How Do We Learn? Four cognitive models explained

By Jacquelyn Kelly, PhD

Introduction

Educational research is driven by an understanding of cognition. Without having some theoretical basis for understanding how students think and learn, there can be no warranted claims about how instructors should teach to maximize student learning and success. However, there seems to be a lack of consensus among cognitive models in the educational research community. This can be a challenge since varying lenses may have different implications for both research and practice. For an educational researcher to choose which cognitive lens will be applied, it is important that one understands these implications. To follow, a general discussion of the predominate views of cognition with respect to educational research will be presented along with the assumptions and implications each brings associated with (1) how knowledge is stored, (2) how learning occurs, (3) how teaching can maximize student success, and (4) how knowledge and understanding can be assessed.

Behaviorism

The Behaviorist Theory

One of the earliest theories developed to understand learning and cognition was behaviorism. In the early twentieth century, Thorndike proposed the beginning ideas for modern behaviorism. He claimed that learning resulted from making connections between experiences and behaviors (Thorndike, 1913). Thorndike described that behaviors were learned if these connections provided the learner with positive outcomes and would not be learned if the learner was provided with negative outcomes. More specifically, Ivan Pavlov developed classical conditioning, which was a procedure that allowed for teaching experiences and behaviors to be linked. He showed that by associating a neutral object with one that naturally caused some observable behavior, eventually, the neutral object could elicit the same observable behavior as the other object but without its presence (Schunk, 2004). This provided evidence that supported Thorndike's original theory. John B. Watson extended these ideas to apply not only to observable behavior but to emotional state as well through his Little Albert experiment (Watson & Rayner, 1920). An 11-month-old infant, Albert, was classically conditioned to fear rats by associating the presence of a rat with the loud sound of a hammer, which Albert was already afraid of (Schunk,2004). While behaviorism thus far showed that experiences could elicit observable behaviors, these behaviors were considered to be purely physiological in nature. B.F. Skinner was the first to develop modern behaviorism which claimed that experiences could provoke both physiological and psychological behaviors through his theory of operant conditioning (Skinner,1938). Operant conditioning assumes that some experience, or eternal stimulus, can cause some behavior, which may be physiological or psychological, and the strength of these connections depends on the strength of some reinforcing experience (Schunk, 2004).

Behaviorist Implications

In terms of behaviorism, learning and knowledge is behavior(Driscoll, 2005). This means that evidence that students are learning can be obtained through them demonstrating a desired behavior. For example, performance objectives, as outlined by many StateStandards for K-12 education, list specific behaviors that students should be able to complete. A historic performance objective in the Arizona StateHigh School Science Standards from 2009, related to scientific inquiry, once read"PO 2. Develop questions from observations that transition into testable hypotheses" (Arizona Department of Education, 2009).This implies a behaviorist view of knowledge, assuming that learning would be achieved by connecting a stimulus, in this case scientific observations, to some desired behavior, described as developing scientific questions.

For learning to occur, behaviorism suggests that students must undergo behavior modification (Schunk, 2004;Driscoll, 2005). This, as described in operant conditioning, would involve the repetitive pairing of stimulus and response, with appropriate reinforcement. So, students would need many opportunities to practice, so many, that stimulus and behavior could be linked. However, through this process of practice, students must be given appropriate reinforcing cues. For example, in mathematics, students are often assigned tedious amounts of similar problems to practice. This practice is behaviorist in the sense that it allows students to connect that particular problem type (stimulus) to the correct mathematical procedure (behavior). Often, student work is graded where students are praised for good behaviors (correct process and answers) and penalized for poor ones (incorrect processes and answers). Behaviorism suggests that through cycles such as this learning will occur.

