# CONSOLIDATING TRADITIONAL AND CONTEMPORARY PERSPECTIVES OF TRANSFER OF LEARNING: A FRAMEWORK AND IMPLICATIONS[+]

A diverse set of theoretical perspectives has informed the study of transfer of learning. While transfer has traditionally been defined as the ability to apply what is learned in one context to a different context, over the last decade or so some researchers have expanded their view of transfer and have begun examining transfer from the point of view of knowledge construction rather than knowledge application, per se. Here we ask the question: Can these two seemingly different perspectives be consolidated into a broader overarching theoretical framework? If so, what will such a framework look like and what are its implications for research and instruction? In this paper we begin to address some of these questions and present the beginnings of a framework that we believe might provide a lens in examining transfer of learning.

N. Sanjay Rebello, Kansas State University

## Introduction

Traditionally, transfer of learning (Reed, 1993; Singley & Anderson, 1989) is often defined as applying what one has learned in one situation to another situation. Due to the lack of evidence of transfer in many studies based on traditional models, recent views of transfer have shifted to look at transfer from other perspectives.

Traditional models are based on a researcher’s predefined concept that students should transfer. These models also view transfer as a static process. The traditional models of transfer have tended to focus on the cognitive aspects of transfer such as Throndike’s theory of identical elements (1901) or Judd’s theory of deep structure transfer (1908). More recently, the information processing perspective purports that transfer is mediated by abstract, symbolic mental representations (Singley & Anderson, 1989).

Contemporary models of transfer have gone beyond focusing solely on the cognitive aspects of transfer and have included several other mediating factors. Contemporary models of transfer (Bransford & Schwartz, 1999; Greeno, Moore, & Smith, 1993; Lobato, 2003) account for aspects the traditional models neglect. They take into account the socio-cultural factors that mediate transfer and view transfer from the students’ points of view rather than the researcher’s point of view. A common feature of all of these perspectives is that they consider transfer as an active dynamic process. Here I present a theoretical framework that distinguishes between and consolidates the diverse views held by researchers on transfer of learning.

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[+] This work is supported in part by National Science Foundation grants DUE-0206943 and REC-0133621.

## Theoretical Framework

Our model of transfer is based on a framework presented by Redish (2004) which in turn is based on cognitive psychology. Per this framework transfer is the dynamic creation of associations by the learner in a new problem situation. There are two kinds of associations that a learner can create in a problem solving scenario. The first kind of association involves assigning information read out from a problem to an element of the learner's prior knowledge. An example is reading out a numerical value from the problem statement and assigning it to a particular physical quantity. For instance, if a problem states that a car is moving at 20 meters/second, the learner recognizes that the 20 meters/second is the car's 'velocity' and more specifically that 'v = 20 m/s' must be plugged into a particular equation. The equation in this case is a part of the learner's internal schema to solve the problem. These kinds of associations between new information gleaned from the problem and elements of the learner's internal knowledge structure are usually firmly established in the learner's mind and easily articulated by the learner. A second kind of association occurs between a knowledge element read-out from the problem with an element of the learner's internal knowledge structure, which in turn is based on their prior knowledge. This association is usually more abstract and tenuous and often the learner may not be able to clearly articulate it. For instance a student who is shown an animation of a moving car, without being even told that velocity has anything to do with problem, begins to think about the car's velocity as an important feature of the problem. This learner is making an implicit association between two ideas – motion (shown in the problem animation) and velocity (knowledge which is deemed necessary to describe the motion).

These two flavors of associations are tied to two different kinds of transfer processes. In the first kind of transfer – 'horizontal' transfer – the learner reads-out explicitly provided information from a problem scenario that activates a pre-created knowledge structure[1] that is aligned with new information read out from the problem. If such alignment or assignment does not naturally occur, i.e. if the external problem representation does not match the learner's knowledge structure or internal problem representation, the learner is unable to solve the problem. A typical example of horizontal transfer occurs when learners solve 'plug-and-chug' problems at the end of chapters in some science and mathematics textbooks. The learner reads the problem statement, which explicitly provides information in terms of the required variables, e.g. the initial velocity, acceleration and time of a moving vehicle and clearly states the goal of the problem such as finding the displacement of the vehicle. Upon reading out this information from the problem the learner activates a particular equation of motion from their memory -- the learner's internal schema or mental model for solving this problem. Several end-of-chapter problems in textbooks fall under this category. The problem statement often explicitly provides all of the required information and no more. The learner is never

