonstrates how the usefulness of prior knowledge may not be apparent to students until they are given the opportunity to learn new information. For example, Schwartz and Bransford (1998) compared how two instructional interventions prepared students for future learning. In the “invent a method” treatment, students analyzed simplified data sets from classic memory experiments and invented their own graphs to show what they discovered. In the “summarize” treatment, students wrote a summary of a chapter on the same memory experiments. Students in the invention treatment performed poorly on transfer tasks. Interestingly, when students in both conditions received a learning resource in the form of a follow-up lecture, the results reversed themselves. On a subsequent transfer assessment, the “invention” students made twice as many correct predictions about a novel experiment as the “summarize” students. The researchers could attribute the gains to the invention treatment preparing the students to learn from the lecture, because one group of invention students did not hear the lecture and performed poorly on the transfer assessment.

The general methodological approach used in the preparation for future learning perspective can be summarized as follows. Students are assigned one of two instructional treatments. Half of the students from both treatments are given access to a common learning resource such as a lecture or a sample worked problem embedded in an assessment, followed by a request to solve a transfer problem. The other half from both treatments are asked to solve the transfer problem directly without access to the learning resource. The researchers call this a double-transfer paradigm because students need to “transfer in” what they learned from the instructional method to learn from the resource, and they need to “transfer out” what they learned from the resource to solve the target problem (Schwartz & Martin, 2004; Schwartz et al., 2005).

The experimental methods used in the preparation for future learning approach are well suited for exploring the research question: “What conditions facilitate transfer?” Specifically, researchers can compare performance on the transfer assessment to determine which method of instruction prepares students better to benefit from the learning opportunity, and they can determine whether the inclusion of the learning resource changes the performance on the transfer tasks (Schwartz & Martin, 2004). They also can investigate how different habits of mind and dispositions facilitate or constrain the transfer of learning (Bransford & Schwartz, 1999).

In contrast, the ethnographic methods used in an actor-oriented transfer approach are best suited for exploring the ways in which learners construct relations of similarity across situations. The research questions in an actor-oriented transfer study are not: “Was transfer obtained?” or “What conditions produce transfer?” but, rather, “What are the images by which learners construct two situations as similar?” and “How does the environment structure the production of similarity?”

The latter questions can also be addressed from a preparation for future learning perspective if other methods are used. For example, Bransford and Schwartz (1999) cite a study by Burgess and Lin (1998), in which fifth-graders and college students were
asked to create a statewide recovery plan to protect bald eagles from the threat of extinction. Each group was asked to generate questions that they would like to have answered to help them learn more about recovery plans for the eagles. By using qualitative methods to examine the nature of the questions, the researchers ascertained major differences between the children and the college students, which appeared to be related to the students’ prior experiences. Because the Burgess and Lin study provided information about how each group construed the eagle situation as similar to past experiences, the study is consistent with an actor-oriented perspective. It is also consistent with the theoretical assumptions of the preparation for future learning approach because transfer occurred during a learning activity but not during sequestered problem-solving.

Although the use of qualitative methods is a part of what makes the Burgess and Lin study compatible with an actor-oriented perspective, the primary distinguishing feature of the actor-oriented approach is the effort to relinquish normative notions of what counts as transfer and immerse oneself in the learner’s world instead. Because experimental methods rely on measures of improved performance to identify transfer and upon expert models, they tend to miss instances of generalizing that are captured in the actor-oriented perspective.

One could argue that the nonstandard or mathematically incorrect relations of similarity that are identified in an actor-oriented approach are captured in experimental methods also through the construct of negative transfer (National Research Council, 2000). However, there are important differences between actor-oriented transfer and negative transfer. Negative transfer is a behavioral construct (i.e., it is identified when performance is diminished as a result of prior experiences), whereas actor-oriented transfer represents a process of constructing relationships among situations. More importantly, negative transfer connotes interference. In contrast, the actor-oriented approach follows Smith et al. (1993) in conceiving of the construction of relationships of similarity that result in incorrect, unsophisticated, or non-normative performance as being potentially important building blocks for later competence, rather than something to be avoided. Being able to analyze what transfers, rather than treating transfer as a desirable performance outcome, can have positive benefits for design experiments. For example, one can identify levels of increasingly sophisticated actor-oriented transfer, which is powerful for design studies because moving up levels of sophistication may be linked with successive iterations in the design cycle (Lobato, 2003).

How the Location and Nature of Transfer Processes are Related to One’s Unit of Analysis

In classical accounts of transfer in mainstream cognitive science, transfer measures a psychological phenomenon. People construct symbolic representations of an initial learning situation and of a transfer situation. Transfer occurs if these two representations are identical, if they overlap, or if a mapping can be constructed that relates features of the two representations (Anderson et al., 1995; Reed, 1993; Sternberg & Frensch, 1993). Critics maintain that these mechanisms dissociate cognition from its contexts and do not account for the structuring resources of socially-situated activity (Gruber et al., 1996; Lave, 1988). In response, Beach’s (1999, 2003) consequential transitions perspective and the actor-oriented approach conceive of transfer as being distributed across mental, material, social, and cultural planes. However, the particular unit of analysis that one chooses affects which aspects of the distributed phenomenon are foregrounded in an investigation. This notion is explored briefly by comparing the units of analysis in the consequential transitions and actor-oriented perspectives.
In Beach’s (1999) reconceptualization, transfer is not taken as the reproduction of something that has been acquired elsewhere; rather, it is conceived as a transition involving the transformation of knowledge, skill, and identity across multiple forms of social organization. Transitions involve a notion of progress for the learner and are understood best as a developmental process. Because these transitions involve a change in identity—a sense of self, social position, or becoming someone new—they are consequential. Consequential transitions (transfer) are not changes in the individual or in the social context but, rather, are changes in their relationship. Examples of consequential transitions include high school students taking part-time work in fast food restaurants, industrial machinists trained on mechanical machines learning to use computerized numerical control machines, and Nepali high-school students becoming shopkeepers (Beach, 1995; Beach & Vyas, 1998; Hungwe, 1999; Hungwe & Beach, 1995).

