Sabbatical Mini-Report #6:
Learning Theories Overview

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Impossible. It is just not possible to provide a helpful review of general learning theories. Instead, this report will briefly review some general references (books and online pages) in the field, and then review two learning theories which are commonly applied to mathematics.

BOOK REVIEW (general)

These appear in the order in which they were read, which has no other meaning. All books can be obtained by using the "MelCat" link on the library web page.

Goldstein, E. Bruce	Cognitive psychology : connecting mind, research, and everyday experience	2005	Wadsworth

This was the best single source for information. Of particular interest to me were notes on "elaborative rehearsal" versus "maintenance rehearsal" (pg 217), and the fact that letters are identified more quickly as a part of a word (pg 350-351). [Do students see 'words' when they read algebraic statements?]

Speelman, Craig P and Kirsner, Kim	Beyond the Learning Curve: The Construction of the mind	2005	Oxford University Press

Provides practical information. In particular, this book describes the "ACT-R" theory, which is reviewed below.

Kinchloe, Joe L (ed)	Multiple Intelligences Reconsidered	2004	Peter Lang Publishing

This book looks at the validity of Gardner's "Multiple Intelligences", essentially concluding that they represent a philosophical statement (as opposed to learning theory) and have led to some mixed results when implemented. Overall, the authors do not appear to support the basic notions of 'multiple intelligences'. [A particular problem is the association of 'mathematics' with 'logic'; many other authors discuss the negative consequences of this association.]

Bruning, Roger; Schraw, Gregory; Norby, Monica; Ronning, Royce	Cognitive Psychology and Instruction, 4th edition	2003	Pearson

A very helpful source, with research interpreted in a way that makes sense to teachers. One interesting note from this book is that "goal-free problems" (no context) reduce cognitive load, which helps learners develop skills (pg 220).

Campbell, Jamie	Handbook of Mathematical Cognition	2005	Psychology Press (Taylor & Francis)

This book specifically applies learning theories to mathematics, and incorporates other issues – such as race and culture. A good source.

Constas, Mark; Sternberg, Robert (ed)	Translating Theory and Research into Educational Practice	2006	Lawrence Erlbaum Associates

Not as helpful as the prior book; however, the chapter by Slavin provides good information on cooperative learning.

Berliner, David; Calfee, Robert (ed)	Handbook of Educational Psychology	1996	Simon & Schuster

This is an older book, mostly helpful for the chapter by Webb on group learning situations.

Sternberg, Robert; Preiss, David (editors)	Intelligence and Technology: The Impact of Tools on the Nature and Development of Human Abilities	2005	Lawrence Erlbaum Associates

A good source for analyzing the interaction between tools (technology) and intelligence (more general than just learning).

Sawyer, R. Keith (ed)	The Cambridge Handbook of the Learning Sciences	2006	Cambridge University Press

A broad collection of chapters on various themes; you might want to check out the chapters by Scardamalia & Bereite ("Knowledge Building") and Seymour Papert ("After How Comes What").

Houghton, George	Connectionist Models in Cognitive Psychology	2005	Psychology Press (Taylor & Francis)

This is a more technical book, for those who want all the neuron details.

ONLINE SOURCES

Pohl, Michael	Bloom's Revised Taxonomy	2000	http://eprentice.sdsu.edu/J03OJ/miles/Bloomtaxonomy(revised)1.htm

Bloom's Taxonomy: The original was designed for use with elementary school learning outcomes. The updated model is better suited for secondary and tertiary (college) usage; the updated model was done by Lorin Anderson, a former student of Bloom.

Bereiter, Carl	Our Oldest Unchallenged Folk Theory	2002	http://ikit.org/fulltext/edmind/chapter1.pdf

More of a philosophical approach; however, does manage to talk about some learning theories along the way.

TWO LEARNING THEORIES IN MORE DETAIL

Before going in to detail, note that a "learning theory" is not simply some statements about how people learn. A learning theory needs to provide specific predictive statements (given various conditions) and needs to have a "falsibility". "Falsibility" refers to a property that a theory could possibly be proven to be false. One of the most common 'isms' in education is "constructivism"; researchers usually look at constructivism as a philosophy, not a learning theory (it doesn't provide predictions, and does not appear to have falsibility.) However, constructivism has been so influential that it will be the subject of its own report.

Some people connect "learning styles" to learning theory. Most researchers would talk about "learning skills" or "learning capabilities", instead of styles. In other words, "learning styles" is a descriptive (metaphorical) approach; consequently, designing instruction based on these metaphors (learning styles) might be helpful in the short-term … however, just as for metaphors within mathematics, the instructional design needs to be based on the direct objects (learning theory); the metaphors can limit, or even mislead, our work unless we become more abstract and general. [See the Kinchloe book described.]