[1] The term 'internal knowledge structure' refers to a pre-created set of tightly associated knowledge elements. Other terminology that is often used in literature includes 'schema,' 'internal representation,' 'mental model' or 'coordination class.'

called upon to critically examine the situation or the assumptions underlying the model that they use to solve it.

In the second kind of transfer – 'vertical' transfer – a learner recognizes features of the situation that intuitively activate elements of her/his prior knowledge. The learner typically does not have a preconceived knowledge structure that aligns with the problem information. Rather, the learner constructs a mental model *in situ* through successive activation and suppression of associations between knowledge elements. For instance, rather than being told the initial velocity and acceleration of the vehicle the learner is shown a video clip of the vehicle and asked to find out how much farther the vehicle would travel after going off the frame of the video clip. Nowhere is the learner told the initial velocity or acceleration or even that these variables are relevant to the situation. In this case, the learner first must recognize that the vehicle was accelerating and may even confront the assumption that this acceleration may not be uniform. Nowhere is any information provided about the equation that must be used or even that an equation may be applicable. So the learner cannot activate a clearly identifiable preconceived knowledge structure or internal representation that neatly aligns with the situation. At the very least, the learner must choose between competing internal representations or construct a new one for this situation. Choosing the most productive internal representation from several representations depending upon the problem situation is a key feature of 'vertical' transfer. Most real-world problems require 'vertical' transfer. They require learners to decide which variables can be neglected and also decide what schema or model is applicable. Real-world problem solving also requires students to know the limitations of the model that they choose and the hypothetical conditions under which the model is no longer applicable.

Figure 1 shows the difference between 'horizontal' and 'vertical' transfer. The graphical metaphor with a horizontal and vertical axis is a useful pictorial representation to highlight the distinctiveness of the two processes. It also is useful in representing the notion that a given process can have components of both 'horizontal' and 'vertical' transfer.