To analyze transfer as consequential transitions, Beach (1999) utilizes a developmental “coupling” (in the sense used by Varela et al., 1991) as a unit of analysis. A developmental coupling encompasses aspects of both changing individuals and changing social activity. The coupling itself is the primary unit of analysis, rather than the individual or the activity. The coupling is developmental in that one assumes that individuals move across space, time, and changing social activities, rather than being situated in an unchanging context. This coupled unit reflects the fact that both the person and the social context contribute to a consequential transition and are linked reflexively.

In the actor-oriented transfer perspective, many “players” are involved in generalizing activities: individuals who create personal connections across activities, material resources that enable certain actions and connections while constraining others, people who are oriented toward helping individuals see particular similarities or who focus learners’ attention on particular regularities and away from others, and the practices in which activities takes place. Rather than using a coupled unit, the actor-oriented approach coordinates analyses at the individual and social levels (in the spirit of Cobb and Yackel, 1996). First, interview data are analyzed in order to identify the ways in which individuals generalize their learning experiences. Second, aspects of social structuring are identified in the analysis of classroom data. These aspects can include language (which encodes a culture’s theory of the connections among situations, objects, and ideas), artifacts, and actions by more knowledgeable others. Finally the two analyses are coordinated. Details of this method are provided later in this chapter.

By choosing different units of analysis, the consequential transitions and the actor-oriented approaches highlight different aspects of the generalizing process. By investigating changing forms of social organization (e.g., transitions between school to work), Beach (1999) identifies elements that have been missing from other analyses (including actor-oriented transfer accounts), such as how leading activities, the power structure, and social status play a role in transfer. Although Beach includes an examination of individual behavior, such as the use of a variety of arithmetic strategies, he has not focused on psychological processes. In contrast, the actor-oriented approach is useful for identifying individuals’ generalizations (including the particular relations of similarity that people construct as their mathematical strategies evolve) and for demonstrating how individuals’ generalizations are constrained by sociocultural practices (specifically by features of instructional environments).
Part Two: Specific Methods Used in the Actor-Oriented Transfer Approach

In Part Two, I present two specific techniques that evolved in the course of our efforts to document actor-oriented transfer in a variety of mathematics education studies. Although these methods are informed broadly by the constant comparative method and interpretive techniques used in grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1990), the specific techniques have evolved in the course of our efforts to document actor-oriented transfer in various studies. Previous reports (Lobato, 1996, 2003; Lobato & Siebert, 2002; Lobato et al., 2003) placed in the foreground the development of an alternative perspective on the transfer of learning while the methods remained in the background. By contrast, this chapter foregrounds the methods, while backgrounding the content-specific details that appear in earlier reports.

Method One: How to Establish Evidence of the Transfer of Learning in a Design Experiment from an Actor-Oriented Transfer Perspective

In this section, I describe a specific method used to provide evidence for the transfer of learning from an actor-oriented perspective, in the context of a design experiment. Although it is not the only method compatible with the actor-oriented transfer approach (see Ellis [2004, under review] for the identification of generalizing activity during classroom discourse rather than during interviews), it serves as a prototypical example of how we establish relations of similarity from the actor’s perspective.

Structure of the Claims

In general, a case for the existence of the transfer of learning from an actor-oriented perspective in the context of a design experiment is made by providing evidence for the following claims:

- There was significant change in the student’s conceptualization and performance on the transfer tasks from pre- to postinterviews.
- The student’s performance on the other pre-interview tasks and during the early curriculum activities of the design experiment demonstrates limited knowledge of key conceptual components of the transfer tasks.
- A plausible relationship of similarity can be established between the student’s reasoning on the transfer tasks in the postinterview and in some activity during the design experiment.
- A case can be made that the changed reasoning on the transfer tasks is not due entirely to spontaneous construction, but, rather, can be linked to what the student learned during the design experiment.

Each of these four elements is articulated using data reported in Lobato and Siebert (2002). The data were drawn from a design experiment that consisted of 30 hours of instruction during the summer in a university computer laboratory with nine high-school students, taught using an inquiry-based approach (Lobato & Thanheiser, 2000, 2002). A major goal of the design experiment was to help the students develop an understanding of slope as a ratio that measures some attribute (such as speed, steepness, sweetness, or density). This is what Simon and Blume (1994) call a “ratio-as-measure.” First, I describe the task design for the students’ interviews, then turn to the
four claims comprising an argument for an instance of transfer from the actor-oriented perspective.

**Design of the Transfer Tasks**

The design of an actor-oriented transfer study typically includes the use of the same set of transfer tasks in semistructured interviews (Bernard, 1988; Ginsburg, 1997) conducted before and after the design experiment. Task creation begins as it would in the classical transfer approach by generating tasks that, from our perspective as experts, share structural features with activities from the design experiment but differ across surface features. See Figure 9.2 for the interview tasks used in the Lobato and Siebert (2002) study. These tasks were conceived by the researchers as affording opportunities to use the ideas about ratio-as-measures developed in the instruction in the novel context of a wheelchair ramp situation. Once the tasks have been designed, the observer’s perspective is set aside and the approach to the tasks differs from the classical transfer approach in three ways.

First, in the classical transfer approach, the researcher uses the transfer tasks to see

---

**Task 1.** Suppose you work for a company that builds wheelchair ramps. You want to measure or calculate the steepness of each ramp model that your company builds. You feel this information is important so that people will know how difficult it is to climb each ramp in a wheelchair. How would you go about determining how steep any ramp is (and what measurements would you need to take)?