Instructors have an important role under a behaviorist lens. They are responsible for maximizing opportunities for students to develop desired connections between stimuli and behavior. But even more importantly, they are responsible for providing necessary reinforcement so that student behavior can be modified in the desired way. Under this lens, curriculum will generally take on a linear stance, in which an underlying goal becomes to maximize efficiency of building stimuli-behavior connections (Callahan,1962). Linearism principles describe educational curriculum as being behavior oriented, systematic, predetermined, and particularized (Callahan,1962). A systematic curriculum would be consistent across the country such that there could be some standard comparison across institutions. This could be achieved through creation of standards for learning, and in this case, a set criterion of stimulus-behavior connections that should be achieved. A predetermined curriculum is one that is determined prior to teaching, and not deviated from. This would mean that a desired set of behaviors, such as performance objectives, would be outlined, and the role of the instructor would be to ensure those behaviors were learned in the specified order and not deviate from them. Particularization calls for learned behaviors to be broken up into well-defined pieces such that they could be easier to learn and assess. Thus, behaviors would need to be organized into an increasing degree of complexity such that the easier stimuli-behavior connections are learned before the more complex ones.

Assessing knowledge from a behaviorist view is simple since learning is exhibited through behavior. Student behavior would just be compared to the desired behavior for some stimulus. If these behaviors were consistent, then evidence of student learning would be achieved. If the behaviors were different, then there would be evidence that additional behavior modification was necessary, and the instructor would need to continue to strengthen the connection between the stimulus and desired response through reinforcement.

Constructivism

Following behaviorism came a wave of ideas about cognition from psychology. It is at this point that theories for cognition and learning become muddy and interrelated. No longer were theories describing identical ideas with similar implications. Instead, various facets of cognition were being examined, but not adding to a holistic view of how students may think and learn. Constructivism, as a result, is not representative of a single theory, but rather a category that describes many theories of learning and cognition that operate under two general assumptions:(1) that learners enter classrooms with prior knowledge and experience about how the world works and (2) that leaners are constructing new knowledge as it somehow interacts with prior knowledge and experience (Driscoll, 2005). To follow, some notable constructivist theories will be addressed below.

Conceptual Change Theory

Often, constructivist theories for learning try to understand how to change students' prior knowledge such that it becomes consistent with scientific theory. To do so, it is common to refer to concepts. Concepts are mentally constructed groupings of objects, thoughts, events, pictures, or symbols that enable learners to organize knowledge by being able to associate additional objects, thoughts, events, pictures, or symbols as either fitting or not fitting to the concept (Howard,1987). But not all concepts are identical or of the same type. Concepts may describe tangible objects (such as a metal wire or a polymer bottle),abstract objects (such as electronegativity or energy), or a variety of additional objects as discussed by Medin, Lynch, and Solomon (2000). From a constructivist perspective, it is assumed that students come into the classroom with a variety of formed concepts (Driver, Asoko, Leach, Mortimer,& Scott, 1994). These preformed concepts, referred to as preconceptions, are created as learners experience and observe phenomena throughout daily life (Sandoval, 1995). Some of these preconceptions maybe consistent with scientific or normative conceptions. However, others,such as the belief that heavier objects fall faster than lighter objects (Halloun & Hestnes, 1985) are non-normative, incorrect beliefs. These non-normative preconceptions can act as barriers to student learning and prevent students from properly conceptualizing new information. When preconceptions hinder student learning or provoke incorrect explanations or predictions of scientific phenomena, they are referred to as misconceptions (Sandoval, 1995).

Posner, Strike, and Hewson (1982) studied how to move a student from an initial concept to a differing concept. In doing so, they came up with four conditions necessary for conceptual change: (1) apparent *dissatisfaction* with the currently held conception, (2) the presence of a new, *intelligible*, conception, (3) the existence of a new, *plausible*, conception, and (4) the ability for a new conception to be *fruitful* (Posner et al.,1982). After revisiting their ideas nearly ten years later, Strike and Posner (1992) returned to make claims about the implications of their previous findings on interpreting student conceptual frameworks. Concepts, they claimed, are not unrelated to other concepts, but instead "they exist in semantic and syntactical relations with one and other so that they are interdependent for their meaning and not readily appraised in isolation"(Strike & Posner, 1992). It is for this reason, they suggested, that misconceptions were so resistant to change. This resistance, according toStrike and Posner (1992), not only sparked thinking about how knowledge was organized in the mind, but also was the underlying research question to be answered by constructivist theories.

