Research on Student Thought Processes During Computer-Based Instruction

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It wasn't many years ago that a journal with the stature of *JID* would have refused an articles that promised to review research on *thinking*. Until recently, strong behaviorist biases have greatly influenced decisions about what is acceptable, both in journal articles and in instruction. Generally, behaviorism has been a positive force in instructional development. Most of our tested, robust instructional methods have been derived from behaviorist principles. Those principles reflect an emphasis on research that examines how instructional variables such as reinforcement, feedback, practice, and measureable objectives *directly* contribute to student achievement. In contrast, research on thought processes examines how instructional presentations influence what students think, believe, and feel and how those thoughts in turn influence achievement. This cognitive research adds another link to the chain of constructs that connect instruction and student cognition. The second link is between student cognition and learning or performance. The distinctive characteristic of cognitive research is the idea that instruction influences achievement through student thought processes. That is, instruction influences thinking and in turn thinking influences learning and performance. The cognitive approach therefore assumes that instruction is *mediated* by student thought processes.

What follows is a brief sampling of cognitive research in the areas of motivation, computer effects, learner control, instructional methods, left brain, right brain effects, and anxiety. These capsule status reports on each research area are frankly offered to encourage design professionals to consider cognitive views. Since space is limited and these summaries skip over complexities, the reader is encouraged to follow up the citations provided before using these limited generalizations in instructional design. Each section begins with an attempt to summarize the most defensible conclusion of current research and thinking about the area. However, the reader is cautioned that other views exist; compelling alternatives are indicated by citations.

1. The motivation or effort students invest in computer-based instruction depends, in large measure, on their beliefs about how difficult it is to learn from computers. Beliefs that computers are either very easy or very difficult may result in less persistence at learning tasks.

Behaviorist views of motivation linked increased persistence at a task with reinforcement. It was probably Julian Rotter (1966) who first documented the fact that many human subjects in experiments did not persist when reinforced. He attributed to them an external locus of control of reinforcement and suggested that these externals did not notice reinforcement since they were fatalistically unconcerned with the effects of their own learning strategies. External learners believe that chance or fate governed their performance and reinforcement was viewed as arbitrary. Only "internals" persisted with reinforcement, which they take to be evidence for the efficacy (success or failure) of their efforts to learn.

Salomon (1983) has been responsible for applying a cognitive model of motivation to understanding the student thinking process that influences the effort spent on CBI. He has claimed that persistence at instruction depends, in part, on the students' judgement about how *difficult* it will be to learn from media such as television or computers. The relationship that Salomon proposes between difficulty beliefs and effort invested follows the classical, arousal theory "inverted U" shape. That is, learners will invest relatively less effort when they believe that computers are moderately difficult. Salomon describes this phenomenon in a model which hypothesizes a relationship between variables he lables "PDC" (Perceived Demand Characteristics—of the medium) and "AIME" (Amount of Invested Mental Effort). One could interpret Salomon's model and data to suggest that CBI may fare better than television as an instructional medium since many students attribute difficulty to learning from computers but tend to think of television as "shallow" and easy.

Another sense in which beliefs about computers influence motivation can be found in the literature on the social psychology of instruction. Hess and Tenezakis (in Clark, 1983) reported that Mexican-American, low SES middle school students liked remedial CBI math better than teacher presented math because they believed the computer to be more fair. Presumably, they perceived that the computer gave consistently accurate feedback whereas teachers occasionally were making decisions based on student heritage. The positive attitudes towards CBI translated into increased persistence and helped increase their scores on math tests over other instructional options. This was true even though the same students thought that teachers were more flexible and responsive to student wishes to change the direction or content of instruction.

Clark (1983) has reviewed other attitude and belief studies that suggest a relationship between teacher attitudes towards CBI and their attitudes towards science and mathematics. There is some evidence that, if teachers dislike science and math, they will also dislike CBI.

It is important to keep in mind that beliefs about computers are more or less arbitrary and changeable. In a research sense, beliefs are learner variables, not instructional variables. If we find a relationship between beliefs and effort, the presumed cause is not the computer but the student's belief. We therefore cannot conclude for example, that Hess and Tenezakis found out something about the influence of computers on motivation. We may only conclude that the typical relationship between perceived demand and effort may also influence the effort students will spend on CBI.

2. All learning benefits that are attributed to computer-based instruction are readily available from other media. Analysis of computer instruction research indicates that they have no new or unique qualities that cause changes in student learning.

CBI is such a new and compelling instructional tool that most designers are curious about its potential to make a unique contribution to learning and performance. There are also many research and evaluation studies that show large learning gains from computers when CBI is compared to other media such as live teachers, textbooks, television, and audio-tutorial media. What makes the problem confusing is that there are many other studies which just as clearly demonstrate that these other media are superior to computers. Advocates from one or another medium can always find evidence for their point of view but the objective observer has had difficulty sifting among conflicting claims.

