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ABSTRACT

This paper reviews findings from over 70 published studies investigating various facets of learner-control in computer-based instruction (CBI). General conclusions about the relative effectiveness of learner-control versus program-control are equivocal. Across these studies, however, are strong suggestions that individual learner differences can greatly contribute to both the choices students make and to the effectiveness of those choices. Some researchers examine those differences on a global level, interacting with such broad instructional variables as learner-control versus program-control, following an aptitude-treatment interaction paradigm. Other investigators, however, look for interactions occurring on a moment-by-moment basis under micro-instructional conditions, that is the task-specific situation encountered during the course of the lesson delivery. Other paradigms are also discussed. The review extends the previous surveys of Carrier (1984), Hannafin (1984), Milheim and Martin (1981), and Steinberg (1977, 1989), paying particular attention to the role of learner individual differences in the effectiveness of learner-controlled CBI. Specifically, the impact on learner-control effectiveness of both rational-cognitive processes and emotional-motivational states of the learner are highlighted. Useful instructional prescriptions are proposed which take into account these variables. Recommendations for future research are offered. (Contains 188 references.) (Author/KRN)

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A Comprehensive Review of Learner-Control: The Role of Learner Characteristics

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Abstract

The current paper reviews findings from over seventy published studies investigating various facets of learner-control in computer-based instruction. General conclusions about the relative effectiveness of "learner-control" versus "program-control" are equivocal. Across these studies, however, are strong suggestions that a number of individual learner differences can greatly contribute to both the choices students make and to the effectiveness of those choices. Some researchers (e.g. Carrier & Williams, 1988; Ross & Rakow, 1981; Snow, 1979; Tobias, 1987a) examine those differences operating on a global level, interacting with such broad instructional variables as "learner-control" versus "program-control," following an aptitude-treatment interaction paradigm (ATI; see Cronbach & Snow, 1977). Other investigators, however, look for interactions occurring on a moment-by-moment basis under micro-instructional conditions, that is, the task-specific situations encountered during the course of the lesson delivery (e.g. Fisher, Blackwell, Garcia, & Greene, 1975; Johansen & Tennyson, 1983; Seidel, Wagner, Rosenblatt, Hillelsohn, & Stelzer, 1975). Other paradigms are also discussed.

This review extends the previous surveys of Carrier, (1984), Hannafin, (1984), Milheim and Martin (1991), and Steinberg, (1977, 1989) paying particular attention to the role of learner individual differences in the effectiveness of learner-controlled CBI. Specifically, the impact on learner-control effectiveness of both rational-cognitive processes and emotional-motivational states of the learner are highlighted. Useful instructional prescriptions are proposed which take into account these variables. Recommendations for future research are offered.

Learner-control of instruction: Overview

A supposed advantage of computer-based instruction (CBI) over more traditional forms of instruction is its capability to deliver to students "individualized" lessons. That is, the computer can assemble and present to different students tailored lessons with wide variations in sequence of information, amounts of examples and practice questions, or kinds of feedback and review, to name just a few possibilities. Alternatively, the computer may abrogate such decisions and allow the learner to select the instruction they are to receive. Here, the learner operates to control the "flow" or "path" of instructional materials.

To many educators and instructional designers, the phrase "learner-controlled instruction" suggests a class of instructional events or tactics intended to increase learner involvement, mental investment (or "mindfulness," as Salomon, 1983, would put it), and achievement. The approach is to emphasize the learner's freedom to choose their learning activities to suit their own individual preferences and needs.

There are many common instances of computer-based activities falling under the general rubric of "learner-control." For example,

- ...standard computer-based instruction for direct instruction (e.g. drill & practice or tutorial). This type of software follows an overall instructional design strategy, but permits the students to make their own decisions about, for example, what topics to see and when, how many exercises to take, or when to quit the lesson.
- ...computer-based simulations. These programs operate almost entirely under the learner's control (Reigeluth & Schwartz, 1989) in that the continual and often complex manipulations of the simulation's parameters are nearly totaly left to the discretion of the learner.
- ...tools for indirect learning such as word processing, programming, telecommunications, and databases. Billings (1982) argues that these tools are of a different class from typical computer-assisted instructional lessons. She argues that in these applications learner-control is inherent in the software and offers the potential for more complex learning by the students than more traditional instruction. The object here is not that the student should learn the tools for their own sake, but rather that these softwares be utilized in the pursuit of other learning outcomes (e.g. writing skills, mathematical reasoning, critical thinking).
- ...instruction developed around "hypermedia" technologies (e.g. Bowers & Tsai, 1990). Such innovations offer to learners previously unconceived freedom of movement and choice of media displays. So-called "electronic encyclopedias," especially those designed for K-12 school use, are examples of this type of technology. The structures of these databases have important implications for information accessibility and the ease of navigation around the database, i.e. what learner-control features are offered (Duchastel, 1986a).
- ...on-line computer documentation which allows the user the options of either following a detailed walk-through of major procedures and functions, or jumping around according to the needs of the moment. These "help" features most commonly serve as simply performance job-aids; but they are frequently used as aids for learning, as well.

And as the newer instructional technologies, both hardware and software, proliferate into instructional settings, the possibilities and variations for including learner-controlled activities in instructional designs will likewise multiply.

The first arena of CBI mentioned above, that is, traditional computer-based lessons for direct instruction, presents the largest research base of studies investigating issues of learner-control, and will form the concentration of this review. Suggestions for future research in other arenas are discussed at the conlusion of the paper.

Types of learner-controlled activities

Intentionally or by accident, most instructional designs end up consisting of a mixture of learner-controlled and instructor-prescribed learning experiences. Romiszowski (1986) describes four "levels" for which the designer will need to make decisions about the source of instructional control, the first three are more or less at a "macro" level, that is, apply to large instructional units such as curricula, units, and lessons. (For a discussion of many of the forms which instruction can take at the macro levels when under learner-control, see Gagné, Briggs, and Wager, 1988; Huff, 1984/1985; Rowntree, 1986; and Young, 1982.)

At the lowest level, Romiszowski (1986) recommends that designers consider whether and how to provide learner-control over "micro" instructional experiences, that is, those learning activities which occur within lessons, whose durations span minutes rather than hours or days. Indeed, because CBI seems particularly well-suited to managing such specific micro-instructional events (Gagné, Wager, & Rojas, 1981; Gagné, 1985), the bulk of research on learner-control in CBI falls at the "micro" level.

Several researchers have proposed lists of computer-based micro-instructional activities which they say could or should fall under the heading of "learner-controlled." Steinberg (1984), for example, lists a range of these events which might be offered within a learner-controlled lesson: which topics to study and in what order; number of exercises to practice and their level of difficulty; presentation of review or supplementary materials; the option not to answer questions. Other activities, too, could be made optional: amount or kind of feedback to see following practice questions; whether to exit the instruction; mode of presentation (e.g. verbal or graphic); and even the option whether to allow further learner-control at all.

Laurillard (1987) presents another assortment of computer-based learning strategies which learners might be given control. One category of these strategies, *control of content sequence*, includes provisions for the student to skip forward or backward a chosen amount or to retrace a route through the material, and options to control when to view such features as content indexes or content maps. A rather remarkable early example of learner-control of content sequence in computer-based instruction comes from Grubb (1968). He describes a system whereby the student, with the aid of a light-pen and a content map on the screen, is able to point and jump to any subtopic in the lesson. This approach presages the current "hypertext" environments in which students proceed through instruction in a non-linear "browsing" fashion.

Another category presented by Laurillard (1987) is called *control of learning activities*, and includes options for the student to see examples, do exercises, receive information, consult a glossary, ask for more explanation, and take a quiz. Most of her list of learner-controlled activities is included in Steinberg's (1984) list, but Laurillard's seems more complete and grounded in theory.

Milheim and Martin (1991) present three types of variables for which students might be granted control: *control of pacing*, that is, the speed of presentation of instructional materials; and *control of content*, permitting students to skip over certain instructional units. They suggest that these categories, in addition to *control of sequence* (similar to Laurillard's *control of content sequence*), represent the most germane sets of instructional variables affecting the success or failure of learner-controlled CBI.

