A THEORETICAL FOUNDATION FOR DISCOVERY LEARNING

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The processes of discovery learning are well grounded in current theories of learning. This article describes how cognitive learning theory supports the components of the discovery learning model. Three main characteristics of discovery learning that relate it to cognitive theory are 1) an emphasis on active learning, 2) the development of meaningful learning, and 3) the capacity to change attitudes and values toward the subject and the self as problem solver.

The Learning Theory Behind Discovery Learning

There is a great deal of research to support the idea that active learning is the most effective way to ensure thorough initial learning and long-term retention of materials as well as the development of attitudes. What follows is just a brief look at some of the key ideas about learning and motivation that are represented in instruction based on active discovery.

The overall theory underlying this method is the cognitive model of learning, which focuses on what goes on in the mind of the learner as new information is acquired. According to this model, the primary purpose in learning is to incorporate new information into an already existing network of associations that the learner has. This is done by creating new networks or reorganizing old networks to accommodate the new information. To do this, the learner is constantly monitoring new information and checking in memory for related ideas to make connections. If no related ideas exist, new but very tenuous networks are formed using whatever links to prior knowledge can be made. With repeated use, these new networks are strengthened and elaborated until they become well connected.
integrated into the learner's long-term memory and world view.

In this model, instruction sets the stage for this strengthening or creating of networks. During instruction the learner's attention needs to be focused on the critical information. Connections to prior knowledge are either pointed out by the instructor or discovered by the student. Consistencies in organization are marked, examples and analogies are used to enrich the network, and, finally, the new or revised network is tested through a variety of retrieval opportunities. If the learner finds that responses based on the network structure are correct, the organization stays. If not, the learner searches for a new, more accurate structure. During this entire process, the learner should also be aware of how he or she is making decisions about understanding and correctness of his or her associations. This latter process is called metacognition and represents a level of self-awareness about learning that we hope to foster in students.

The above description of cognitive theory can be expanded by focusing on the following characteristics of learning that are evident in discovery learning.

**ACTIVE LEARNING**

A key concept in the above model is the idea of active learning. The learner is an active participant in the process of learning rather than an empty vessel to be filled by the instructor. Discovery methods all involve some form of active participation on the part of the learner. Active learning produces the following benefits.

While you are actively participating, you are paying more attention to your learning in general. Learning cannot take place if there is not at least some level of attention by the learner. It is easy to let your mind wander when you are just an observer in class. Active participation forces at least a minimum of attention to the task to be able to respond appropriately.

Activities focus your attention on the key ideas that are being examined. Activities are usually designed to illustrate a concept or process rather than just for the sake of doing something active. The first step in any learning is figuring out what needs to be learned and focusing your attention on it. Active learning increases the probability that you are focusing on the key material and not on irrelevancies that may be present and distracting.

Active involvement forces you to construct a response, as is the case in essay questions or problem solutions, and this results in deeper processing of information. During active learning, you are required to draw on your prior knowledge to construct your response to the activity. This results in deeper processing of the material. Deeper processing means looking at the material beyond mere memorization. Information that is processed deeply is more easily recalled later because it has more connections with your specific prior knowledge.

Active participation provides you an opportunity to get early feedback on your understanding. Too often, instruction continues at the instructor's pace with little concern about or information about whether you, the learner, are "getting it." When you are actively involved in solving problems, gaps in your understanding cannot be ignored. Feedback occurs from the task itself: you are successful or you are not. The instructor also can be the source of feedback after reviewing your progress during the task. The instructor is confronted with direct evidence of student understanding in time to do something about it.

Active learning opportunities result in an "episodic memory," which is a type of memory specific to an event. With episodic memory, if you cannot remember the idea, you can reconstruct it from your memory of the event. Episodic memories are particularly long lasting and can serve as the key to the recall of information. For example, if you cannot remember someone's name, you can often remember when you first met, and that in turn can bring the name back. Likewise, when you participate in an activity, that event becomes a memory that is very concrete and meaningful to the learner and forms the basis of the episodic memory. Later, when you are trying to remember some concept, you might be able to recall the activity that was used to illustrate the concept and from there reconstruct what you know about the concept.
Active participation is often very motivating. Most active learning involves solving a puzzle of some sort. The curiosity aspect of an unknown along with the pleasure of resolving it are both basic forms of motivation. The control over your environment that you feel in active participation is also another basic motivational source. Just the increased activity level results in a higher level of arousal, which translates into motivation to continue.

MEANINGFUL LEARNING

A second key to the success of discovery learning is that it is more meaningful to the learner than information simply received from someone else. When the learner is actively involved in problem solving, the connections made and the organization imposed are based on his or her own prior knowledge rather than someone else's. Because the connections are the learner's, they are already more meaningful than an artificially imposed connection.