To best determine how to elicit and resolve these misconceptions, it is necessary to understand how students are organizing, accessing, and assimilating concepts (diSessa, 2006; Chi, 2008; Strike & Posner, 1992; Taber,2001; Vosniadou & Ioannides, 1998). There are many theoretical explanations that have been offered to represent the organization of student thought, or their conceptual frameworks.

Schema Theory

In studying memory, Bartlett (1932) was said to begin creating the foundation for what is known today as schema theory. He claimed that the purpose of memory is for recollection, assimilation, and acquisition of knowledge and knowledge structures (Bartlett, 1932). Bartlett also studied what caused some information to be remembered and others to be forgotten. In having subjects read a story and reassessing their memory of the story overextended periods of time, he found that most commonly things are remembered (1) that make sense to the reader, fit into her current cognitive structure, and seem relevant, (2) that confuse the reader so much that it creates cognitive dissonance, (3) that are relevant to the reader's social and emotional state at the time of reading, (4) that are consistent with the reader's initial recollection, and (5) that are related to the general order or structure of information within the story (Bartlett, 1932).

Alba and Hasher (1983) extended on Bartlett's work and proposed that memory, and thus knowledge, may be schematic. A schema, they say, isa selection of domain specific knowledge that allows for adding, storing, and recalling knowledge about that specific content area (Alba & Hasher, 1983).They describe the processes of remembering, or learning, as having five necessary processes (1) selection, in which only relevant information from the environment is acknowledged, (2) abstraction, in which the meaning of the information is determined, (3) interpretation, in which prior knowledge which is seen to be relevant is activated to help with understanding of new information, (4) integration, where the memory or piece of knowledge is actually formed, and (5) reconstruction, where the memory of knowledge is reproduced or recalled at a later time (Alba & Hasher, 1983). From this perspective, to achieve correct, precise knowledge, it seems that students must be given opportunities to draw from the correct prior knowledge and information to use it to develop new memories. If appropriate and correct prior knowledge is retrieved, then students will be able to select information appropriately, know what framework and detail is important, connect it with relevant prior knowledge and integrate all of this to create a working, correct schema. Consequently, instruction must be centered on accessing student prior knowledge. And students must be taught to draw upon this prior knowledge so that they are able to consistently engage in the four encoding processes and are able to recognize when there may be a problem in their learning or memory creation.

Theory-Theory

In 1998, Vosniadou and Ioannides proposed the application of what is termed "theory-theory" from psychosocial development to science education. In their model, they propose that conceptual change requires awareness of understanding and the ability to alter prior knowledge and understanding as necessary. This theory presupposes that students use preformed concepts and create coherent theories to explain a particular stimulus of phenomena (Vosniadou & Ioannides, 1998). As a result, this theory implies that learners have built a complex theoretical network to explain the world as they understand it; and if misconceptions exist within the theoretical framework, the theory may become faulty in its explanations of some, or all, of physical phenomena. Conceptual change, under this model requires students to undergo complete theory revision.

In an extensive review of science misconception literature, Chinnand Brewer (1993) found that students are often reluctant to change their incorrect preconceptions and replace them with more normative views. Throughout their reading, they found patterns by which students responded to anomalous data, or data inconsistent with preconceptions or theoretical frameworks. It was found that students come to terms with anomalous data in one of seven different ways: (1) ignore the data as if it were never presented; (2) reject the data by "explaining it away"; (3) exclude the data, claiming it is not relevant to segment of their theory at hand; (4) hold the data in abeyance to be dealt with in the future so as to not change any part of their theory; (5) reinterpret data to make it fit or be explained by their theory, which will remain unchanged; (6) reinterpret data and make minor changes to implications of their theory, yet still retain the theory itself; and (7) accept data, abandon or revise their theory, and create new concept necessary to accommodate the data (Chinn & Brewer, 1993). From their findings, it can be seen that of the seven possible responses to data incongruent with theoretical frameworks, only two involve any change at all to the original theory itself. Chinn and Brewer suggested that different presentations of anomalous data may predict the chosen response. This hints at the importance of how students are presented with material that may possibly be misaligned with their previously held notions.