These categorization schemes overlap to a large degree and differ primarily in perspective or orientation. And all provide useful information for designers and researchers studying the use of learner-control in CBI.

Historical background

The idea of learner-control of instruction has a fairly long history which pre-dates the educational use of computers. Some these early efforts at developing learner-controlled instruction grew out of a reaction to the stiffness and inflexibility of programmed learning approaches. For example, Mager and Clark (1963) suggest that while certain remedial branching techniques used in programmed instruction work well for poorly performing students, more knowledgeable students are better able to determine their own instructional paths. Campbell (1964), too, suggests that learner-control over instruction is at least as effective as programmed instruction, and perhaps more so for complex learning outcomes such as problem-solving and transfer. In a related study, Campbell and Chapman (1967) found that over a long period of time, learners who controlled their own instructional paths developed a greater interest in the subject matter, took less time, and performed as well as subjects in the programmed group. They also found that although scores on tests early in the eight month course favored the programmed group, over time scores in the learner-controlled group increased to parity with the program-control students.

Other justifications for developing, learner-controlled or "self-guided" instruction grew out of early efforts to *individualize* instruction. Individualization in these approaches usually referred to instruction which allowed learners to proceed through instruction at their own convenience and at their own pace.

Reiser's (1987) chapter on the history of educational technology traces many important contributions in the evolution of learner-controlled instruction. For example, Postlethwait, Novak, and Murray (1972) created the *Audio-Tutorial Approach*, in which learners proceed through a variety of mediated materials at their own pace, following guidance from a conversational audiotape. Another popular approach was called the *Personalized System of Instruction* (*PSI* or *Keller Plan*; F.S. Keller, 1974). Keller's approach contained five distinguishing features: a mastery requirement; self-pacing; student proctors; a reliance on written instruction; and a de-emphasis on lectures.

Most current literature seems to favor two other phrases as being fairly synonymous with "learner-controlled instruction": "self-guided" and "self-managed" instruction. All of these terms broadly imply instruction where learners are in charge of navigating themselves through instructional activities.

Current rationale for learner-control in CBI

There seems to be several philosophical, practical, and theoretical reasons for allowing learners some control during CBI lessons. For example, the use of traditional, rather rigidly controlled computer-assisted instruction may actually run counter to the educational philosophies promoted by many teachers in the arts and humanities which encourage student exploration and expression. D.W. Hansen (1982/1983) argues that allowing students more user-control will increase the chance these teachers would want to include computer-based activities in their classes.

On a more practical level, Steinberg (1984) says that, if learning is found to be equivalent in both learner- and computer- controlled settings, design costs should shrink, time spent learning should be reduced, and attitudes and motivation should become more positive if a learner-controlled framework for instruction is adopted.

In his instructional design theory, Merrill (1983) prescribes learner-control of content (encompassing curriculum, lesson, and module selection) and of strategy (which includes various forms of presentation). Faust (1974), Fine (1972), and Bunderson (1974) present an assortment of learner-controlled activities derived from Merrill's early theory (Merrill, 1973; Reigeluth, 1979). The *TICCIT* (*T*ime-Shared *I*nteractive, *C*omputer *C*ontrolled *I*nformation *T*elevision) system provides the learner with many options some of which are dependent on the current course (such as reviews, menus, quizzes, faster/ slower, type of feedback, level of question difficulty, and topic surveys) and others are constant across any course delivered by the system (such as backward or forward movement, access to a calculator, access to a glossary, and opportunity to leave on online comment; there is even a feature which gives the student the option to "CUSS" at the computer when things go wrong!).

Reigeluth and Stein (1983) in their instructional design theory also hypothesize that "...instruction generally increases in effectiveness, efficiency, and appeal to the extent that it permits informed learner-control by motivated learners" (p. 362). Federico (1980) suggests that learner-control might be a useful alternative to the classic aptitude-by-treatment interaction approach, in that, "learners can become system independent by enabling them to manipulate and accommodate treatments to their own momentary cognitive requirements" (p. 17).

Additional rationale from a different perspective comes from a survey of adult learning preferences. Penland (1979) found that the top four reasons why adults prefer learning on their own were expressed as desires to "set my own learning pace," "use my own style of learning," "keep the learning strategy flexible," and "put my own structure on the learning project." Discussing the differences between adults and children, Hannafin (1984) argues that under CBI conditions, older students should realize the benefits from learner-control more than younger students because they have acquired more (and presumably better) learning strategies.

Some of the research from the psychology of basic learning processes also implies possible advantages of learner-control. For example, one might expect a learner-controlled instructional treatment to induce more elaborate mental processing from the student as a result of their pondering the choices with which they are faced. Salomon (1983, 1985) refers to the degree of such mental activity as "invested mental effort." The more such effort expended, he implies, the more mental elaborations the student performs, resulting in deeper, more meaningful learning. In contrast, one might not expect as much cognitive elaboration from students proceeding through a more "passive" instructional treatment. In plain language, learners given control over their instruction might be more likely to think about what they are doing because they have to make choices along the way.

Hartley (1985), too, in arguing for the need for more attention to basic psychological processes when studying the impact of computers on learning, supports the use of learner-control of instruction as a means for students to develop their own cognitive structures. That is, consistent with a constructivist view of knowledge acquisition, he proposes that the learning of complex knowledge structures is facilitated when the learner himself/herself can participate in the construction of those mental structures. This constructivist approach is also promoted by Salomon and Gardner (1986) who suggest that "...individuals mold their own experiences by the traits and goals they bring to the encounter, the way they apprehend the technology and the situation, and the particular volitional choices they make. In so doing, learners, particularly when given interactive opportunities with computers, are likely to affect the way these opportunities are going to affect them" (p. 16).

The effectiveness of learner-control in CBI

Unfortunately, the research on learner-control in instructional contexts does not support its unconditional use. Many authors of texts on CBI design caution against cavalierly offering a variety of options to learners (e.g. Alessi & Trollip, 1985; Jonassen & Hannum, 1987; Steinberg, 1984) because such a strategy does not seem to improve overall learning. O'Shea and Self (1983, chap. 3) summarize much of the unpublished research on the effectiveness of the early *TICCIT* system and conclude that it is difficult to support its widespread use. Merrill (1983), too, concludes that college level students generally do not make good use of learner-control options, a position also taken by Carrier (1984). Snow (1980), commenting on the use of learner-control in adaptive instruction, argues that far from eliminating the effects of individual differences on learning, providing learner-control may actually exacerbate these differences.

Research on learner-control in CBI has typically compared learner-controlled and program-controlled treatments in a fashion reminiscent of and analogous to media comparison studies conducted in the 1960's and 70's. The following is a summary of research findings comparing learner-controlled computer-based instruction with either partial learner-controlled versions or complete computer-controlled versions for the three most common types of dependent variables measured in such studies, namely, *learning*, *time-on-task*, and *attitudes and affect*.

Generally speaking, these studies compare treatments which present a mixture of the specific instructional events actually subject to learner-control. Additionally, contrary to the statements of Hannafin (1984), both adults and children seem to have been well represented in these studies. Many of these studies were also reviewed by Steinberg (1977, 1989), but are discussed in this review from a somewhat different point of view.

Learning. On the whole, results have been mixed, but treatments under the learner's control have been shown most often to be as effective or less effective than treatments under more computer control. Also contrary to a suggestion by Hannafin (1984), findings from the literature reviewed here indicate that children do not seem to do any worse (or better) with instruction placed under their control than do adults.