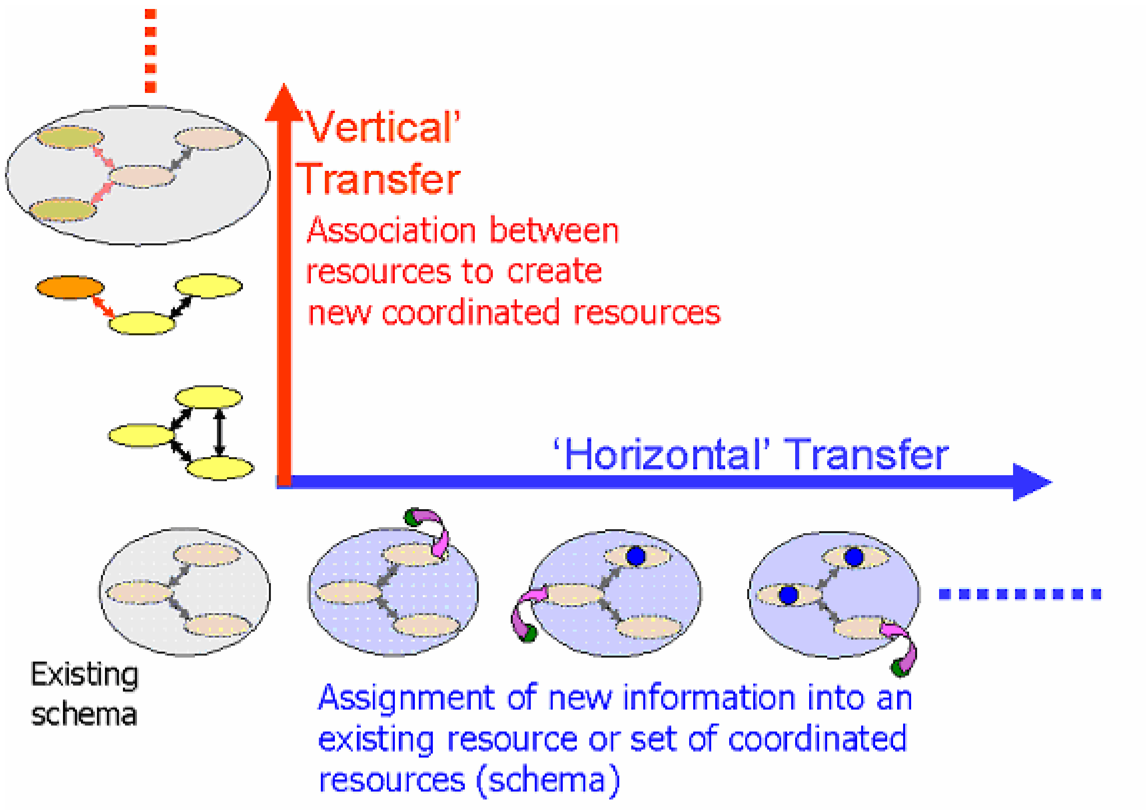


*Figure 1*. 'Horizontal' transfer involves assignment of new information onto an existing knowledge structure. 'Vertical' transfer involves creating a new knowledge structure to make sense of new information by associating different resources.

Our ideas of horizontal and vertical transfer described above are not new. There is a vast body of literature on knowledge and conceptual change that expresses ideas along these lines. Several decades ago Piaget (1964) proposed two mechanisms of conceptual change – assimilation and accommodation. Although Piaget's ideas focused on conceptual change and not on transfer, the mechanisms of assimilation and accommodation align closely with horizontal and vertical transfer respectively.

Broudy (1977) similarly identified at least two kinds of knowing – applicative (knowing what and how) and interpretive (knowing with) knowing. Applicative knowing includes clearly articulated schema that a learner uses in a given situation. Interpretive knowing, which is more intangible, refers to intuition that a learner brings to bear as he/she makes sense of a new situation. Broudy's notions of applicative and interpretive knowing align closely with our ideas of horizontal and vertical transfer respectively.

The ideas of horizontal and vertical transfer are consistent with the ideas that have been used to design instruction for conceptual change. Karplus' (1974) Learning Cycle and more recently Hestenes' (1987) Modeling Cycle refer to the Model Development phase during which a learner constructs a model to explain their observations of phenomena. This phase is followed by the Model Deployment phase during which the learner applies the model in a new situation. Model Development involves vertical transfer since it relates to the learner building a new schema based on experiences. Model deployment involves horizontal transfer since the learner has to apply the schema to a new situation.

More recently, diSessa and Wagner (2005) distinguish between Class A and Class C transfer. Class A transfer occurs when a learner applies "well prepared" knowledge such as a coordination class to a new situation. Class A transfer is similar to horizontal transfer. Alternatively, Class C transfer, which occurs when "relatively unprepared" learners use prior knowledge to construct new knowledge, is similar to vertical transfer.

Salomon and Perkins (1989) distinguish between Low Road and High Road transfer. Low Road or more typically near transfer occurs when the scenario in which original learning had occurred is similar to the new problem scenario so that the learner can successfully apply preconceived problem-solving processes. Low Road transfer is similar to horizontal transfer. High Road, which is similar to vertical transfer, is much more challenging in that it requires the learner to abstract the new situation and engage in reflection and metacognition to help construct a way to solve the problem.

Bransford and Schwartz (1999) compared two measures of transfer – Sequestered Problem Solving (SPS) and Preparation for Future Learning (PFL). Sequestered Problem Solving focuses on whether students can directly apply their learning to a new situation without any scaffolding or support. Preparation for Future Learning focuses on whether their learning has prepared them to learn in the future. To measure transfer from the PFL perspective we must observe whether a learner can bring to bear their earlier experiences to learn to construct new knowledge that would enable them to solve the problem in the new situation. Bransford and Schwartz (1999) point out that most traditional transfer measures focus on SPS rather than PFL and consequently fail to find evidence of transfer. SPS view of transfer focuses primarily on horizontal transfer in that it assesses whether a learner can apply their existing schema to new situations. SPS does not even consider the possibility that a learner may need to learn how to solve the problem in the new situation. Alternatively, the PFL view of transfer focuses primarily on vertical transfer in that it assesses whether a learner can create a new schema to solve the problem.