---

**Task 2.** Here is a ramp that has all kinds of measurements. How can you determine the steepness of this ramp?

---

**Task 3.** Suppose a customer needs to have a wheelchair ramp that reaches to his doorstep, which is 3 ft high (point to ground and door). This particular ramp won’t reach because it’s only 2 ft high. How can you change the dimensions so that you have a new ramp that is the same steepness as this ramp but that reaches the door?
whether the learner perceives a particular predetermined similarity. This restricts the researcher to an investigation of the psychological conditions under which an individual perceives this predetermined similarity. As a result, researchers operating from the classical transfer perspective often learn more about the theorist’s construction of similarity than the learner’s (Pea, 1989). In the actor-oriented perspective, the tasks are used as settings in which to explore students’ often idiosyncratic ways of connecting learning and transfer situations.

Second, the central organizing metaphor for the classical transfer paradigm has been that of “applying knowledge,” which suggests a static process in which the “transferor” reproduces existing relations between fixed tasks (Beach, 1999). However, in the actor-oriented transfer approach, the metaphor of production replaces that of application and transfer is conceived of as a dynamic process. In fact, the Lobato and Siebert (2002) paper provides an instance in which a student reconstructs and changes the transfer situation until it becomes similar to something he knows (see also Bransford & Schwartz, 1999; Carraher & Schliemann, 2002; Rebello et al., 2005). In this sense, the interviews conducted in the actor-oriented transfer approach collapse the “transfer in”/“transfer out” distinction made in the preparation for future learning approach because the transfer interviews are treated as settings in which change, modification, adaptation, and learning can occur also.

Finally, at the heart of the classical transfer approach is an assumption that the initial learning and transfer situations share a similar level of complexity (for students). In the actor-oriented approach, this assumption is made for the researchers but not for the students. For example, several studies have demonstrated that a surface feature for an expert may present a structural complexity for students (Lobato, 2007; Lobato & Thanheiser, 2000, 2002; Olive & Lobato, in press). Consequently, follow-up questions in the interviews make students’ conceptualization of transfer situations the object of inspection. For example, as a follow-up to Task 1 (Figure 9.2), students were asked how increasing or decreasing the length of the base or the length of the platform would affect the steepness of the ramp. To probe their conceptions of steepness, students were asked if the ramp was the same steepness throughout or whether it was steeper in some places than in others (which is surprisingly difficult for many high-school students to differentiate, as indicated in Lobato et al. [2005]). These questions allowed us to explore the complexities that accompany the attribute of steepness for students, rather than treating steepness as a surface feature of the transfer task.

Establishing the Four Claims

1. Changes exist in the student’s conceptualization of the transfer tasks

In the study reported by Lobato and Siebert (2002), both researchers worked separately to infer analytic categories of the case study student’s (Terry’s) conceptualization of the wheelchair ramp situation from the transcripts of the pre- and postinterviews (Glaser & Strauss, 1967; Miles & Huberman, 1994; Strauss & Corbin, 1990). Because Terry’s responses to the transfer tasks were complex and not understood easily, we revised our conjectures repeatedly by making multiple passes through the same data set. We sorted out troublesome cases through a process of argumentation, seeking confirming as well as disconfirming evidence, and revising our conjectures until we settled on a common set of inferred conceptions (Cobb & Whitenack, 1996; McClain & Cobb, 2001).

The most striking difference in the way that Terry comprehended the wheelchair ramp situation before and after instruction is described briefly. Analysis of all of Terry’s
work on the wheelchair ramp tasks led to several inferential claims: (a) height dominated Terry’s image of steepness, (b) height had greater status than length, and (c) length was dependent upon height. We reported only claims for which relatively strong evidence existed; that is, when there were multiple utterances in different parts of the interview supporting the conception or when the participant offered the idea independently (as opposed to answering a question from the interviewer with a “yes” or “no” response).

For example, evidence that Terry did not conceive of length independently of height was gathered in part from the drawing he produced in response to a follow-up question to Task 1 (Figure 9.2). The interviewer asked Terry what would happen to the steepness of the ramp if the length of the base were shortened. Rather than shortening the length of the base directly, Terry fixed the leftmost tip of the ramp and moved the rightmost vertical portion of the ramp to the left until it was lined up with the spot in the diagram indicated by a dashed line (see Figure 9.3). This allowed him to use his better-developed understanding of the effect of changing the height to reason that he had made the ramp “taller and steeper.” Because the length of the base of the new ramp was shorter now, decreasing the length of the base indeed had resulted in a steeper ramp. It is important to note that rather than reasoning directly about the length, Terry reasoned about the effect of changing the height and treated length as dependent upon changes in height.

We conjectured that the lack of independence of height and length in his conceptions affected negatively Terry’s ability to conceive of height and length in a proportional relationship (which is necessary in order to understand slope as a ratio of height to length). In the third wheelchair ramp task (Task 3 in Figure 9.2), the interviewer asked Terry to construct a new ramp 50 percent higher than the ramp in the figure but with the same steepness. Terry had great difficulty with this question. Initially, he suggested decreasing the length from 15 ft to 10 ft, so that the height of 2 ft would increase. When the interviewer reminded Terry that the goal of the task was to create a ramp that was taller than, but just as steep as, the original ramp, Terry was stumped.