A few studies have supported the use of learner-control of at least some instructional events (Avner, Moore, & Smith, 1980; Campanizzi, 1978; Ellermann & Free, 1990; Kinzie, Sullivan, & Berdel, 1988; Mayer, 1976; Newkirk, 1973). Most of these support Hannafin's (1984) suggestion that learner-control promotes a deeper or more long-lasting effect on memory. Newkirk (1973), for example, found a long-term learning benefit for learner-control, but not for program-control. Mayer (1976) found that more complex outcomes were learned better when learners were able to control the order of presentation while simple outcomes were learned better under experimenter-controlled conditions. In one of the few long-term studies of the effects of learner-control in CBI Avner et al. (1980) found that students using highly "interactive" learner-control showed a greater degree of high-level skills than did the students within a more "passive" type of CBI. There were no differences between these groups on low level skills, however. In a pair-associate task investigated by Ellermann and Free (1990), students who could select the order of presentation seemed to have a stronger memory-trace, implying more engagement of cognitive structures.

In contrast, studies by R.C. Atkinson (1972), Belland, Taylor, Canelos, Dwyer, and Baker (1985), Johansen and Tennyson (1983), Lee and Wong (1989), MacGregor (1988a), Morrison, Ross, and Baldwin (1992), Olivier (1971), Pollock and Sullivan (1990), Reinking and Schreiner (1985), Rivers (1972), Tennyson, Tennyson, & Rothen (1980), Tennyson and Buttrey (1980), Tennyson, Park, and Christensen (1985), Tennyson, Welsh, Christensen, and Hajovy (1985) all found various types or degrees of program-control superior to learner-control of the same instructional elements for posttest achievement. Many of these authors speak of learners not having or not knowing how to utilize appropriate strategies when they are left to themselves to manage their learning environment.

Interestingly, most studies in which the computer controlled the rate of pacing, that is, the length of time which screenfuls of information were presented to the student (Belland et al., 1985; Dalton, 1990; Tennyson, Park, & Christensen, 1985; Tennyson, Welsh, Christensen, & Hajovy, 1985), found learning under those conditions better than self-paced conditions (in which the learner controls the speed at which material is presented), the usual fixture in most CBI programs. One study by Milheim (1990), however, found learning better under learner-controlled pacing conditions.

Additionally, in a meta-analysis of 10 years of interactive video instruction, McNeil and Nelson (1991) conclude that, as a general statement program-controlled conditions are superior to learner-controlled. They suggest however, that partial (i.e., "guided") learner-control over review and practice activities might be the most optimal for learning, although they caution that too few studies included such conditions to make the conclusion unequivocal.

However, most studies found no differences between learner-controlled and program-controlled treatments (Arnone & Grabowski, 1992; Balson, Manning, Ebner, & Brooks, 1984/1985; Beard, Lorton, Searle, & Atkinson, 1973; Carrier, Davidson, Higson, & Williams, 1984; Carrier, Davidson, & Williams, 1985; Carrier, Davidson, Williams, & Kalweit, 1986; Fredericks, 1976; Goetzfried & Hannafin, 1985; Gray, 1987; Hannafin & Colamaio, 1987; Holmes, Robson, & Steward, 1985; Hurlock, Lahey, & McCann, 1974; Judd, Bunderson, & Bessent, 1970; Judd, O'Neil, & Spelt, 1974a; Kinzie & Sullivan, 1989; Klein & Keller, 1990; Lahey, 1978; Lahey & Coady, 1978; Lahey, Crawford, & Hurlock, 1976; Lahey, Hurlock, & McCann, 1973; López & Harper, 1989; McCann, Lahey, & Hurlock, 1973; Pridemore & Klein, 1991; Ross, Morrison, & O'Dell, 1988, 1989; Schloss, Wisniewski, & Cartwright, 1988; Strickland & Wilcox, 1978; Wilcox, Richards, Merrill, Christensen, & Rosenvall, 1978; Williams, 1992). The various conclusions drawn from this "no-difference" finding are interesting and tend to reflect a good deal of rationalization. Some of the researchers use this finding to support the use of learner-control, saying that programming the computer to handle the myriad complex types of branching which could potentially occur in a lesson is far too difficult. So therefore, since their research indicates it would at least do no harm, it is better to let the student handle their own lesson branching. Other researchers use the "no-difference" result to justify program-control of instruction, saying that other benefits, such as time savings (discussed next) are realized by not letting learners control their own instructional paths.

Time-on-task. Several studies also included as a dependent variable the length of time students took to complete a lesson. Two studies found students in learner-controlled CBI groups taking more time to finish the lesson than program-controlled groups. In a study by MacGregor (1988a), elementary students worked in pairs, and those in the learner-controlled group were given the opportunity to participate in an online instructional game; students in the program-controlled group were not. The author attributed the time-on-task differences to the fact that the game aroused quite a bit of interest, thus generating a lot of talking and other social activity within the pairs, naturally consuming more time in the process. Dalton (1990) also found that students in a condition in which the computer controlled the pacing of materials spent more time than those in learner-controlled pacing. He, too, suggests that the amount of socializing observed among the paired members of the learner-controlled condition accounted for the longer time spent. Another study (Avner et al., 1980) found that while students in learner-control conditions spent more time during online tasks, they spent less time during related offline tasks, in this case laboratory activities.

A few studies found no differences in time spent (Hurlock et al., 1974; Kinzie & Sullivan, 1989; Lahey et al., 1973). The bulk of studies, however, found that learner-controlled groups spent considerably less time than program-controlled groups (Fredericks, 1976; Johansen & Tennyson, 1983; Lahey et al., 1976; Rivers, 1972; Ross et al., 1988; Tennyson et al., 1980; Tennyson, 1980; Tennyson & Buttrey, 1980).

Researchers investigating "efficiency" of time spent during a lesson found mixed results. Dalton (1990) found no differences on achievement-per-time-spent between self-paced and lesson-paced interactive video formats. Another study (Goetzfried & Hannafin, 1985) did find differences between groups on an efficiency variable they define as the number of concepts a student sees per minute. In their study, learner-control was the least efficient, that is, promoted a slower progression through the lesson.

In some of these studies (Goetzfried & Hannafin, 1985; Johansen & Tennyson, 1983; Tennyson et al., 1980; Tennyson, 1980; Tennyson & Buttrey, 1980), shorter time was also linked to poorer performance. One possible explanation for these findings lies in the confounding of instructional control, time-on-task, and amount of instructional material seen. That is, learners navigating their way through a lesson might spend less time because they opted to skip over large amounts of instructional material. If this omitted material were crucial for overall lesson performance, these students might naturally be expected to perform more poorly than would students progressing through a program-controlled, but more "complete" lesson package. Lepper (1985) suggests that students under learner-control might see differing amounts or kinds of instructional material than students under program-controlled treatments. (In fact, for some situations it is entirely likely that each student under learner-control selected their way through a completely different instructional treatment!) Therefore, in these studies we do not know whether the culprit for the supposed failure of learner-control is the fact that students were granted control, per se, or simply saw suboptimal amounts of instruction as a result of "poor" choices. Indeed, three of these studies do report that students in learner-control spent less time because they saw fewer instructional screens, (e.g. fewer examples). This issue surfaces again later in this paper.

Commenting on the problem of learners choosing low amounts of instruction, Higginbotham-Wheat (1988) and Ross and Morrison (1989) draw the conclusion that learner-controlled instruction should only allow students to select context, sequence, and presentation style variables, and should not allow students to choose instructional events which could alter the amount of content support. It seems safe to say that the confounding of learner-control, time-on-task, and amount of instructional material is a matter which can prevent clear conclusions about the relative merits of offering control to learners.

As with the findings of no difference in learning between learner- and program-controlled groups mentioned earlier, the authors of the studies who found shorter time for learner-control also are quite creative in the implications they draw from that finding. Some authors claim that if learning is equivalent, but time spent is shorter, learner-control is desired because of the time "savings" or "economies." Others say that the shorter times from the learner-control groups mean less time-on-task, an inherently undesirable outcome, and thus should be avoided.