Jonassen (2003) has distinguished between well-structured and ill-structured problem solving, which also aligns with our ideas of horizontal and vertical transfer. Well-structured problems have clearly defined information and goals. Therefore, they are akin to problems that require mainly horizontal transfer. Ill-structured problems on the other hand have multiple solutions, may require the learner to choose between several competing internal representations and may require the learner to question several underlying assumptions about what model or representation is applicable in the given situation. Unstructured problems typically require significant vertical transfer.

Thus our framework is consistent with ideas of educational researchers who have examined learning, conceptual development and transfer for several decades.

## Implications for Instruction

Educators have speculated whether providing students with a structured problem followed by a semi-structured isomorphic problem could increase performance on the latter. Our framework predicts, as observed by researchers, e.g. Cui, Rebello, & Bennett

(2005) that the former which requires horizontal transfer may not necessarily facilitate the latter, which requires vertical transfer.

Schwartz and Bransford (2005) suggested the notions of efficiency and innovation in transfer. Efficiency, which is akin to horizontal transfer, refers to a learner's ability to rapidly recall and apply their knowledge in a new situation. Innovation, which is akin to vertical transfer, is their ability to restructure their thinking or reorganize the problem scenario so that it becomes more tractable than before.

Schwartz and Bransford (2005) also suggest that efficiency and innovation are both equally important goals. For instance, we want students to be innovative and develop new strategies for solving new and previously unseen problems. However, we also want students to be efficient in solving previously seen problems so that they do not have to reinvent problem solving strategies each time they are faced with a problem. In other words, we want students to be adaptive learners who can distinguish between situations in which proven strategies can be applied and those in which they cannot be applied, necessitating the innovations of new strategies. Thus students must be guided along what they call an Optimal Adaptability Corridor (OAC) – a diagonal path as shown in Figure 2 that simultaneously promotes both efficiency and innovation.

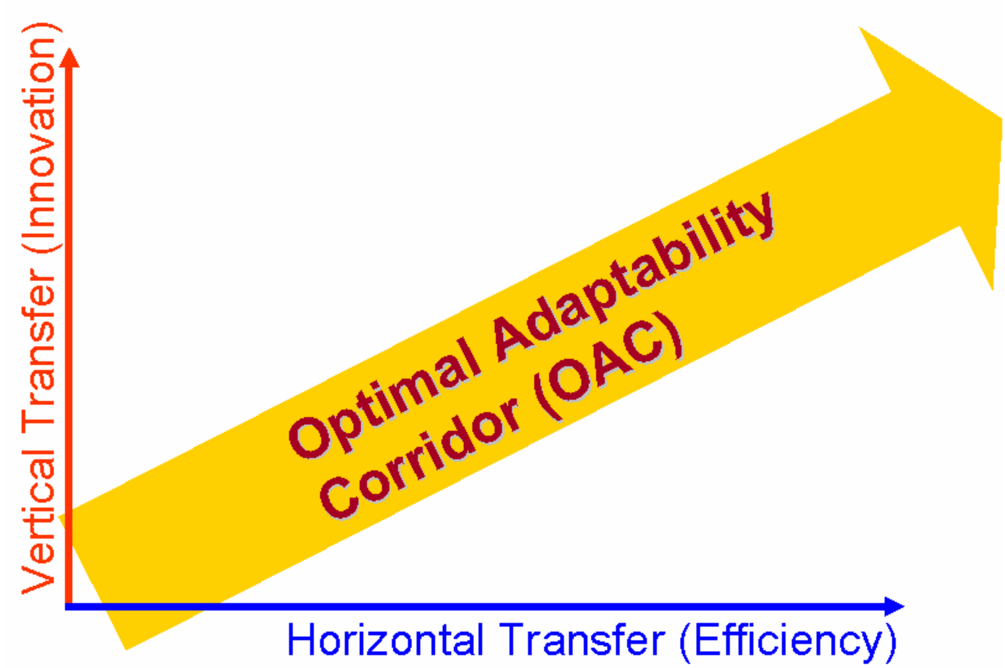


*Figure 2*. The Optimal Adaptability Corridor (OAC) by Bransford and Schwartz (2005) describes a learning trajectory leading to adaptive expertise – balancing both efficiency and innovation.