After instruction, Terry appeared to conceive of height and length independently of each other. When the interviewer returned to the proportion problem that had eluded Terry before instruction (Task 3, Figure 9.2), Terry not only solved the problem correctly, but also solved a much more difficult follow-up task; namely, to predict the height of the ramp if the length were increased from 15 ft to 16 ft. To solve this problem, Terry appeared to have created a different image of the ramp than he exhibited in the pre-interview. In this new image, Terry was able to vary height and length independently of each other. In Terry’s words:

Mmm [pause], all right, like you could pull up this [the height] a little bit [draws a 1/4 inch vertical segment extending up from the point where the incline meets the platform (see Figure 9.4)]. Like, you could lift this, but then you should make this
Terry manipulated the length and height independently of each other. To determine the height, Terry divided 2 by 15, explaining that he was trying to determine how much height he needed for one foot of length. He correctly interpreted his quotient of 0.13 as “how high it has to be [for] one foot [of length]. So you can just make this [points to the height] point 13 feet taller.” Terry’s explanation indicates that he formed a ratio between height and length and interpreted the ratio appropriately for the ramp situation.

Figure 9.4  Terry’s Drawing for Finding the Amount by which he Needs to Extend the Height of the Wheelchair Ramp in Order to Keep its Steepness the Same when the Length is Extended by 1 foot.

Evidence for actor-oriented transfer is gathered by examining a given activity for any indication of influence from previous activities. Specifically, we made several passes through the transcripts of the instructional sessions in order to identify examples of Terry’s reasoning with ratios in a manner similar to that of the postinterview. It is certainly easier for the researcher if a student states explicitly how one situation is like another situation (e.g., if Terry had proclaimed, “Oh, the wheelchair situation is just like the speed situation”). However, an account of transfer should allow for the construction of relations of similarity to be unarticulated by students. Thus, establishing students’ personal connections across experiences often involves gathering evidence to create a plausible inferential case.

Near the end of the design experiment (session eight of ten sessions), Terry demonstrated sophisticated proportional reasoning quite similar to that which he demonstrated in the postinterview. This occurred during an exploration of the ratio of distance
to time as a measure of speed. The students had been working with the speed simulation software *MathWorlds* (Roschelle & Kaput, 1996). Specifically, they were shown a character who walked 10 cm in 4 s (at a constant rate) and were asked to enter different time and distance values for a second character to make it walk at the same speed as the first character. Terry’s reasoning was nonproportional at the outset of the activity but advanced dramatically during the three-hour instructional sequence. In the relevant episode, Terry explained to the whole class why walking 10 cm in 4 s was the same speed as walking 2.5 cm in 1 s.

In both the speed and the wheelchair ramp situations, Terry appeared to form a ratio as a composed unit (Lamon, 1995). In the speed situation, he created a “10 cm in 4” unit (referred to here more succinctly as a 10:4 unit). In the wheelchair ramp situation, he created a “15 ft of length to 2 ft of height” unit (or 15:2). In both situations, Terry provided explanations in which he attended to the conservation of the attribute measured by the ratio (namely, speed and steepness). In both situations, Terry appeared to partition the composed unit to create a unit ratio. In the speed situation, he partitioned the 10:4 unit into four equal parts. In the wheelchair ramp situation, he partitioned the 15:2 unit into two equal parts.

Additionally, in both situations, Terry appeared to connect the arithmetic operations of division and multiplication correctly with the quantitative operations of partitioning and iterating, respectively. In the speed situation, he partitioned the 10:4 segment into four equal parts and said that 2.5 could be found either by calculating $10 \div 4$ or finding one-fourth of 10. In the ramp situation, he appeared to partition the 15:2 unit into two equal parts and calculated $15 \div 2$ to obtain 7.5, which he interpreted correctly as 7.5 ft of length for 1 ft of height. In the ramp situation, he iterated the 7.5:1 unit 3 times (by multiplying each quantity by 3) to arrive at a length and height of 22.5 ft and 3 ft, respectively. In the speed situation, he talked about the 2.5:1 unit as going into the 10:4 unit four times. In sum, Terry appeared to create a set of relations of similarity between the speed and the ramp situations.

4. **The Student’s Reasoning Is Not Entirely Spontaneous**

Finally, we need to consider that Terry’s proportional reasoning in the wheelchair ramp situation might have been a spontaneous construction, one that was unconnected to his experiences in the design experiment. The mathematics education literature on proportional reasoning suggests strongly that Terry’s reasoning in the postinterview is unlikely to be a spontaneous construction. Research indicates that the task of creating a ramp with the same steepness when the length was increased from 15 ft to 16 ft is particularly difficult for students, given that 15 and 16 are relatively prime (Harel & Behr, 1989; Kaput & Maxwell-West, 1994; Lamon, 1994). This suggests that Terry’s demonstration of sophisticated proportional reasoning on this task likely was rooted in prior experiences involving proportional reasoning, rather than a spontaneous construction. Furthermore, Terry’s dramatic change from the pre- to postinterview suggests strongly that the design experiment influenced his reasoning, especially because he entered the study exhibiting very limited proportional reasoning. Additionally, our ability to locate specific relations of similarity between Terry’s explanation for the speed and wheelchair ramp tasks suggests that Terry’s work in the postinterview was not a spontaneous construction.
Method Two: Coordinating Social and Individual Levels of Generalizing Activity in the Actor-Oriented Transfer Approach

The method used in the actor-oriented approach presented above highlights the role of the learner’s agency in the generalization of learning. I turn now to methods for linking conceptually individual generalizations with social aspects of generalizing activity. The idiosyncratic forms of transfer often identified through the use of the actor-oriented transfer perspective may seem arbitrary or random at first, especially when considering generalizations that result in incorrect mathematical performance (such as Jarek’s work shown in Figure 9.1). However, our work on the construct of focusing phenomena is demonstrating a basis by which actor-oriented transfer is constrained (Ellis & Lobato, 2004; Lobato, 2003, 2005; Lobato & Ellis, 2002a, 2002b; Lobato et al., 2003).