Attitudes and Affect. Most of the studies which measured the students' attitudes toward computer-assisted instruction or toward learner-control over instruction found either no differences or a favorable attitude from students who experienced a learner-controlled treatment compared with program-controlled groups. The author of the one study which did find more negative attitudes in the learner-controlled group (Gray, 1987) explained the findings as due to resentment and frustration at the complexity of the instructional decisions the students under the learner-controlled condition were required to make.

A few studies (Arnone & Grabowski, 1992; Beard et al., 1973; Judd et al., 1970; Kinzie et al., 1988; Lahey, 1978; Pridemore & Klein, 1991) found no differences in student attitude toward CAI between learner-control and program-control groups. Additionally, one review (Judd, 1972) also concluded that generally, learner-control does not contribute to improved attitudes. However, it is quite possible that the early computer studies included in Judd's paper do not exactly represent the highly interactive approaches used for instruction on modern microcomputers.

Six studies did find positive attitude effects for students in learner-control groups (Hintze, Mohr, & Wenzel, 1988; Hurlock et al., 1974; Judd et al. 1974a; Milheim, 1989; Morrison et al., 1992; Newkirk, 1973). For example, the study by Milheim (1989) exploring computer-driven (interactive) videodisk instruction found better attitudes toward the instructional activity for students under learner-control pacing compared with students who experienced program-control of lesson pacing. In most of the studies examining attitudes, students were only exposed to one type of program (i.e., they only saw a learner-controlled version or a program-controlled version). One of the most interesting of all the studies examining attitudes is presented by Hintze et al. (1988) who compared attitudes in dental students in Denmark, each of whom actually had a chance to experience several versions: completely learner-controlled; partially learner-controlled; and computer-controlled instructional situations. They found the overwhelming majority of students preferred at least some learner-control. Interestingly, males by far preferred complete learner-control, while female preferences were split between partial and total learner-control preferences. Dalton (1990) also found some interesting interactions between gender and learner- or program-controlled treatments on attitudes. Specifically, he found that females under lesson-controlled pacing ended up with better attitudes toward instruction and toward the content of the lesson than females under learner-controlled pacing. Males, however, under program-controlled pacing had significantly worse attitudes toward content than males under learner-paced lessons.

Some researchers investigated the effects of learner-controlled instruction on one particular type of attitude measure called *continuing motivation* (Maehr, 1976; Seymour, Sullivan, Story, & Mosley, 1987) which indicates how likely a student's ongoing willingness to return to a learning activity at a later time without external pressure, essentially a variable measuring the student's desire to learn voluntarily. Kinzie and Sullivan (1989) found positive effects on the students' desire to pursue science activities following computer assisted instruction, generally, and following learner-controlled CAI, specifically. However, this effect was not replicated by López and Harper (1989) who found no advantage for learner-control over program-control on continuing motivation.

Lastly, a few early studies investigated the effects of learner-controlled computer-based instruction on student state (i.e., temporary) anxiety, with mixed results. Judd (1972) recaps one study which shows a reduction in anxiety as a result of learner-controlled CBI. J.B. Hansen (1974) also found a lowering of initial state anxiety as a result of learner-control over computer-delivered feedback. However, neither Judd, O'Neil, and Spelt (1974b) nor Judd, Daubek, and O'Neil (1975) were able to lower state anxiety as a result of their particular types of learner-control (control over access to mnemonic devices in the first case, and control over access to pictures in the second case).

Summary of the effectiveness of learner-control of CBI. After reviewing all of these findings for the various types of dependent variables, we are presented with an apparent dilemma: learner-control *should* be better than program-control; however, students left on their own do not uniformly make good use such strategies. Duchastel (1986b) sums up the frustrating ambiguity of learner-control research: "Nevertheless, the research leads one to be cautious about the general learner-control hypothesis, namely that the student is the best judge of the instructional strategy to be adopted. Some results in instructional research indicate that not all students are capable of making appropriate educational decisions. Other results, however, indicate the tremendous benefits of learner-control in particular situations. The sophistication of the learner and the type of objectives pursued, as well as the particular context of the system, will probably impact on the nature and effectiveness of learner-control in given situations." (p. 391)

The role of learner characteristics

Individual learner characteristics play a huge role, of course, in how fast and how well overall learning will occur. Since its inception, CBI has continually been held up as a promising vehicle able to somehow tailor instruction to meet the individual needs of each learner (Suppes, 1966; U.S. Congress, Office of Technology Assessment, 1988). Just how these instructional adaptations are best generated, however, is a matter of debate.

Some proposals for adaptive CBI are program-controlled and attempt to present to each student appropriately matched instructional events according to some relevant individual difference variable. Examples of such approaches include: regression models which stable trait variables (McCombs & McDaniel, 1981) or on-task state variables (Rivers, 1972) to optimize instructional presentations; or schemes to branch instruction according to some optimizing mathematical model (R.C. Atkinson, 1972; Holland, 1977; Smallwood, 1962; Tennyson, Christensen, & Park, 1984). Few of these approaches have made it into commercially produced CBI, however.

On the other hand, for reasons of feasibility, attractiveness, and understandability, most of the CBI found in school software libraries has at least some learner-controlled features which their manufacturers tout as helping to accommodate the learning needs of each individual student. The idea, as Merrill (1973, 1975) and Federico (1980) have propounded, is that students will make their own decisions throughout a lesson so as to best match their own learning styles, personality, or other relevant traits.

As we have seen, however, learner-control does not seem to be a superior overall strategy. However, a closer examination does seem to indicate differential student effectiveness of instructional choice and options use, although perhaps not in the way the software producers had intended. That is, some students are able to use learner-control to their advantage; others, however, use it actually to their detriment.

Paradigms. There are several methods available to researchers wishing to study the interaction between learner characteristics and learner-controlled CBI. One common approach examines such an interaction within an "aptitude-by-treatment interaction" (ATI; Cronbach & Snow, 1977) perspective. That is, students stable cognitive and personality "trait" variables are viewed as possibly interacting with predetermined instructional features to produce differentially effective learning, particularly within a learner-controlled context (Snow, 1980). One example is found in Judd et al.(1974a) who found that the personality variable of "achievement via independence" predicts certain behaviors under learner-control. Snow (1979) also takes an ATI approach and presents some data using various statistical profiling techniques which appear to be fairly successful at sorting college students enrolled in a BASIC programming course into good and poor options selectors according to their scores on a variety of aptitude measures.

But the usual aim of ATI studies is to find instructional treatments which would somehow benefit students possessing different learner characteristics or profiles. However, in spite of Federico's (1980) suggestion that learner-control might allow students to effectively select instances based on their own cognitive requirements, there is ample evidence that learner-control serves to *magnify* student differences rather than eliminate them. Wilcox (1979) for instance, presents a review of non-computer-based ATI studies and concludes that learner-control tends to exacerbate problems arising from individual differences instead of minimizing them. Snow (1980), too, argues that a learning environment which allows learners to control instruction might possibly produce *stronger* relationships between individual differences and learning to the degree that these individual differences are free to operate than would "fixed" instruction. In a variation on ATI approaches which Tobias (1976) calls an "achievement-by-treatment interaction," differential results have also been found for effectiveness of options selection for students with differing amounts of prior knowledge (Ross & Rakow, 1981; Tobias, 1987a).

Merrill (1975) discusses several assumptions regarding "aptitudes" and "treatments" in Cronbach and Snow's (1977) ATI model. He points out that quite often the most germane learner characteristics are unstable and vary from moment to moment during instruction. Likewise, treatment effects may similarly not always hold under the variety of conditions present in typical educational settings. Lastly, he argues that instead of instruction being adapted to the individual, we should allow the students to adapt the instruction for him/herself. This forms one of the bases for the inclusion and importance of learner-control in his theory of instruction.

That is, while ATI approaches seek to understand the differential effectiveness of learner-control with individual differences measured *prior* to instructional intervention ("trait" variables), other approaches choose to explore learner variables measured *during* the instructional task, so-called "within-task" variables (Federico, 1980) or situational "state" variables. These presumably reflect momentary variations in certain learner characteristics which also could interact with the specific instructional situation. Tennyson and Park (1984) discuss the need to investigate the phenomena of moment-by-moment interactions of instruction and individual differences, in particular within learner-controlled environments.