While Bransford and Schwartz (2005) propose an OAC they do not propose any specific instructional strategies that can help students navigate the OAC and become adaptive learners who are both efficient and innovative. However, based on our own understanding of the cognitive processes underpinning efficiency and innovation, we believe that prior literature on learning offers some clues.

As noted earlier, the ideas of horizontal and vertical transfer are consistent with the ideas that have been used to design instruction for conceptual change.  Particularly, the ideas of horizontal and vertical transfer are consistent with the model deployment and model development phase of the Modeling Cycle (Hestenes, 1987) respectively.  Thus the OAC can be navigated by designing a sequence of alternate model developing and model deploying activities as shown in Figure 3.

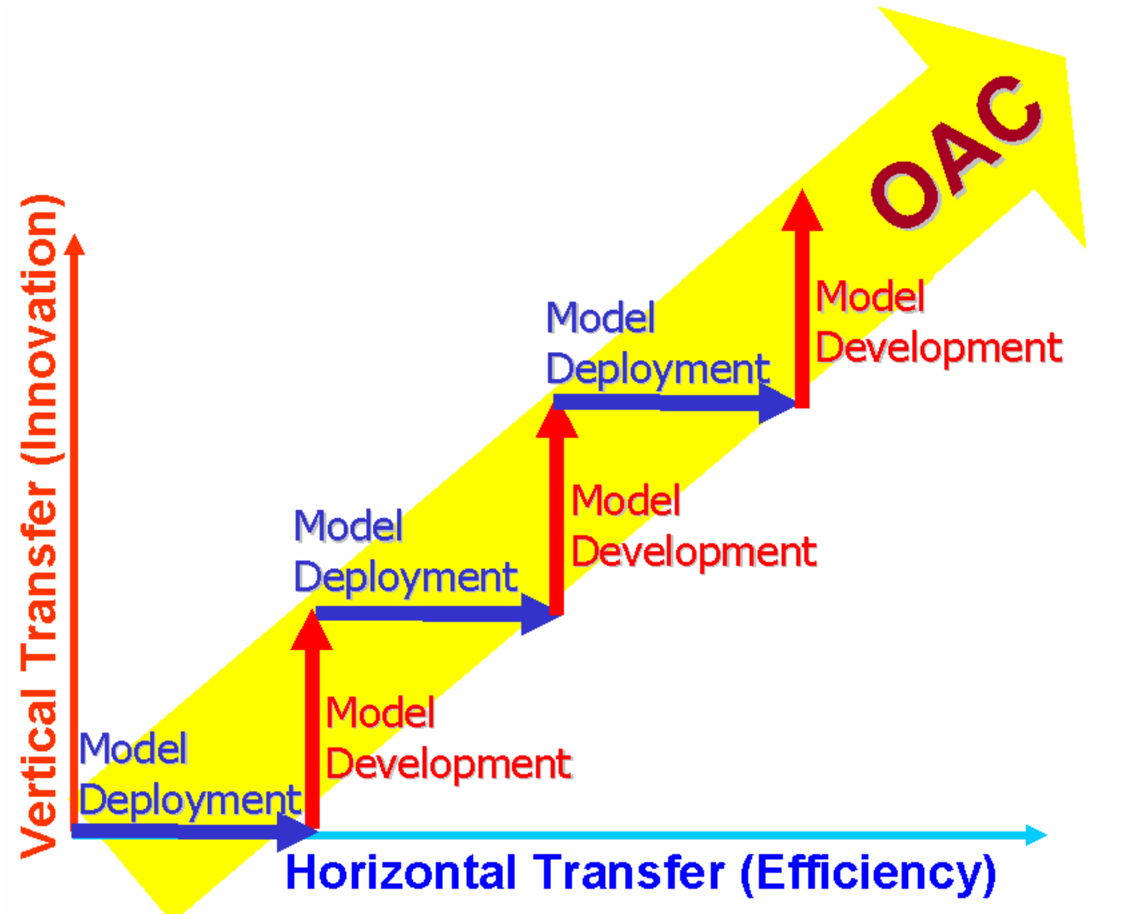


*Figure 3*.  Navigating the Optimal Adaptability Corridor (OAC) using sequential Modeling Cycle (Hestenes, 1987) phases of model deployment and model development.

Thus in light of our framework students should be guided through a sequence of model development and model deployment steps (Hestenes, 1987) that will guide them through the OAC toward the development of adaptive expertise.  Although the Modeling Cycle provides a pedagogical model for designing instruction, it does not per se provide any guidance on how these phases should be designed or what criteria must be considered while designing these phases. When applying a sequence of model development and model deployment phases (Hestenes, 1987) to navigate the OAC, one important question might be raised: What criteria determine the points of transition between model deployment and model development? In other words, what determines the location of the foot of the vertical step and the height of the vertical steps in Figure 3, or more generally speaking how can we ascertain the students' optimal learning trajectory.