Focusing phenomena are features of classroom environments that regularly direct students’ attention toward certain (mathematical) properties or patterns when a variety of features compete for students’ attention. Focusing phenomena emerge not only through the instructor’s actions but also through mathematical language, features of the curricular materials, and the use of artifacts. This notion has allowed us to account for the ways in which features of social environments influence what students attend to mathematically, which, in turn, becomes a central basis from which students generalize their learning experiences (Lobato et al., 2003). Rather than studying the occurrence of transfer as a function of controlling external conditions, as is typically the case in transfer studies (de Corte, 1999; Gentner et al., 2003), the construct of focusing phenomena affords the study of transfer as a constrained, socially situated phenomenon.

In this section, I describe the specific method used to coordinate social and individual aspects of generalizing activity from the actor-oriented transfer perspective. The details of our original focusing phenomena study are reported in Lobato et al. (2003). The results of the study are backgrounded in this section and the method is foregrounded. The method draws upon the constant comparative method of grounded theory (e.g., Strauss & Corbin, 1990) and extends the approach presented in Method One above by accounting for the ways in which instances of actor-oriented transfer are afforded and constrained by features of classroom environments. The data described briefly in this section are drawn from a study situated in a reform-oriented, high-school, introductory algebra class that emphasized the use of real-world situations. The study consisted of two sets of video-taped individual interviews of a subset of better performing students and video-taped classroom instruction of 15 90-minute lessons on slope and linear functions.

Phase One: Analysis of Individual Generalizations

The design of the individual component of the study is similar to that described above in Method One. Thus, it is discussed briefly here, highlighting only the unique features of the design and presenting the data necessary to make sense of the later analysis of the classroom data. Purposive sampling (Patton, 1990) was used to select seven (of 36) students to participate in semistructured interviews (Bernard, 1988; Ginsburg, 1997). Because we were interested in the generalization of learning, it was important to select interview participants who were poised to learn from the instruction (so that there would be something to generalize). Therefore, all interview participants were identified by the classroom teacher as students who were prepared for the curriculum, based on the criteria of average to high mathematics grades, willingness to participate in classroom discussions, and discipline in completing homework assignments.
Interview tasks were designed to include what, from our perspective as content experts, represented near and far transfer tasks. It is important to note that it was not our intent to evaluate the curriculum or to assess all the aspects of learning, which is one way in which we distinguish our studies of transfer from studies of learning. We heed Barnett and Ceci’s (2005) warning that assessments may be misleading if they merely measure children’s ability to reproduce specified procedures in the classroom without assessing the transfer of broader principles to novel problems. By giving students problems that they have not seen in their instruction, we gain a better picture both of what has been learned and of how learning experiences influence students’ comprehension of new settings.

Once the interviews had been conducted, we set aside our expert assumptions and used the actor-oriented transfer perspective to look for any evidence of the influence of the instruction on students’ reasoning patterns, rather than predetermining what would count as transfer. It was striking that all of the students who were able to write an equation for a given line or table wrote “y = mx + b” (rather than the more standard $y = \frac{y_2 - y_1}{x_2 - x_1}$) and referred to the value in the first box as the “starting point” and the value in the second box as “what it goes up by.” The students appeared to have generalized a linear equation as “y equals the ‘starting point’ plus ‘what it goes up by’ x,” which was unusual and clearly tied to the language and inscriptions used in class.

Analysis of the interpretations that students held for the value of the second box in $y = \frac{y_2 - y_1}{x_2 - x_1}$ (which is the m or slope value) proceeded through the use of open coding (Strauss, 1987), a process used to infer categories of meaning. Two members of the research team developed analytic categories independently and coded the transcripts from Interview One. We sorted out troublesome cases through a process of argumentation and settled on a common set of categories. We tested for the validity of the categories by reviewing the transcripts for Interview One, seeking confirming as well as disconfirming evidence. We then applied the categories to the data from Interview Two and made appropriate modifications to the categories.

The analysis revealed three different meanings for $m$: (a) a difference in $y$ values, (b) a difference in $x$ values, and (c) the scale of the $x$ axis (a particularly troubling conception because the nature of the function is not dependent upon the value chosen for the scale of either axis). In each case, the students appeared to have conceived of $m$ incorrectly as a difference and generalized this understanding to the novel interview tasks, rather than interpreting $m$ correctly as a ratio of the change in values of the dependent variable for each one-unit change in the corresponding independent variable. From a classical transfer approach, we would have concluded that there was a massive failure to transfer. However, the actor-oriented perspective revealed distinct and compelling evidence that the students were generalizing, albeit in ways that resulted in incorrect mathematical performance, on the basis of features of the classroom instruction. In response, we conducted a detailed analysis of the data video-taped in the classroom in order to understand how the instructional environment supported these unintended generalizations.

Phase Two: Analysis of Features of the Instructional Environment

Our primary goal was to understand how the instructional environment might have supported the development of the students’ generalizations of $m$ as a difference, rather than as a ratio. One method for coordinating psychological and sociocultural accounts of learning is Cobb and Yackel’s (1996) Emergent Perspective, in which collective units of analysis are used to identify emergent mathematical practices, social norms, and sociomathematical norms and then coordinated with psychological analyses of individuals’
conceptions, general beliefs, and mathematical beliefs (e.g., see Stephan et al., 2003). Because our goals were more constrained, namely, to make sense of generalizing activity rather than all of the learning, we used individuals’ generalizations (as inferred from the interviews) as our starting point, then sought to explain how the instructional environment (unwittingly) supported each of the three categories of meaning for $m$.

The classroom analysis drew generally upon the constant comparative method used in the development of grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1990), which involves constantly comparing data as they are analyzed against the conjectures generated thus far in the data analysis and revising the conjectures accordingly (Cobb & Whitenack, 1996; McClain & Cobb, 2001). In addition to being compared against conjectures, incidents of the participants’ activity in the classroom are compared against one another. This gives rise to general themes or patterns and leads to an ongoing iterative refinement of the broad theoretical categories developed from the data (Cobb et al., 2001).