Studies by Seidel, Wagner, Rosenblatt, Hillelsohn, and Stelzer (1975) examining students' on-going expectancies of success, by Fisher, Blackwell, Garcia, & Greene (1975) on momentary changes in attributions for success and failure, and by Goetzfried and Hannafin (1985), Johansen and Tennyson (1983), Tennyson (1981) and Tennyson and Buttrey (1980) investigating on-task mastery self-assessment by students, illustrate the utility of variables which occur during the course of learner-controlled CBI.

However, still another possibility not discussed by either Cronbach and Snow (1977) or Merrill (1975) is not necessarily to adapt instruction to fit the student, but rather to attempt to change the *student* to optimally use the instruction. That is, if we can identify modifiable characteristics of the students which typically produce dysfunctional interactions with instructional treatments, we might attempt to alter those characteristics so the student and instruction are better matched.

So, both person and instruction variables can be considered either stable or unstable, perhaps reciprocally changing throughout the course of instruction. This paradigm also allows for the occurrence of aptitude-by-treatment "corrections" (Gehlbach, 1979), that is, selecting treatments to *eliminate* the effects of individual differences rather than to accommodate them.

This expanded "adaptive instruction" paradigm presents a revised set of larger questions to the researcher: when might instruction respond to variations (both stable and unstable) in individual learners; and how might learners react and respond to changes (macro and micro) in the instruction? Within this framework, there seems to be sufficient theoretical, empirical, and practical justification for investigating the mutual relationship between learner differences and instruction under some degree of learner-control.

Instructional choice

Learner-controlled instruction is, by definition, instruction where students are required to make decisions at various points. In order to guide the design and use of learner-control, it is necessary to understand the composition of such decisions; i.e. can we specify the precursors and effects of the decisions students will make?

Choice is at root a psychological phenomenon determined by both general and situational psychological variables. For example, a student might have a proclivity to select certain types or large numbers of optional instructional activities, generally irrespective of the specific lesson in which they may be engaged. However, the particular situation may moderate the general tendency. For example, say, as a general rule, a particular student tends to choose to experience large amounts of instruction when offered such an option. However, under certain conditions, that student may perceive specific material encountered as being, say, too easy, and may override their tendency to experience "complete" instruction. They might instead elect to skip over such material because it's "a waste of time." Both of these classes of behaviors, the general "trait" variables and the situation-specific "state" variables, vary in degree from learner to learner.

We seek at this point to identify the different kinds of person variables which, it is conjectured, in combination with the actual choices made (i.e. the instructional materials encountered) help to account for the unevenness of learning found under learner-controlled instruction.

As was pointed out earlier, Reigeluth and Stein (1983) advocate the use of "*informed* learner-control by *motivated* learners" [emphases added]. This statement suggests two qualitatively different sets of individual difference variables which could influence the effectiveness of learner-controlled instruction.

We should first be interested in a student's capacity to make rational choices (i.e. an "informed" student). "Rational" means how adequately they can appraise both the demands of the task and their own learning needs in relation to that task in order to select appropriate instructional support. Tennyson and Park (1984) call this the student's "perception of learning need," and also point out the need for its further study in order to be of use in effective learner-controlled instruction. These perceptions of learner need, too, will vary across learners.

Secondly, because both motivation and learner-controlled instruction are, at least in part, defined by choice activities, individual differences in motivational variables might also contribute to our understanding of the differential effects of learner-controlled instruction on learning. We therefore need to ask if there are there certain characteristics of the student and the task which would allow us to predict how inclined (motivated) a person is to make a particular choice? We are concerned with identifying emotion-related predispositions, tendencies, and preferences of the students which operate to direct a choice toward one alternative or another.

The review presented here examines the relationships between students' rationale understanding of their learning needs, their motivations to choose on an emotional level, their on-task performances and learning when offered instruction which is to some degree under their control. First, the rationally-cognitively oriented variables are presented. Following that is a discussion of emotional-motivational variables which influence choice and learning.

Rational-cognitive aspects of choice and learning

Two kinds of cognitive traits, prior knowledge and ability, offer useful possibilities for explaining some of the negative results of providing learners with choices during instruction. The relationships of learner-control with achievement and with ability will be presented in turn, together with some hypothetical instructional prescriptions which could take advantage of these relationships.

1. Prior knowledge. A possible explanation for these findings proposes that individuals do make appropriate decisions, but within their own perceptions of the problem at hand, not according to some optimal outside decision rules. This view suggests that an increase in an individual's accuracy of perception of their learning state in relation to the learning task should result in their making more appropriate choices. Students are therefore expected to make instructional choices which are rational only to the degree they have accurate information about their current learning state. This suggests an approach based on learner prior knowledge or achievement.

What kinds of information would students need to know to make a more rational choice of material? Certainly one important element would be some sort of estimate of how much one knows and how much one needs to learn. However, there is substantial evidence that, left on their own, both children and adults very often overestimate how much they know about a given topic, and indeed, perhaps those with more knowledge are better able to judge their knowledge level than people fairly ignorant in that area (Flavell, 1979; Lichtenstein & Fischhoff, 1977; Nelson, Leonesio, Shimamura, Landwehr, & Narens, 1982).

This finding that students are generally poor at estimating their current state of knowledge extends also to computer-based contexts. Lee and Wong (1989) found students unable to predict their own learning of both general and specific types of knowledge. Additionally, Garhart and Hannafin (1986) found little correlation between self-rating of knowledge and performance on several tests. These latter authors use this finding plausibly to explain why many students under learner-controlled conditions tend to terminate instruction prematurely (e.g. the review of *TICCIT* by O'Shea & Self, 1983, mentioned earlier).

It could very well be, then, that people often really don't know what they don't know, and that those who know very little know even less about what they don't know. (Apologies for the last sentence.) If this is the case, one would predict that students with higher levels of knowledge would make wiser choices (better instructional decisions) than those with lower knowledge levels. Evidence for this phenomenon is provided by Seidel et al. (1975) and Fredericks (1976). In learner-control CBI studies, high performers were much more able than low performers to estimate their performance capabilities prior to their taking quizzes on the lesson material.

The notion that poor performers are incapable of judging how much they know has implications for the idea of instructional support, as well. That is, if students are unable to estimate their current state of knowledge, they may also be unable to assess whether they need additional instruction when given the chance to choose more. This would imply that a pretest given prior to instruction could predict the success of students given learner-controlled instruction, an extension of the achievement-treatment interaction notion of Tobias (1976, 1981), but here the instructional support is controlled by the learners. Such an interaction has indeed been found in studies by Ross and Rakow (1981) and Ross, Rakow, and Bush (1980), although neither study occurred in a computer-based environment. College students scoring higher on a pretest performed as well under learner-control as similar students under program-control. This was not the case for low prior knowledge students who performed much worse under learner-control. It is plausible that low prior knowledge students were not as able to judge the instructional support they needed as were higher prior knowledge students.

Additional evidence within a CBI context is provided by Tobias (1987a) who found that knowledgeable students (as measured by a pretest) selected more options to review material than did less knowledgeable students. He states, "...the presence of instructional support is no guarantee that less knowledgeable students will use it frequently or effectively to improve learning" (p. 160). This is echoed by Judd et al. (1970) who found a similar result in their early study, namely that students who need additional instructional support tend to avoid seeking it.

So, prior achievement has been found to be a major factor affecting the effectiveness of learner-controlled instruction. A reasonable interpretation for this is that students with some knowledge about the topic being taught seem better able to sense at any given choice point what they don't know and to choose additional instructional support accordingly. Here the key instructional variable seems to be amount of instructional support. Students with low amounts of topic knowledge have inaccurate perceptions of what they know, and consequently make poor use of needed instructional support. Two possibilities for improving the effectiveness of learner-control are suggested: informing learners directly of their progress (i.e. supplanting the self-monitoring function); and instructing students to try to gauge their current knowledge (i.e. activating the self-monitoring function).