The ideas of constructivism by Piaget (1964) and Vygotsky (1978) appear to provide some guidance in addressing the above question. First, let us consider the point of inflection or transition between model deployment and model development. This is the point when a learner makes a transition engaging in horizontal transfer i.e. being efficient to vertical transfer i.e. being innovative. What is necessary to promote this change in modes of thinking – from horizontal to vertical? Piaget's theory of intellectual development (1964) seems to suggest that an important criterion for conceptual change is cognitive disequilibrium. When a learner is faced with a situation in which their existing schema or model is unable to explain their experience, they become more amenable to conceptual change. To achieve conceptual change they engage in a process of accommodation to alter the schema such that it is consistent with the new evidence. Thus, the points of inflection as shown in Figure 3 are in fact points of cognitive dissonance (Festinger, 1957) or disequilibrium when a learner recognizes that their current schema or mental model is inadequate and recognizes the need to build a new one.

Second, let us consider the other important feature of Figure 3 i.e. the vertical height of the model development steps. What determines the height of these steps? In other words, what determines the extent to which a learner can develop a model. Vygotsky (1978) suggests that learners' development occurs within a Zone of Proximal Development (ZPD). A learner's ZPD can be defined as the 'distance' between what they can learn by themselves and what they can learn with help from a more experienced peer or teacher. Other researchers have pointed out that the ZPD is not necessarily an attribute of a learner, rather it is a function of the interaction between the learner and the environment, which includes both learning materials and peers or a teacher who facilitates learning. The ZPD determines the extent to which a learner can, with the help of others develop a new schema or mental model. In other words, the level of innovation or complexity of the model is determined by the learner's ZPD. Thus, the vertical height of the model development steps in Figure 3 is directly related to the learners' ZPD.

We can thus annotate the figure to indicate the points of dissonance and the ZPD as shown in Figure 4.