The two learning theories covered here are: ACT-R and APOS, both of which are frequently applied to the learning of mathematics.

ACT-R Adaptive Control of Thought–Rational (primary originator: John Anderson)
This theory is a rule-based system with a strong research base. The components of ACT-R are:

Interface Modules (dealing with perception and processing perceptual information)

Memory Modules (types: declarative (facts, recall) and procedural (actions))

Buffers (providing a mechanism to access interface and declarative modules)

Pattern Matcher (deals with information in the buffers, connects with procedural modules)

The pattern matcher is modeled by "If … Then …" statements. If multiple matches are made, ACT-R provides a conflict resolution routine. ACT-R is an operational theory – meaning that you can download a software package that can be applied to particular content (if you have enough time). Much of the theoretical work in ACT-R is stated mathematically.

There are literally hundreds of documents on ACT-R located on its website; here is the link to an 'about' page:

http://act-r.psy.cmu.edu/about/

A technical description of the model (as of 2004) is at http://act-r.psy.cmu.edu/publications/pubinfo.php?id=526. If you would like to look at the conflict resolution technical information, see http://act-r.psy.cmu.edu/papers/413/rvb-esm03.pdf .

The ACT-R theory and model have been under development for almost 30 years, in various forms; the "R" (rational") was added to the model in the late 1990's to account for the handling of uncertainty. (Originally, the model was "ACT Atomic Components of Thought; both names are still seen in use for the theory.) The psychology department at Carnegie Mellon University hosts a separate web site (http://act-r.psy.cmu.edu), and hosts annual workshops; the theory is also used by numerous other researchers internationally.

If you think about the components of ACT-R, you might notice that the theory connects well to mathematics. In fact, the most common research domain for ACT-R is mathematics. The theory has been applied in "Cognitive Tutors", with positive results.

ACT-R is a very strong theory; it accurately predicts learning in the domains where it has been applied. The only criticism I have found of this theory is that it does not provide a complete model of the human brain. However, this is not much of a criticism for a learning theory – a learning theory does not need to model the brain completely, only enough to predict learning. (There obviously is more to the human brain than learning.)

For one review of the validity of this theory, see this link:

Rutledge-Taylor, Matthew	Can ACT-R Realize "Newell's Dream"?	2005	http://www.psych.unito.it/csc/cogsci05/frame/talk/f706-rutledgetaylor.pdf

As a teacher, the main problem is ACT-R is application. The system is so detailed that there is no "quick application"; the theory needs to be studied in some detail before applying it to the classroom (instruction or curriculum). The quickest way to use ACT-R is to use a Cognitive Tutor, which is exactly what a number of schools are doing (in mathematics particularly).

APOS Action-Process-Object-Schema (primary originator: Ed Dubinsky)
This theory attempts to describe learning from a constructivist view. The words in the name of the theory (Action … Process … Object … Schema) come from the sequence in this description. The idea is that learning starts with an action in the environment, which the brain models with a process; these processes, in turn, become an object of thinking. The final stage is the connection of objects into schemas, where linkages are made.

The primary web site for APOS is http://www.cs.gsu.edu/~rumec/

APOS was developed to research the learning of undergraduate mathematics. A good source for details of the APOS theory can be found in this chapter:

Meel, David	Models and Theories of Mathematical Understanding: Comparing Pirie and Kierne's Model of the Growth of Mathematical Understanding and APOS Theory	2003	in Research in Collegiate Mathematics Education V (edited by Seldon)

A problem with APOS theory is that the primary researchers are all connected to the originator, in general; few others have adopted this theory for research. Some of the other researchers who have looked at APOS have discovered problems with its predictions. For example, see these sources:

Tall, David	Reflections on APOS theory in Elementary and Advanced Mathematical Thinking	1999	http://www.warwick.ac.uk/staff/David.Tall/pdfs/dot1999c-apos-in-amt-pme.pdf
Bayazit, Ibrahim; Gray, Eddie	Understanding Inverse Functions:The Relationship Between Teaching Practice And Studentlearning	2004	http://www.emis.de/proceedings/PME28/RR/RR199_Bayazit.pdf
Herman, Jan; et al	Images Of Fractions As Processes And Images Of Fractions In Processes	2004	http://www.emis.de/proceedings/PME28/RR/RR024_Sulista.pdf

The most common issue seems to be the transition from “process” to “object”, which is a critical stage for this theory; research is showing that learners may not show the ‘object’ stage as predicted by the theory.

APOS theory has, therefore, not been validated. After an initial surge of interest in the early 1990’s, relatively little seems to be happening with this theory.