The students' continual estimation of their level of knowledge (a metacognitive strategy, according to Flavell, 1979) affects the effectiveness of their choices. Without data from the instruction about their knowledge level, students with more prior learning seem better able to assess what they do and do not know, and therefore how much more or what kinds of instruction (i.e. optional material) they need to see. Hannafin (1984), Milheim and Martin (1991), and Steinberg (1989) suggest that learner-control which regularly informs the learner of the state of their learning might provide an aid, perhaps in the form of coaching or advisement to the students, in deciding whether they need more instruction.

Additionally, Steinberg (1989) suggests that instruction should gradually wean the student from such crutches in order to promote more internalization of the metacognitive processes. Such information supports to the learner fall under the category of "decision aids" which have been shown to be quite useful in helping people make judgments and select appropriate courses of action (Pitz & Sachs, 1984).

Related to the case where students left to assess their own current learning state is the case where this assessment is performed by the instructional program (a "decision aid") during the course of the lesson. One would also predict that providing students with updated information as to their moment-by-moment mastery level would improve the effectiveness of learner-control over providing no such information. Studies by Arnone and Grabowski (1992), Holmes et al. (1985), Schloss et al. (1988), Tennyson (1980, 1981) and Tennyson and Buttrey (1980) support this contention. Here the researchers provide students under learner-control with such information and show beneficial effects over students not given such information. Related to these studies is a study by Steinberg, Baskin, & Hofer (1986) who found that providing informative feedback to students during the course of a CBI lesson increased the chances that learner-controlled memory tools would be used. That is, students were able to use the feedback information to help them decide when and how to use the memory tools.

Results are not unequivocal, however. Ross et al. (1988) did not find an interaction between student selection of density of text displayed on the computer screen (high and low densities) and student pretest scores. Additionally, Goetzfried and Hannafin (1985) did not replicate in a CBI setting the achievement-by-treatment interaction which was demonstrated by Ross and Rakow (1981) in a non-CBI setting.

An additional wrinkle is suggested in results reported by Pridemore & Klein (1991) who compared selection of feedback by students under two learner-controlled feedback conditions differing in the elaborateness of information provided. They found generally that students in the less elaborate condition selected less feedback than those in the more elaborate condition. This suggests that students select their instructional support *only to the degree they perceive it will help them*. It's possible then, that students chooseto experience more instruction, not just based on their perceived learning need, but also on the perceived usefulness of the material to be offered.

Instruction, then, designed for learner-control should have as its goal the expansion and clarification of the student's own perception of the task and their progress toward it, particularly for those whose are deficient in the accuracy of their self-monitoring.

However, it is not known at this point whether students even need to be aware that self-monitoring is important in learner-controlled instruction as a type of learning strategy (Garner & Alexander, 1989). It might be that simple directions to the student to think about what or how much they know might be enough to dislodge them from more habitual "mindless" activity. If we could somehow activate the learners own untapped self-monitoring skills, it is speculated, then it may be unnecessary to directly inform the learners of their mastery using some decision superstructure (e.g. Bayesian probabilities, Tennyson & Rothen, 1979). This approach, however, has not been explored in learner-controlled CBI contexts.

In addition to supplanting a student's monitoring activities, or activating existing monitoring strategies, instruction might attempt to *improve* the student's conscious use of metacognitive strategies. This would involve some type of strategy training (Garner & Alexander, 1989, present a review of some of these training approaches). Tobias (1987a) supports metacognitive strategy training indicating that many students might need to be taught when and why to use various instructional supports. However, at this point, metacognitive strategy training has not been investigated in a learner-control CBI context.

2. *Learning strategies and ability*. Another explanation for the general ineffectiveness of providing instructional options begins with the suggestion that individuals have developed either good or poor means for dealing with learning problems. The metacognitive self-monitoring processes mentioned earlier in the section on *Prior Knowledge* represent a subset of a larger collection of cognitive processing strategies most often called "learning strategies." Jonassen (1985) reviews some of

the research on learning strategies, and describes four classes of strategies, all of which have clear implication for learner-controlled instruction:

- *Metacognitive strategies* are those processes which by which the student tells themself how much they know. It is often described as "self-monitoring," and reflects a sense of both knowledge and ignorance.
- *Information-processing strategies* make up the largest group of learning strategies. These strategies include developing readiness, reading/viewing for meaning, recalling material, integrating it with prior knowledge, expanding or elaborating on the material, and finally reviewing what has been learned. These strategies seem to correspond to what Merrill (1984) calls "conscious cognition" processes.
- *Study strategies* (in the past been called "study skills") are explicit techniques to help learners actively process information. These consist of such activities as note-taking, outlining, underlining, and the identification and noting of patterns in the new material.
- *Support strategies* relate to the mental climate or attitude at the time of learning, such as the degree the student can internally motivate themself and stay on-task during the instruction. Jonassen (1985) says these last strategies are a sine qua non for learning, and are required in order for the other strategies to be effective.

When many people using both good and poor strategies are averaged in a study, a less-than-ideal picture is painted of the effectiveness of decision-making as a whole. Some researchers suggest that the use of these of these strategies is linked closely with the concept of general intelligence (Snow & Yalow, 1982). It is not unreasonable to imagine that higher ability students might have a greater repertoire of strategies to draw upon when faced with a learning problem. In fact, as Snow and Yalow point out, very often the concept of ability is equated with the capacity of learn.

If indeed we can infer that 1) higher ability students consciously or unconsciously bring to bear the mental resources appropriate to the learning task and avoid using inefficient ones, 2) lower ability students somehow either lack or don't know how or when to activate their learning strategies, and 3) the success of learner-control depends to a large degree on students judiciously applying their mental resources to the learning problem, then we can begin to explain the mixed results of learner-control of instruction as being to a degree a function of learner ability, with higher ability students capitalizing on learner-control and lower ability students left floundering.

An opposing viewpoint that higher ability will predict better learning strategy use comes from Clark (1982). In a review of aptitude-interaction studies he first hypothesizes that high ability students would profit most from activating or cueing methods, that is, techniques which prompt the student to adopt an appropriate mental strategies from their repertoire of strategies for a given problem. Second, he suggests that low ability students would do best under the supplanting or modeling methods, which are techniques which do not rely on the student to use their own mental resources, but rather explicitly guide the student through the optimal learning strategies. But regardless of what they would *need*, he suggests that high ability students would *prefer* to choose supplantation or modeling, while low ability students would *prefer* activating or cueing methods. Each group does so because that is the method perceived to be the lowest "mental work load" for the student. In this case, he proposes, neither group selects an appropriate strategy. In support of this hypothesis, one *TICCIT* study (Sasscer & Moore, 1984) found that when students were given the option of terminating the lesson, the dropout rate was related to the types of options chosen. These options patterns were typically the "easier" kinds.

Studies examining learner-control have found some positive associations of ability measures with certain patterns of choice activities in learner-controlled CBI. Snow (1979) found that aptitude measures of fluid-analytic ability and perceptual speed (in addition to a personality variable) predicted the choice activities of successful college students in a BASIC programming task. The best choice activities were described as indicating a reflective and thoughtful style, and were more frequently selected by high ability students. However, the data analysis presented is sketchy, and contains too few subjects to unequivocally trust the multivariate analysis employed.

Carrier et al. (1985) found that between a measure of general ability and a measure of locus-of-control (Rotter, 1966), the best predictor of amount of options selected was the ability measure, with high ability students selecting the most options in the lesson. Additionally, Kinzie et al. (1988) also found that students higher in reading ability selected a high proportion of options to review material than did lower ability students.