Knowledge in Pieces

In contrast to theory-theory, the idea of "knowledge in pieces" argues that student knowledge is fragmented (diSessa, 2006;Purzer, Krause, & Kelly, 2009). While diSessa and Minstrell, early proponents of fragmented knowledge, agreed that knowledge was constructed, they argued that prior ideas were more helpful than they were problematic (diSessa,2006). Minstrell compared preformed ideas to threads of fabric, claiming that inconsistencies occurred when threads were woven together to produce anon-normative conceptual fabric, or misconception, but simply needed re-weaving to produce a fabric more consistent with normative models (diSessa, 2006). This was in great contrast to theory-theory which recommended a reorganization of the entire conceptual framework at the existence of a misconception.

Instruction under a fragmented knowledge lens would involve providing students with enough appropriate experiences so that they could practice activating appropriate pieces of knowledge to explain and predict appropriate situations or phenomena. From this, students would be able to start learning patterns of how varies fragments of knowledge could work together to describe the world and how it works. However, students may have difficulty understanding phenomena over and above those examples used in an instructional setting. To aid students in transferring their knowledge, a diverse and substantial set of examples and situations must be presented.

Ontological Categorization

In contrast to theory-theory and fragmented knowledge, is an additional theory of conceptual change referencing students' ontologies (Purzeret. al., 2009). Chi's theory describes that students categorize concepts to best make sense of them. Chi (2008) claims that students create categories of concepts based on entities, processes, and mental states and that misconceptions occur as a result of the improper categorization of these concepts based on the mentioned ontological properties by which they are categorized (Chi, 2008). In order for misconceptions to be addressed and conceptual change to occur, Chi (2008) identifies three possibilities: (1) belief revision, in which a student modifies a single idea, (2) mental model transformation, in which a learner experiences multiple belief revisions and, as a result, changes the entire concept, including all ideas associated with it and (3) categorical shift, in which a student realizes that the concept, or misconception, must be placed in a different, or new, ontological category.

For students to be able to have ontological or categorical shift, they must first be aware that objects can be categorized ontologically. Many students may have never thought about objects being classified this way before. Thus, for optimum knowledge construction, students must be taught not only knowledge, but about the nature of knowledge, or epistemology, and how to monitor their knowledge and epistemological beliefs throughout the learning process.

General Constructivist Implications

While each of the constructivist theories may have specific or unique implications, as a whole, there are some general implications that are associated with the underlying assumptions of constructivist theory. Recall those assumptions being that students come to the classroom with prior knowledge and that they build upon that prior knowledge as they learn new information. Asa result, if operating under a constructivist lens, it becomes imperative to assess what knowledge students enter an instructional setting with and assess their knowledge again to monitor the knowledge constructing process.

Concept inventories, created under a constructivist view, were developed to measure conceptual understanding. They allow instructors to be able to quantitatively determine the degree to which students construct normative concepts by comparing student scores prior to and following instruction. However, they also give a qualitative description of students' prior knowledge so that instructors can have a clear picture of what ideas students bring into the classroom. Concept inventories measure this conceptual understanding by probing, through multiple choice questions, for conceptual coherence rather than procedural ability (Jenkins, 2004). To answer each question, students must use conceptual knowledge to decide on a response appropriate for the scenario. Correct choices represent a concept consistent with a normative view while incorrect choices represent anon-normative view. It is irrelevant weather students answer choice is done by accessing part of a cohesive theoretical framework as predicted by theory-theory, weaving together strands of fragmented knowledge as suggested by a knowledge in pieces perspective, or drawing from different categories as suggested by an ontological lens. Concept inventories measure how students' preconceptions (and possibly misconceptions) compare to their understanding at a future time giving the power to determine the degree of knowledge construction, or learning. Recent literature has suggested that emotion and affect play a role in knowledge construction (Dole and Sinatra, 2005). However, the mechanisms and connections are still being explored throughout the educational community (Linnenbrink, 2008; Dweck & Mangels,2004; Kazyn & Kuhl, 2005; Moons & Mackie, 2007; Pugh & Bergin,2006; Elliot & Dweck, 2005; Turner & Patrick, 2008; Fugate, Gouzoules,& Barrett 2009).