More specifically, we started by investigating one of the most striking and ubiquitous elements of the interviews, namely, the use of the phrase “goes up by” to refer to the $m$ value in a linear equation. We coded each classroom transcript for every instance of the “goes up by” language. Open coding (Strauss, 1987) was used to identify and name five meanings for “goes up by”: (a) the change in $y$ values of the function per one-unit change in $x$ values (what the line goes up by), (b) the change in $y$ values of the function (what the $y$s go up by), (c) the change in $x$ values of the function (what the $x$s go up by), (d) the scale of the $x$ axis (what the $x$s go up by), and (e) the scale of the $y$ axis (what the $y$s go up by). Only the first is a mathematically correct meaning for slope (which was used by the teacher); the other interpretations represent differences (and were used repeatedly by the students). Because of the ambiguity of the language, the students were able to engage in discussions in which the teacher may have thought the students were using “goes up by” to refer to a ratio, whereas, in actuality, they often used it to refer to a difference (for details, see Lobato et al., 2003).

Additionally, we compiled all of the class episodes in which slope was discussed formally or informally. For each of the three types of meaning for $m$, we assembled the relevant classroom episodes. For example, over half of the interview participants had referred incorrectly to the $m$ value as the scale of the $x$ axis. We then located every instance of reference to the scale of the $x$ axis in class. These instances clustered around the use of the graphing calculator. Next, we applied open coding to all of the relevant graphing calculator episodes in order to identify the ways in which the use of the calculator may have focused attention on the scale of the $x$ axis.

As instructional categories emerged, such as the “goes up by” language or the particular ways in which the graphing calculators were used, we employed axial coding (Strauss, 1987) to identify conceptual relationships between instructional categories and categories for the meaning of $m$. As a result, the central theoretical construct of focusing phenomena emerged and informed further passes through the data. We continued with this process until we had created a plausible set of conceptual connections between classroom events and each of the three meanings for $m$ demonstrated in the interviews (see Figure 9.5). Analysis of the classroom data revealed four focusing phenomena: (a) the ambiguous “goes up by” language, (b) the use of uniformly ordered data tables, (c) the ways in which graphing calculators were used, and (d) an emphasis on uncoordinated sequences and differences. The details provided in Lobato et al. (2003) demonstrate how the focusing phenomena regularly directed students’ attention to various differences—$\Delta y$, $\Delta x$, and the scale of the $x$ axis—rather than to the coordination of two quantities.
Figure 9.5 illustrates what Strauss and Corbin (1994) call “theory” in the grounded theory approach, namely the “plausible relationships proposed among concepts and sets of concepts” (p. 278). As seen in Figure 9.5, these four categories interact and affect one another. In particular, the “goes up by” language occurred throughout the entire instructional unit and served to facilitate the attention on differences within each of the other three focusing phenomena.

To demonstrate how two focusing phenomena work together, consider an example in which both the use of well-ordered tables and the “goes up by” language appear to draw students’ attention to slope as the difference in \( y \) values, rather than as a ratio between \( y \) and \( x \) values. The curricular unit on linear functions opened with a lesson that had many features desirable in reform-oriented classrooms. Students collected data to investigate the relationship between the distance of an overhead projector from a wall and the enlargement factor between real and projected images. Messy, real-world data were used, rather than “canned” data. Students were actively involved, and the teacher tried to use informal language that appeared to be meaningful to the students. While the data were being recorded in a table (see Table 9.1), the teacher invited the students to look for patterns, as indicated in the following excerpt from the transcript:

**Ms. R:** What does that 10.3 tell us, then?

**Student:** It goes up by 3.

<table>
<thead>
<tr>
<th>Distance of the projector from the wall (in meters)</th>
<th>Enlargement factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>4.8</td>
</tr>
<tr>
<td>3</td>
<td>7.8</td>
</tr>
<tr>
<td>4</td>
<td>10.3</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

*Table 9.1 Data Collected by Students Showing the Enlargement Factor of an Overhead Projector Placed Varying Distances from the Wall*
Ms. R: It goes up by 3? So you mean, this way it goes up by 3 [she sweeps her hand vertically down the column of y values in the table]?

Student: Yeah.

Ms. R: That looks like a good pattern. Approximately 3? Very good.

This excerpt includes the first instance of the “goes up by” language in the instructional unit. The students used this language first, which was appropriated by the teacher. The teacher gestured by sweeping her hand vertically down the y column, likely focusing additional attention on the y values. When asked to predict the enlargement factor when the projector was 5 m and 6 m from the wall, several students responded that the enlargement factors would be 13 and 16, respectively, suggesting that they attended to the difference between successive y values.

After the data were collected, the teacher introduced the equation \( y = \frac{\Delta y}{\Delta x} \) to express the relationship shown in the table. To obtain the value for the second box (i.e., the m or slope value), the teacher explicitly directed the students to focus on the change in y values by asking: “So if we took one of the measurements that we have right now, how would we get to the next number? Would you add exactly 2 or exactly 3?” The students suggested finding the average of the change in y values, which is 2.7. The teacher summarized the meaning of 2.7 by stating: “To get to the next number, you add approximately 2.7, so 2.7 is how much you do to one number to get to the next number.” In order to produce an equation (in this case, \( y = 0 + 2.7x \) or \( y = 2.7x \)), the teacher instructed the students to “remember what is the starting value and what you are doing to get to the next value.” Thus, she directed the students’ attention to the change in y values, rather than to the dependency relationship between the corresponding x and y values. It was possible to do this and generate a correct equation because the data were uniformly ordered, with the change in y values. It was possible to do this and generate a correct equation because the data were uniformly ordered, with the change in y values.