Cognitively oriented researchers have viewed the problem from the student's perspective. What, they ask, would be the impact on student cognitive learning processes as a result of the use of computer versus some other medium? In every case, it seems that computer features which might influence cognition are available from some other medium, often easily available. Therefore, it is impossible to speak of *unique* contributions to learning from computers (cf. Clark & Salomon, in press). Why then do so many studies indicate that CBI leads to greater achievement than other media? Recent meta-analytic studies provide some of the answer. In meta-analyses of hundreds of CBI studies, there is clear evidence of consistent confounding in the research (Clark, 1983).

It seems that when CBI is found to promote more learning than some other medium (e.g., classroom-based, teacher-centered instruction), closer inspection of the studies show that some other factor probably caused the learning gains. The most powerful other factor that is seldom controlled in these studies is a greater effort to design the CBI presentation than its competitor. This greater effort probably results in more effective instructional methods being used in the CBI presentation. When the same methods and content are employed by all media being compared, there are no significant learning advantages found for CBI.

This lack of a learning gain from CBI use is particularly evident when long-term studies are reviewed. In shorter term observations (three and four weeks) students seem more motivated to invest more effort and learn more because the CBI experience is novel and exciting. As with all former media, however, the novelty wears off after a few weeks and learning benefits diminish.

One of the most obvious lessons from this comparative research is that learning gains come from adequate instructional design theory and practice, not from the medium used to deliver instruction. It is also important to note that there may be cost benefits and student enjoyment advantages to using computers for instructional purposes even though they do not contribute to unique learning gains.

There are and will continue to be disputes about the role of computers and other media in directly influencing learning. A particularly interesting expansion of the cognitive point of view on this issue is offered by Salomon and Gardner (1984).

3. When computer based instruction offers "menus" of learner and system controlled study aids, students may learn less from the options they like the most. This may be most true for students at the extreme ends of the ability scale.

One of the advantages of CBI is its potential to easily offer instructional support to students on demand. This "student assigned " (Rigney, 1980) capacity of CBI is used in many contemporary software programs and is a feature suggested to new CBI designers. And yet, the research evidence shows that CBI support menus have very mixed learning consequences. Clark (1982), in a review of aptitude-treatment interaction (ATI) studies on the issue, offered a cognitively-based explanation for the mixed results. He found that high general ability students typically seek high support during learning when they are offered a choice. Higher support often means additional examples, practice exercises, organizational strategies, self-testing, and study strategies. Yet, these same high ability students learned much less with high support than they did when left more on their own. Conversely, lower ability students tended to prefer less support in the form of self-paced, "discovery" instructional options.

Here again it was an analysis of student thinking that provided an insight. It seems that students incorrectly assess the impact a particular kind of instructional support will have on their learning. High ability students tend to use supports quite often even though they typically achieve more when they use their own skills. Clark hypothesized that able students believe that more support will make their effort to learn more efficient. On the other hand, low ability students tend not to use supports when given the choice. Clark suggests that these students are avoiding the extra effort provided by high support options when they expect to fail anyway. Lower support methods usually allow the student to loaf.

It is important to note that this finding was only possible when ATI researchers asked how instructional treatments were mediated by student

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ability. Many CBI evaluations do not include ability differences and therefore can report only that the evidence linking support menus and achievement is mixed.

4. There may be very different transfer consequences produced by designs which follow behaviorist models versus those which are cognitively based. Behaviorist methods seem to support context-bound learning whereas learning from cognitive methods may be more generalizable.

Though the computer will accommodate nearly any instructional design model, designers typically assume that the medium is more amenable to behaviorally-based design. This is probably due to early attempts to adcpt programmed instruction methods in the first demonstrations of computer assisted instruction. Whatever the reason, there is compelling recent evidence (e.g., DiVesta & Peverly, 1984) that behavioral designs promote different types and generalizability levels of achievement than do cognitive designs.

When designs specify the use of highly directed, shorter step instruction with more feedback, with opportunities for specific practice, and with identical elements in both lesson and test environments, learning tends to be more "near transfer." Near transfer means more specific to the examples and context where it was learned and therefore more difficult to use to solve novel problems. This is the kind of behaviorally-based learning often desired by military and business clients.

On the other hand, when design models specify student control over the direction and monitoring of instruction at higher difficulty levels and in larger chunks, learning tends to be available for "far" transfer. Here skills are more easily generalized to novel settings or problems. This is the design model often favored by clients who need to train students to solve novel problems in settings that are difficult to specify in advance (e.g., formal schooling, management problem solving, command decisions). These design characteristics are more typical of cognitive instructional design models (cf. Reigeluth, 1983, for examples of both types of design).