There is also evidence that ability helps determine the *kinds* of options chosen rather than the *amount*. Carrier et al. (1986), and Snow (1979) both found near zero correlations between standard ability and achievement measures and *frequency* of choice of instructional options in computer-based concept lessons. Morrison et al. (1992) also report no relationship between amount of instructional support selections made by students under learner-controlled conditions and their posttest performance. Carrier and Williams (1988) found that students choosing *medium* level frequencies of instructional options had the highest ability levels. A study by MacGregor (1988b) also found differences in reading strategies employed between low and high reading ability groups. In contrast, however, Reinking and Schreiner (1985), however, found no differences between low and high reading ability groups in any type of options selected. Examining time spent as presumed indicator of on-line strategies, MacGregor (1988a) compared high and low reading ability groups, and found that higher ability students spent more time when under learner-control conditions than did lower ability students, presumably reflecting the differential utilization of on-line strategies.

A common methodological problem in studies investigating differential options selection is the confounding of ability, pretest performance, and posttest performance. That is, some studies compare options selections between low and high pretest groups (which is frequently correlated with student ability) and low and high posttest groups (also confounded with ability). These surrogate ability measures might limit the inferences one can draw about learning strategy use for ability groups, but still can provide insights useful for further research.

For example, a reanalysis of data presented in Seidel et al. (1975, p. 29, Table 6) shows that while low posttest performers selected overall more options (supporting Clark's (1982) hypothesis mentioned earlier), high performers selected proportionally more of certain types of options, namely QUIZ options, than did low performers; this was not the case for RECAP or REVIEW options available in the lesson. Gay (1986) found high pretest students more "efficient" in their on-line time (this presents a possible contrast to MacGregor, 1988a, where high ability students spent more time).

There is also evidence that ability plays an important role on the attrition of students in large instructional units. An early example, the *TICCIT* system (Merrill, 1973) offered college students a great deal of choice in selection of both content and strategy. Results showed a high dropout rate, but positive results for those who persisted. Those who stayed were generally higher ability students to begin with (O'Shea & Self, 1983, p. 92).

The finding by Tobias (1987a) discussed earlier in the *Prior Knowledge* section, who found the amount of optional review material selected by students positively related to the student's level of pretested knowledge, also might be interpretable as a broader difference in student abilities, as well. However, this confounding of ability and prior knowledge is not universal. For example, neither Holmes et al. (1985) or Rubincam and Olivier (1985) found a relationship between pretest and options chosen.

The mixed results from these studies, while indicating the potential for ability and learning strategies to explain overall performance in learner-controlled CBI, also demonstrate that more research needs to be done. It is likely that the specific type of tasks presented to the students need to be more precisely matched with the specific learning strategies it most corresponds with. Overall ability measures don't have the power to differentiate the more relevant learning strategies adopted by a given student at a given time.

Some types of instructional interventions do appear to work to compensate for the poor use of mental resources in low ability learners. Jonassen (1985) presents several suggestions for improving the use of learning strategies in computer-based instruction in the four categories listed earlier in the *Prior Knowledge* section.

Ability appears to predict, in addition to the individual's perception of need for instructional support (a metacognitive strategy), other types of mental learning strategies in which the student might engage. Although the relationship between ability and choice seems more tenuous than that of prior achievement and choice, there still seems cause to believe that appropriate choice strategies can be made salient to the learners when lacking spontaneously, perhaps via simple instructions or suggestions, and perhaps by changing the attractiveness of the various choices to be made. Additionally, the types of options selected appear more related to ability than quantity of options chosen.

Only one instance was found of a learner-controlled CBI study which attempted to improve students' strategy use. Elementary school students in Jacobson and Thompson's (1975) study were given prompts at various points to help them make appropriate instructional decisions. Although the instructional treatments used in the study were quite large and in may ways not comparable, the authors still conclude that such strategic prompting can help students to make appropriate decisions. Reigeluth (1979) proposes that learner-controlled instruction offer students an "advisor" option, a sort of prescriptive "help" feature, which would suggest to the student various so-called "optimal" strategies for how to process information or what to do next in the lesson. The potential flaw in this proposal is that students might not know how or when to access the advisor. Another intervention system is proposed by Allen and Merrili (1985), which provides to the learners varying amounts of learning strategy suggestions depending on their aptitudes for accomplishing the learning tasks. For students of low abilities, for example, the computer would provide explicit processing representations for the students to follow; for medium ability students, the system would "guide" the learner to use certain previously learned strategies; high ability students would be left with the most freedom to select and apply their previously acquired processing strategies without external suggestions or interference from the computer system. This type of system has not yet been tested.

The idea behind all these approaches is to promote the conscientious and mindful use of instructional options according to individual needs for instructional support. The following section shifts the examination of the rational predictors of learner choices to the emotional or affective predictors.

Emotional-motivational aspects of choice and learning

"Motivation" is a very slippery concept. J.M. Keller (1983) defines motivation as the "magnitude and direction of behavior. In other words, it refers to the choices people make as to what experiences they will approach or avoid, and the degree of effort they will exert in that respect" (p. 389). Both intuition and research (Tobias, 1987b) inform us that poorly motivated students are also very often poor performers in educational settings, too. However, the derivation of instructional prescriptions to help students improve their motivation to learn requires a much more detailed exploration of both the determinants of motivated behavior, and the effects of motivation on choice and learning. That is, we need to uncover the reasons (motives) behind particular choices a student may make, to clarify which variables determine, or at least predict, both general patterns and levels of choice and situation specific choices students will make. Additionally, we need to investigate the relationship between motivation and learning. In path analytic terms, both direct and indirect (via the actual instructional choices made) relationships of motivation and learning require clarification.

A terminology issue needs to be raised at this point. Many researchers would argue that a "motivated" behavior might be based on rational, logical decision-making processes, and thus is not best described in terms of "emotional-motivational" processes. This is true to a large extent (although some could argue it is moot). However, for clarity sake in this paper, learner "motivation" refers largely to the emotional states and reactions (and their consequent overt behaviors) experienced before, during, and after instruction which have an impact on learning and choice. So-called "rationally" motivated behaviors were discussed earlier in this paper.

A large body of research and several psychological theories exist which attempt to describe and explain the relationships among emotional-motivational variables, choice, and learning, and will only be touched upon here. Instead, the implications of these findings about motivation and learning for the design of learner-controlled instruction will be explored.

1. Achievement motivation and learner-controlled instruction. The history of motivation research contains a sizable body of literature concerning what is called "achievement motivation," in simple terms, a person's desire to perform and achieve. Because of the behaviorist tradition from which the concept sprang, authors on the topic have tended to present "motivation" as a fairly broad and inclusive construct defined by overt behaviors such as persistence and perseverance, and have tended to not investigate the specific underlying emotional states which could be said to be the sources for such achievement-related behaviors. Nevertheless, their research is still very relevant in our discussion of learner-controlled instruction and deserves exploration. Discussion of learner motivation in terms of the emotional states experienced by the learner will follow in the next section.

Following this tradition, Lepper (1985) suggests that motivational factors could operate on learning under learner-controlled computer-based instruction in two possible ways. First, students' simple exposure to instructional materials and time-on-task will vary according to their motivation to choose. That is, the often repeated failure to demonstrate the effectiveness of learner-control might simply be a function of the fact that less instructional material is selected by those students, hence they received an "incomplete" lesson compared with their program-controlled counterparts. In other words, learner-control ineffectiveness would be totally unrelated to the learner's emotional or motivational states or tendencies, and would be more an artifact of the particular set of instructional events they experienced (or more likely, did not experience). This is a similar argument to that given earlier in the section on *Prior Knowledge*.

Indeed, Ross and Rakow (1981), Tennyson et al. (1980), Tennyson (1980), and Tennyson and Buttrey (1980) all showed that students in the learner-controlled treatments saw many fewer instructional examples than did students under program-control. The sheer result of pooling students seeing both low and high amounts of instructional material would certainly be expeected to show lower overall scores than students only given high amounts of instruction.

However, in these studies, effects of the amount of material seen were confounded with the treatment, learner or program-control. That is, lower amounts of instructional material were inextricably linked to the learner-control treatments. Carrier and Williams (1988) experimentally controlled the amount of material seen, and found a positive effect for amount of material separate from learner-or program-control effects. In a study by Morrision et al. (1992), amount of instructional material was controlled for by having two program-controlled versions: one with "minimum" instructional support, one with "maximum." They found that the students under learner-control actually performed poorer than those with the "minimum" program-control treatment.