Discovery learning is more meaningful because it makes use of your own personal associations as a basis for understanding. Being able to parrot back the instructor's version of a concept is not as good a strategy for learning as being able to put the concept in your own words using your own examples. When you can do the latter, you will have more ways of accessing a given bit of information than if you simply memorized it because you are using already-existing and usually strong memory networks. Those are networks to which you have ready access. Incorporating new information into those networks allows you to use all the network's retrieval cues to get back the new information when you need it.

Discovery learning results in greater meaning because of the deeper processing of information in which you figure out the process rather than just following directions. As noted earlier, deep processing of material results in better retention. In discovery learning the problem situation results in a solution unique to the learner, which will ultimately be easier to reconstruct.

Discovery learning forces you to confront your current ideas about a topic, many of which may be misconceptions, and reconcile them with what you now observe to be the case. In science education one of the hardest problems is the problem of misconceptions that students bring into the classroom. Unless these are confronted directly for each student, it is easy for the learner to not see the contradictions. Simply hearing someone refute a misconception is not as powerful as having the evidence as a result of your own manipulation of the environment. In addition, many instructors forget to address common student misconceptions because their own understanding of the subject is so great that they forget how a novice might think about it.

Discovery learning is more concrete and therefore easier for beginners in a field to understand. Most discovery tasks are based on real problems or real situations. Their "concrete" nature makes them easier to visualize and relate to. Because you are able to see the principles actually at work, you have a better way of picturing what is happening with an idea. Abstractions require a great deal more background for you to mentally manipulate them. This is particularly evident in beginners in a field. Without a strong background in a field, you tend to revert to an earlier level of conceptualizing, in this case, a level of Piagetian development called "concrete operations." Just as children ("beginners" in life) have difficulty dealing with abstractions until they get older, beginners in any field will have difficulty mentally manipulating abstractions; they need to be more concrete in their thinking. At this level, learners need concrete examples of concepts to use as initial organizers until they have sufficient examples to create an abstract concept or prototype of the concept.

Discovery learning in general occurs in a context that is similar to the eventual contexts of use, which helps you learn when to use information as well as what to do. This is the concept of authentic retrieval cues based on situated learning. Many times you can learn information devoid of context; this is referred to as "inert" knowledge. Later on, you fail to recognize an opportunity to use that information because of that lack of context. Because discovery learning is intended to be done in a "real life" context, you learn the context along with the information. This situation is called situated learning because what is learned is not just the information, but the situation. Later, when that context or a similar one appears, you have a greater chance of remembering what to do because
you have already been through it once and the authentic retrieval cues present in the situation flag it as appropriate for this information use.

In discovery learning, the value of the information is clearer. Too much of what you learn in school settings seems to have no connection to the "real world" and is therefore not very clear or very motivating. Because discovery learning presents concepts in a context of use, it is easier for you to see how it will eventually be used, and that increases the value of the concepts for you as a learner.

Discovery learning encourages you to question and solve problems without expecting someone else to give you the answer; the result is that you develop much more confidence in your ability to handle problems in this area, which in turn encourages you to go further. It is particularly true in science that learners often feel "disenfranchised" or helpless in the face of even simple science problems. They have no confidence in their own abilities because science has always been presented as true facts that have been discovered already by someone who knew what they were doing. In discovery learning, you learn that you can ask good questions and reason out good answers in what seems to be a very complex field. Success in doing this increases your confidence in your own abilities, and it is only natural to continue in a field of study in which you have been successful.

CHANGES IN BELIEFS AND ATTITUDES

The previous item segues into this area of values, by which is meant a change in the way students think about advanced knowledge and their ability to conquer it.

Discovery learning supports the belief that understanding can be constructed by you rather than received from a higher authority. Science progress is often made because someone felt the need to test what authorities said was true. Yet, we present science through authoritative texts and lectures that perpetuate the belief on the part of students that science is a set of proven facts to be learned. Discovery learning replicates the original situation in which someone saw something interesting and tried to figure out what it was or in which someone was willing to question received truth.

Discovery learning supports the attitude that science is a process, not a set of facts. Most instructors in science believe that the most important thing students can learn in a class is how to look rather than what to see. However, classes are seldom constructed to allow the students to observe real science in action and to try it themselves. Discovery learning is designed to provide that opportunity and to teach the steps in the process itself.

Discovery learning places much of the responsibility for learning on the learner. It is too easy in a standard lecture/lab structure to expect the instructor to "teach" rather than the student to "learn." When you are placed in the position of having to figure out a problem, you have much more responsibility to take charge of your own learning. In the long run this is much better than having to depend on someone else.

What is presented above is, of course, the theory behind discovery learning, but the research into the use of this class of instructional methods indicates that students can learn to function at a higher level when given appropriate opportunities. College students solve real-life problems every day without the need for an instructor telling them what to choose. Discovery learning brings that experience to bear on academic learning in hopes of drawing them into the community of scholarship that a college education should represent.

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SUGGESTED READINGS ON LEARNING THEORY