It is important to note that near transfer may be achieved somewhat at the expense of far transfer (and vice versa). There is evidence from a number of recent studies that task-specific skills are gained initially at the expense of ability to transfer those skills to new contexts. The same seems to be true for the more generalizable, far transfer learning—it is simply not as efficient as near transfer learning in solving any specific application problem. This might provide some of the more rational basis for the disputes between proponents of these two kinds of design models (cf. Clark & Voogel, 1984).

This distinction is important to CBI design because many designers assume, without examination, that CBI must utilize behavioral models. Of course, this is not the case, even though it has been common practice in the past.

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5. Hemispheric dominance and brain lateralization studies will probably not yield important CBI design prescriptions. The preference of each hemisphere seems to be fleeting, influenced by expectations, and not obviously influential in complex learning.

Instructional designers occasionally wonder whether research that indicates information processing differences between the left and right hemispheres can be adopted to CBI design. Essentially, there is research evidence that the left cerebral hemisphere specializes in more verbal and analytical messages and that the right hemisphere favors spatial and aesthetic information. This is true for right-handed learners; the reverse is the case for left handed learners. This research area has been the impetus for a number of popular articles and workshops focused on methods of "training the right brain." These popular presentations are only loosely based on the available research (cf. Gardner, 1982).

In a review of both psychobiological and instructional research on the topic, Hellige (1980) cautions against attempts to apply this research to design models. There has been little in the research since his review to contradict his caution. Hellige's argument is that in the normal brain, both hemispheres interact constantly and are able to perform each other's functions. The main difference between them seems to be a momentary advantage in the *decoding* of different types of information. However, he notes that the hemisphere initially activated will depend as much on our expectations for the kind of information we are going to receive as on the exact type we do encounter.

6. Efforts to alleviate the kind of test anxiety that inhibits performance in CBI and testing have largely failed. Many anxiety researchers now assume that instructional anxiety may have to be circumvented rather than cured.

Highly anxious students tend to learn less and drop out of CBI programs more frequently than those who experience only moderate anxiety. Anxiety-reducing elements in CBI design would be a positive contribution to learning and performance. However, there has been a recent reformulation of theory concerning the way that anxiety influences learning which may significantly change our design strategies in this area (Tobias, 1983).

Whereas in the past we have tended to use desensitization therapy procedures to decrease anxiety, there is evidence that this method only reduces the emotion connected with fears; the learning itself is still depressed after desensitization (cf. Tobias, 1983). This implies that our current methods for decreasing computer related anxiety will influence only its non-learning elements. Recent explanations for this finding point to two possible contributors: interference and skill deficits.

The interference explanation for the influence of anxiety on learning notes that fear of failure may be two-sided: on the one hand anxiety produces psychological responses such as shaking and sweating, and on the other hand there are cognitive (worry) consequences. It is the physiological responses that are alleviated by desensitization, but worry seems to be left intact. Worry (the compulsive thinking about fears) is said to *interfere* with the mental processing "space" needed for learning, and thus achievement is reduced (Tobias, 1979).

The second contributor to decreased learning is thought to be *skill deficits*. Analyses of student thought processing during learning suggest that students who assume that they lack the skill necessary to successfully complete the CBI lesson will experience anxiety (Tobias, 1983). Notice that anxiety is a dependent measure in this research. Here, researchers do not assume that anxiety *causes* learning problems but instead that student conclusions about their own skills produces anxiety. It is the skill deficit that lowers learning scores.

Since worry seems difficult to treat, it is possible that the best we can do now to overcome the effects of stress in CBI is to increase the level of instructional support. If interference is contributing to lower learning scores, more support for the student will lower the demand on processing space. If a lack of skill is the problem, increased support will tend to help also, at least over the short term. Tobias recommends ample opportunity to review instructional material, shorter steps, a high degree of embedded organization, the use of good examples, and constant feedback on progress. Note again that these methods do not decrease worry or anxiety, they tend to circumvent it by reducing the cognitive load on the anxious (worrying) learner.

Conclusions

The purpose of this article is to illustrate the distinctive perspective that underlies research on student thought processes during instruction. In this perspective, it is assumed that learning results from instruction *only after* that instruction has been *considered* by students. These considerations or cognitions are thought to *mediate* the effects of instruction and, in turn, influence learning, performance, and transfer.

The cognitive approach to research on instruction is offered as a supplement to behaviorist strategies, not as a replacement. It is highly likely that some learning occurs with minimal cognitive mediation and behaviorist instructional methods are recommended as ideal when near transfer (context bound) learning is desired. Yet, it is also the case that the cognitive view of learning provides significant alternative views of certain behaviorist-inspired instructional models. Evidence was presented for cognitively-inspired alterations in our understanding of such familiar instructional variables as motivation, the relationship between CBI and learning, learner control, the transfer of learning, hemispheric dominance, and anxiety. In each case, an analysis of student thought processes have extended the robustness of the principles available to support instructional theory and design.

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