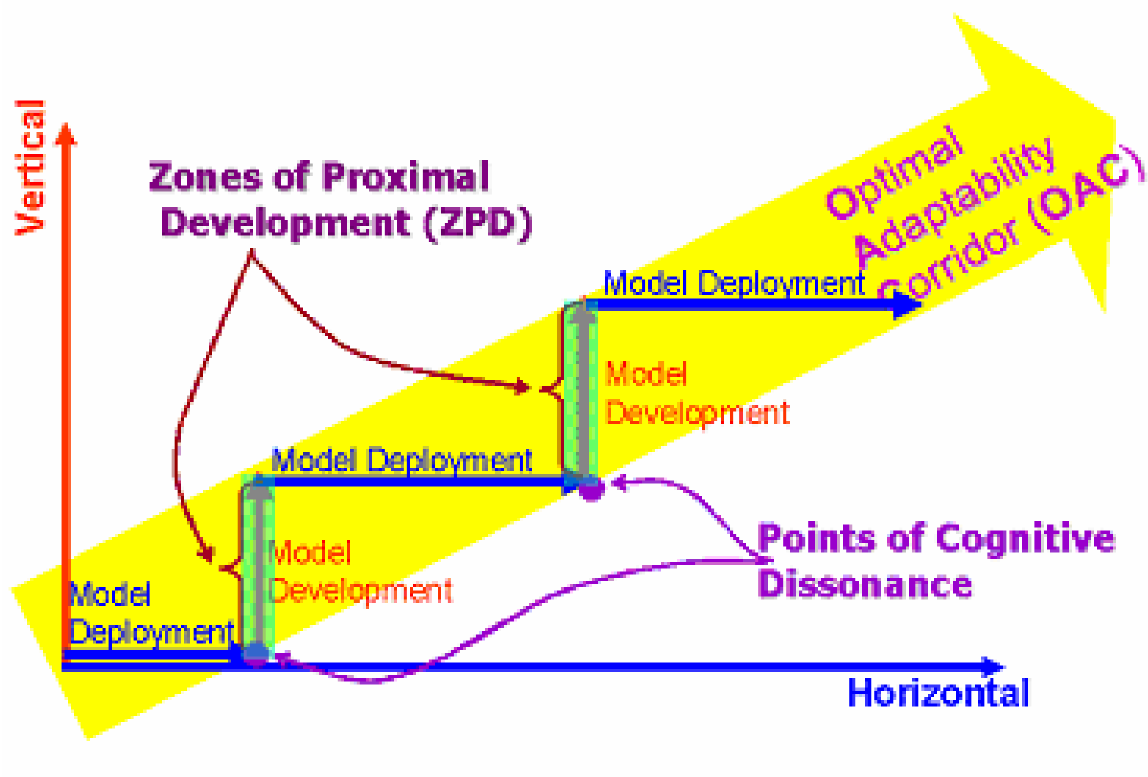


*Figure 4.* The points of transition between model deployment and model development phases are marked by the points of cognitive dissonance, while the extent of model development is directly related to the Zone of Proximal Development (ZPD).

## Summary

We have presented a theoretical framework that builds on our previous work on dynamic transfer of learning (Rebello et al., 2005). Our theoretical framework identifies two kinds of transfer processes at a small-grain size level. Horizontal transfer occurs when a learner recognizes new information that can be easily assigned or assimilated into their existing schema. Vertical transfer occurs when a learner restructures their knowledge to create a new schema to address a previously unfamiliar situation. The distinction between these two kinds of transfer is not new. Several other researchers have described similar ideas in their work.

Our framework has some important implications for designing instructional strategies to promote intellectual development. It has been recognized (Schwartz et al., 2005) that we must enable learners to be both innovative as well as efficient so that they can effectively solve the problems they encounter in their everyday life. In other words, our goal is to facilitate students to develop adaptive expertise. To achieve this goal, we must facilitate students to navigate an Optimal Adaptability Corridor (OAC) that balances efficiency (horizontal transfer) with innovation (vertical transfer).

The Modeling Cycle (Hestenes, 1987) provides a useful instructional model to help learners navigate the OAC. By designing an appropriate sequence of model development and model deployment phases we can help students develop adaptive expertise to become both innovative and efficient learners. Further examining this notion, we find that the points of transition from model deployment (horizontal transfer) to model development (vertical transfer) are points when the learner recognizes the need for innovation of a new model of schema to address the situation. Typically, this point of transition occurs when learners recognize through an experience of cognitive dissonance (Festinger, 1957) that their existing schema is inadequate and must be restructured into a new schema. The extent of restructuring is a function of both the learner's conceptual resources and the environment, which includes the learning materials as well as peers or more experienced individuals who can facilitate the process of model development. Thus, the extent to which a learner can develop a new model is directly related to their Zone of Proximal Development (ZPD) (Vygotsky, 1978).

Thus, a number of different factors are relevant to the design of learning experiences to facilitate learning that produces adaptive learners who are both innovative and efficient when solving the problems they encounter in their everyday lives.

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