It is important to distinguish how assessing knowledge under a constructivist lens differs from doing so under a behaviorist lens. Behaviorism, assuming knowledge to be some desired behavioral response to a stimulus, would assess knowledge by seeing if the desired behavioral response is achieved. This would call for assessments to be procedural in nature as procedures that students may engage in are indicative of learned behaviors, and, under that lens, knowledge. However, under a constructivist lens, learning requires building upon prior knowledge to create additional normative knowledge. Assessment, as a result, will require more than procedure. It will require that students demonstrate why or how they came about an answer. Assessing student knowledge would mean probing for evidence that they could draw upon prior knowledge and use new information to extend it towards more sophisticated knowledge. Let's revisit the previous performance objective, "PO 2. Develop questions from observations that transition into testable hypotheses" (Arizona Department of Education, 2009). Evidence of student learning under a behaviorist lens would be the actual questions that students developed. However, evidence of learning under a constructivist lens would be the development of the questions along with an explanation of how the questions were derived from the observations based on an understanding of the actual observations, prior experience with similar situations, and an understanding of what makes a strong question and hypothesis.

Social Constructivism

Extending Past Constructivism

Vygotsky (1986) placed heavy weight on the importance of social interactions for cognitive development. He argued that actions that could be performed in the presence of others would eventually be able to be performed alone. Because he added a requirement of social interaction to constructivism for learning to occur, his theory was deemed social constructivism. In this idea, he theorized that in a social environment, students would be brought up to the highest social level present. For example, if a social environment was comprised of a low performing student and an average student, the low performing student would have the potential to beat the same understanding level as the average student after the interaction was over. These experiences, to Vygotsky, were invaluable because they allowed for the opportunity of peers to negotiate content meaning, increasing their critical thinking and reasoning skills. But, as implied, the knowledge level of each student must be known to ensure that she is paired with peers of appropriate levels. Vygotsky's idea, of which he is most well-known for, to ensure proper instructional levels is known as the zone of proximal development (ZPD). If the instructional level (or social interaction) is too advanced for the student, it will not be effective. Also, if it is too low, it will not be effective in bringing the student to a higher level. He explains the ZPD as the target level for instruction and interaction.

Implications of Social Constructivism

Under social constructivism, in order to advance conceptually, students must have the ability to socially interact with others. This may be in the form of peer-to-peer interactions or teacher-to-peer interactions. But it is the exchanging of ideas that facilitates learning. Students must be able to vocalize and interact with others. The implementation of this idea is most obvious through the use of teamwork and team-based learning. While working in teams, students have the ability to work through ideas, concepts, challenges, or problems together. In doing so, they are consistently exchanging ideas and knowledge. This allows for the team to advance together. And with the help of the teacher, social interaction has the potential for allowing students to greatly expand their intelligence. However, for this to be effective, the instructor must be aware of each student's ZPD. To do this, student thought must be elicited to gain insight into student reasoning. Because social constructivism adds to how students construct knowledge, assessing student knowledge under social constructivism is similar to doing so under the constructivist lens. However, as a result of the importance of how thought and language are linked, assessing student domain specific language proficiency should be done as well.