However, the influence of beginning the unit with a uniformly ordered table in which \( \Delta x = 1 \) was seen throughout the unit. Every time a table was used in which \( \Delta x \neq 1 \) (all the tables used in the unit were uniformly ordered), many students associated m with the difference in y values. A typical example occurred during the warm-up activity for Day 10. Students worked individually to find the rate of change of a function depicted in tabular form. The values in the x column were 0, 3, 6, and 9, and the corresponding y values were 20, 32, 44, and 56. During the class discussion of the problem, the teacher guided a student through the process of calculating the rate of change, reminding him to divide his response of 12 by the change in x values. She noted the widespread response from students that the slope of the function was the change in y values: “A lot of people put 12 as their slope. You’re right that it is going up by 12 when x goes up by 3, but we want to know what it goes up by if x is only going up by 1.” Although the teacher was able to use the “goes up by” language to coordinate the change in y values with the change in x values in a uniformly ordered table, many students appear to have focused on the slope as the difference in y values.

Discussion: Implications of the Use of Alternative Transfer Perspectives and Methods in Design Experiments

In considering the implications for design experiments, it is tempting to address only the implications of adopting an actor-oriented transfer perspective because that is the approach I have been developing. However, this plays inadvertently into the “linear march of progress” (see Cobb, 2005) by conceiving of an alternative transfer...
perspective as overcoming the limitations of the classical approach and thus replacing it. In contrast, Cobb points to a different metaphor for comparing theoretical perspectives, namely, that of “co-existence and conflict.” In keeping with this latter metaphor, I claim that there is no one best approach to conceive of the transfer of learning. Instead, there are points of tension and compatibility among the various emergent models of such transfer, and trade-offs that each approach makes, given the purposes for which each perspective was developed.

Consider for a moment the trade-offs made by using ethnographic methods (in the actor-oriented transfer perspective) and experimental methods (in the preparation for future learning perspective). These two transfer models are compared because they utilize different methods but are both well suited to classroom studies. By using experimental methods, the preparation for future learning approach capitalizes on the logic of stochastic causality to make causal claims about the effectiveness of particular preparatory activities on students’ ability to perform on transfer tasks (Schwartz & Martin, 2004). As a trade-off, the amount of generalization of learning that is captured is underestimated because of reliance on an observer’s perspective, despite the fact that the preparation for future learning approach captures more instances of generalizing than the classical transfer approach does. Additionally, experimental methods are better suited to answer “is there” questions (i.e., Is there a systematic effect?) than “why or how” questions (i.e., How is the instructional environment influencing the ways in which individuals construe novel situations?) (Maxwell, 2004).

In contrast, the grounded theory methods used in the actor-oriented perspective allow researchers to posit new conceptual constructs, explore conceptual connections between instructional features of environments and individuals’ generalizations, and capture a broad range of generalizing activity by detecting the influence of prior learning experiences on activities in novel settings. The trade-off is the small scale of the work, the associated difficulties in generalizing researchers’ claims and accounting for selection bias, and the emphasis on model formation, rather than validation (Sloane & Gorard, 2003).

A Multistage Approach to Design Experiments
Rather than choosing a single transfer perspective, researchers could select one that is appropriate for the stage in which they are operating in a multistage model of design research. Researchers from the fields of engineering and product design typically have conceived of design research as entailing multiple stages of cyclic research and design (Kelly, 2003). Bannan-Ritland (2003) brings a multistage design model from engineering to education research by positing four stages: (a) informed exploration (involving needs analysis, brainstorming, and the development of an initial prototype), (b) enactment (cycles of intervention, design, and redesign on a small scale), (c) local impact (a cycle of formative evaluation, revision, implementation, and summative evaluation to establish internal validity), and (d) broader impact (studies of implementation, adaptation, and diffusion with summative evaluation to establish external validity). The first two stages fit roughly into what some scholars have called the context of discovery and the last two fit into the context of verification (Holton, 1998). In the context of discovery, exploratory studies are conducted that lead typically to the generation of hypotheses, concepts, categories, and models; in the context of verification, theory-driven, systematic experimentation is conducted in an effort to achieve model estimation or model validation (Kelly, 2004; Sloane & Gorard, 2003).
The actor-oriented transfer perspective is well suited for the initial stages of design research for three reasons. First, the actor-oriented transfer perspective provides a way to examine the processes employed by novices in the generalization of learning, thus responding to the opening epigraph for this chapter. If one considers that the classical transfer approach investigates only highly valued, expert generalizations, then it is not surprising to find overwhelming evidence in the literature for the lack of transfer of learning because we know that novices do not make the same set of connections as experts.

Second, the actor-oriented approach provides a way to use information gained through the investigation of students’ generalizations (including incorrect and non-normative generalizations) to inform revisions in curricular materials and pedagogical approaches during iterative cycles of instructional design. For example, in our focusing phenomena study (Lobato et al., 2003), we identified relationships among instructional features, what students attended to mathematically, and their accompanying generalizations, with sufficient detail to suggest principled ways in which we could make design responses. Preliminary findings of two subsequent revisions of the instructional approach suggest that: (a) by regularly directing students’ attention to the coordination of covarying quantities, they are more likely to generalize slope as a ratio, and (b) it is possible to identify a nuanced and differentiated view of levels of transfer (Ellis & Lobato, 2004; Lobato, 2005; Lobato & Ellis, 2002c). Identifying levels of increasing sophistication in non-normative or incorrect displays of the transfer of learning is related to Minstrell’s (2001) articulation of facets of students’ understanding of physics. In Minstrell’s approach, one can identify a particular facet as indicative of more complex and sophisticated understanding than another facet, even when both facets represent incorrect or non-normative reasoning. Similarly, one can identify levels of actor-oriented transfer, which is powerful for design studies because moving up levels of sophistication may be linked with successive iterations in the design cycle.