Situated Cognition

In the situated cognition model, learning does not occur entirely in the mind. Instead, it is situated and occurs between objects, people, and artifacts in any given environment (Brown, Collins, & Duguid, 1989). Knowledge is considered the proper use of some tool within a setting within a social group. As a result, knowledge changes based on environment, and is stored between situations rather than in the mind. Under a situated cognition mode, the role of tools, or inscriptions, in learning differs depending on if we are examining the learner as an individual or the learners as a social group (Hutchins & Palen, 1997). For the individual, inscriptions can be used to aid with conceptual offloading. Because inscriptions carry transferable meaning, learners can use them to store knowledge and "free up" space in the mind. For example, a graph allows a learner to store knowledge about some relationship externally so that she can use space in the mind to interpret it, work on something else, or consider its implications. For the group, inscriptions are used as a tool for sharing knowledge which might coordinate activities, translate information, articulate knowledge, or convey some generalized meaning. Under this model, misuse or lack of proficiency with some representation of knowledge results from lack of experience rather than cognitive difficulty (Hutchins & Palen, 1997). As a result, students need meaningful and contextualized opportunities to practice with tools.

As an instructor, operating under the situated cognition model, it must be goal to create a meaningful learning environment. Interactions, tools, discussions, and references must be for well thought out purposes in order to create the type of knowledge desired in the environment. Here, student affective state can affect the entire group's learning experience as her not engaging, or feeling sad, will surely change the environment, thus changing the knowledge that will be created. The main role of the instructor is to facilitate this environment. Additionally, learning must be multi-layered (Hutchins & Palen, 1997). Knowledge must occur in multiple modes or representations. This, however, must occur on two levels. First, students must be taught via multiple modes such as physical layouts, graphical outputs (in reference to actual mathematical graphs), diagrammatical representations (like sketches or drawings), verbal representations, kinesthetic representations (gestures or some movement), written representations, and analytical representations (like math or arithmetic models). Second, students must be encouraged to express knowledge through all these modes when working through tasks as a class community. By doing this, we can create a "multi-layered" learning environment which will more closely mimic real-world decision making and problem solving.

Assessment under a situated cognition model aims to provide evidence that students can utilize tools in specific ways within a community setting. As a result, assessments would be conducted for communities as a whole in a specific setting rather than for individuals.This results because knowledge is considered to occur between tools, the individual, and the community, not in the mind. So, to assess knowledge, tools, individuals, and the community must be given chances to interact. Individual assessments do not make sense under this model, as that would not be assessing knowledge as defined by situated cognition. Because knowledge is not in the mind or owned by an individual, individual grades could not be assigned as they are now. The practice of ranking individuals or schools would be inappropriate. Also, because knowledge is fluid due to its dependency on both the physical and social environment, assessment of it one day may differ greatly from that on another day.

Summary and Conclusion

There are many models of cognition aimed at explaining and predicting psychological processes and how we learn. Behaviorism defines knowledge as being a desired response to a stimulus. Learning, from a behaviorist perspective, involves receiving appropriate reinforcement to strengthen the behavior-stimulus connection. Constructivism, in its many forms, defines knowledge as the ability to make connections between new information and previous knowledge to explain phenomena. Learning, from a constructivist perspective, involves activating prior knowledge and using it to help construct new knowledge. Social constructivism defines knowledge just as constructivism but with an additional requirement for effective communication of ideas. Learning, under a social constructivist perspective, occurs as groups socially construct meaning by negotiating content and working within one's zone of proximal development. Situated cognition defines knowledge as being outside the mind and between tools, individuals, and social settings. Learning, under the situated cognition model, requires practice and discourse between communities within various settings with various tools.

Each cognition model carries with it distinct implications for teaching and assessment. And, because none are said to be incorrect or completely refuted, many practitioners and researchers operate under different models, holding to the different assumptions associated with each and coming up with varying implications from each. Educational research operating under varying models will, without a doubt, draw very different conclusions and implications. And these differing implications are passed on to practitioners of the field: instructors and teachers. Implied classroom instruction under each of these models would look very different, ranging from a quiet row of students to a seemingly chaotic environment with constantly varying tools and discussions. It is contrary to the nature of science to claim that there should be one model and all others discounted. And, with the nature of educational research, it would be improbable to find the appropriate evidence needed to do so. This makes it imperative that as educational researchers we are explicit about the models that we use to drive our research.

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