Third, through the notion of focusing phenomena, the actor-oriented transfer perspective can link conceptually features of instructional environments with students’ reasoning patterns and performance. The notion of focusing phenomena addresses the need for examining the conceptual links and processes by which some events influence other events (which Maxwell [2004] calls process causation and Miles and Huberman [1994] call local causality). This is how Shadish et al., prominent proponents of experimental research, distinguish between causal description and causal explanation:

The unique strength of experimentation is in describing the consequences attributable to deliberately varying a treatment. We call this causal description. In contrast, experiments do less well in clarifying the mechanisms through which and the conditions under which that causal relationship holds—what we call causal explanation.

(2002: 9)

Our work with focusing phenomena in an actor-oriented transfer perspective has afforded an investigation of causal explanations and of “how and why” questions in the initial stages of design research, leaving causal description and “what works” questions for the verification stages.
Verification Stages

I have argued that, in the early stages of design research, it is important to dissociate from normative or correct performance as a criterion for transfer in order to permit an investigation of how students’ generalizations (whether correct or not) are afforded and constrained by specific instructional practices. However, by the time the design study moves to the definitive trial stage, the design innovation should be working well enough to support productive, actor-oriented transfer for students, in which case transfer perspectives based on expert models could be used. For example, the classical transfer approach may work well for studying mature understanding in Bannan-Ritland’s (2003) final stage of design research (the “broader impact” phase). The avoidance of sequestered problem-solving and the inclusion of measures to assess learning readiness make the preparation for future learning perspective (Bransford & Schwartz, 1999) an attractive model for studies conducted at the “local impact” stage of design research.

By using experimental methods, the preparation for future learning approach allows researchers to make claims about systematic effects regarding the effectiveness of preparatory and learning activities on students’ performance on novel tasks. At some point, instructional innovations that have been revised based on information gathered from the actor-oriented transfer approach should be validated experimentally, which could be accomplished by using the preparation for future learning approach. Furthermore, the design used in the preparation for future learning approach to compare several instructional approaches allows researchers to test their conclusions against plausible alternative interpretations.

Remaining Challenges

When using different methods for different stages of design research, a central challenge remains of how to conduct the various studies so that they are connected conceptually and can inform each other. Without such a connection, researchers could demonstrate significant effects of instructional treatments but still be unable to explain why a particular approach works. Resolving this dilemma is beyond the scope of this chapter. However, I conclude by suggesting that the resolution involves two important areas of work—assessment and the design of studies that can bridge the discovery and verification stages. With respect to assessment, more sophisticated techniques for assessing non-normative instances of transfer need to be designed in a form that can be used on a large scale (e.g., online or by using paper-and-pencil tests with multiple-choice items) in the verification stages of a design experiment. With respect to bridging the discovery and verification stages, it is important to note that the independent variable in many experimental designs is the instructional approach. In contrast, the independent variable in our focusing phenomena studies is an interaction between teachers’ actions, other instructional features, and the mathematical saliency of particular features for students. Thus, in order to move from small-scale ethnographic work to large-scale experimentation, it is important to conduct bridging studies in which this interactional variable changes while other factors, such as students’ entering knowledge of key concepts, are controlled.

Conclusions

Although the methods used in the classical transfer approach are well established, the methods used in most of the alternative transfer perspectives are emerging. Therefore,
one goal of this chapter was to present two specific methods that emerged during efforts
to document the transfer of learning from an actor-oriented perspective in a variety of
mathematics education studies. One method is used to identify instances of actor-
oriented transfer in classroom settings; the second method is used to coordinate social
and individual aspects of generalizing activity.

However, it is important that research methods are not presented as isolated tech-
niques. Thus, the second major goal of the chapter was to demonstrate the relationships
between transfer theory and research methods. By comparing five theoretical perspec-
tives on transfer, I illustrated how a close examination of the particular research
methods refine the definition of transfer used in a given perspective, and, reflexively,
how a shift in one’s definition of transfer influences the methods that one employs to
measure such transfer. Similarly, the use of experimental versus ethnographic methods
to identify instances of transfer affects the nature of the research questions that one can
pose related to the generalization of learning. Finally, the theoretical assumptions that
one makes about whether transfer is a psychological or a distributed phenomenon
affect the unit of analysis that one takes methodologically.

By conceiving of the methods used to measure transfer as a function of the theoretical
assumptions that one makes, we were able to explore the points of tension and compat-
ibility among various models of transfer. As a result of describing what is gained and
lost by adopting a particular perspective, it is possible to transcend pitting one perspec-
tive against another and, instead, to see the selection of a transfer perspective and its
accompanying methods as dependent upon its appropriateness for the stage in which
one is operating in a multistage model of design research.

Acknowledgments

The research described in this chapter is supported by the National Science Foundation
under Grant REC-9733942. One of the design experiments was conducted in a com-
puter laboratory funded by the National Science Foundation under Grant DUE-
9751212. The views expressed do not reflect official positions of the Foundation.

I offer my gratitude to Anthony E. Kelly, John Baek, and Christina De Simone for
their thoughtful feedback on an earlier draft of this paper.

Note

1 A special MathWorlds script was designed by Jeremy Roschelle and Janet Bowers for the
Generalization of Learning project, in which students could control the starting position,
distance, and time of characters who traveled across the screen.

References


Bannan-Ritland, B. (2003). The role of design in research: The integrative learning design frame-

Barnett, S. & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far


In J. P. Mestre (ed.), Transfer of learning from a modern multidisciplinary perspective
(pp. 295–312). Greenwich, CT: Information Age Publishing.


Gentner, D., Loewenstein, J. & Thompson, L. (2003). Learning and transfer. *Journal of Educational Psychology*, 95, 393–408.