A second link between motivation and achievement, says Lepper (1985), is more direct and related to covert states in the learner. It is possible that a person's level of motivation during the performance of a learning task affects key components of information processing related to learning, a position also taken by Salomon (1983). Emotional-motivational variables may influence the direction and intensity of attention processes, arousal, depth of processing, and problem representation. Even though Lepper (1985) points out that many of these information processing ideas are at present hypothetical, there does seem to be an emerging unification of the underlying mechanisms linking motivation and achievement (Humphreys & Revelle, 1984).

Some motivation researchers (J.W. Atkinson, 1974b; Brophy, 1983; J.M Keller, 1983) posit a curvilinear (inverted U-shape) association between student motivation level and learning. That is, both very low and very high motivational levels can have dysfunctional effects on learning.

Given this relationship it would be interesting to look for interactions of level of motivation and learner- or program-controlled instructional treatments. Such an ATI has been found by Carrier and Williams (1988). Using task persistence as the overt motivational index, they found that under two program-controlled treatments (with low and high amounts of instruction) students performing best were those in the *middle* levels of persistence; under learner-control, the best performers had the *highest* levels of persistence. In other words, the curvilinear relation between motivation and learning was found under program-control, but a mostly linear relationship was found under learner-control. (Similar data was collected in a study by Morrision et al., 1992; however, they only reported on the linear relationship --none-- between task persistence and achievement. It would be interesting to reanalyze their data to see if such a curvilinear relationship emerges.)

A possible explanation for these differential treatment effects can be inferred from a paper by Humphreys and Revelle (1984). Following their theory describing the underlying relationships between effort and performance, it is speculated that students behaved as though learner-control was an easier or less complex condition; i.e., it placed fewer demands on their learning resources. Alternatively, the learner-controlled treatment produced less overall anxiety which could have interfered with learning. This interpretation is also consistent with Salomon's (1983) general notion of "perceived demand characteristics" of instructional treatments.

Although still hypothetical, three instructional factors are proposed here which might be expected to interact with a person's average general level of achievement motivation: learner or program-control; task complexity; and extrinsic motivation variables.

Learner- and program-controlled treatments might be perceived by different students to be easier or more difficult to manage. It is possible that general motivational level could have an influence on performance by interacting with these treatments in a linear or curvilinear fashion, depending on the perceived "ease" of learning under the treatment.

Second, fairly simple tasks given under both learner and program-controlled treatments might find no differences for highly motivated students. However, for difficult tasks, or those tasks requiring careful and deliberate thinking, one might expect learner-control to surpass program-control, at least for highly motivated (persistent) students. It is not clear yet what to expect for students of low or middle levels of motivation under tasks of varying difficulty or complexity.

Last, the object of using extrinsic motivators would be to try to increase the learner's persistence or effort expenditure, particularly for those students with low motivation levels, through instructional manipulations. J.W. Atkinson (1974a) lists as examples of extrinsic motivators authority, competition, social approval, and external rewards. Three studies from the learner-control literature support the use of these extrinsic motivators. Tennyson and Buttrey (1980) and Tennyson (1981) found that providing students under learner-control with *advisements*, that is instructional recommendations about whether they should select more material (based upon a mastery diagnosis) did result in higher amounts of material chosen and in learning equivalent to the program-controlled version. Similarly, Carrier et al. (1986) found that encouragements within a learner-controlled treatment did increase the amount of material chosen by the students over a learner-controlled treatment without encouragements. There is evidence, then, that simple instructional guidance can alter the overall level of task persistence and other on-task behaviors.

One broad prescriptive framework for the general improvement of student motivation comes from J.M. Keller (1983, 1987a, 1987b). He presents a well integrated model, which subsumes much of the previous discussion, for the design of motivating instruction which offers prescriptions consistent with the previously mentioned basic research on learner motivation.

2. *Emotional-motivational patterns and learner-controlled CBI.* The remainder of this section attempts to peer beneath the overt motivational variables (e.g., persistence) to see how learner emotional states might have direct or indirect impacts on learner-control effectiveness. Dweck (1986) and Dweck and Leggett (1988) offer a useful integrative approach to understanding student behaviors in terms of the student's own internal beliefs about the nature of their performances and their striving to confirm those beliefs. In their model, students are continually forming implicit theories about themselves which orient them to seek particular goals related to confirming these theories. Dweck (1986) describes so-called *adaptive* (or "mastery-oriented") and *maladaptive* ("helpless") motivational

patterns. The maladaptive pattern is characterized by an avoidance of challenge and a deterioration of performance in the face of obstacles. Students who exhibit an adaptive pattern, in contrast, tend to seek challenging tasks and the maintenance of effective perserverance under failure circumstances.

What follows is an example of *one* avenue of promising theory, to date fairly unresearched withiin CBI contexts, which holds promise for explaining the heretofore mixed effects of learner-controlled CBI, and suggesting means of improving instructional designs which adopt learner-control. The investigation of other theoretical frameworks is encouraged, as well. In all cases, however, the idea is to try to understand the nature of emotional states the learner experiences which produce healthy (*adaptive*) or dysfunctional (*maladaptive*) expression in terms of choices, persistence, and perseverance during learner-controlled instruction.

A major portion of Dweck and Leggett's (1988) model is based on research in the area of student *attributions* of their success and failures. Here the conception of motivation becomes that of a somewhat unstable factor affected on a moment-by-moment basis by the person's perception of events happening during instruction and their own inferred role in those events. Generally, an "attribution" refers to an individual's perceived causes of their own success or failures. Early conceptualization by Kukla (1978) and Weiner (1974) explain that the degree to which a person ascribes the causes of their own success or failures to ability, effort, task difficulty, or luck will differentially predict whether or what kinds of subsequent performance opportunities the student is likely to voluntarily select. These four variables can be grouped along two primary dimensions: internal versus external (analogous to, but not the same as the familiar "locus of control" dimension of Rotter, 1966); and stable versus unstable.

Other researchers have recently extended, refined and reconceptualized attribution theory. For example, Covington and Omelich (1984a, 1984b, 1985) attempt to frame student attributions in terms of emotional states they imply such as pride, shame, guilt, and humiliation. Additionally, Dweck and Leggett (1988) present a model which seeks to explain the precursors of an individual's attributions along the "controllability" dimension. That is, they attempt to explain why some individuals feel more in control of their performances outcomes and others feel more "helpless." These developments in attribution theory have potentially important consequences for the design of motivational interventions during instruction.

Very few studies have explicitly examined attribution-like variables in connection with learner-controlled CBI. Treating perception of internality/ externality of reinforcement (or "locus of control," Rotter, 1966) as a predictor variable has yielded generally unimpressive results in differentially predicting learning under several instructional conditions (Tobias, 1987b) and in predicting overall choice levels or learning in learner-controlled instruction (Carrier et al., 1985, 1986; Gray, 1989; Hannafin, 1984; Klein & Keller, 1990; Santiago & Okey, 1992). In fact, López and Harper (1989) conclude that there is little to be gained by further research investigating Rotter's locus-of-control construct in connection with learner-controlled instruction. Nevertheless, these negative findings could be masking potentially valid discriminations within groups broadly labeled externals or internals. For example, the differences between the two internal attribution styles, ability and effort, might be expected to affect options selection in either adaptive or maladaptive ways.

One early study (Fisher et al., 1976) treated various attributional variables as dependent variables under conditions of learner- and program-controlled problem selection. The authors found that subjects in the choice group made significantly more internal and stable attributions during or following instruction than did students in the program-controlled group. They also found no treatment differences for an attribution variable they called "control-no control;" but they do not provide an operational definition of this variable to aid interpretation. Additionally, even though these researchers did not take baseline measures of attribution, nor plot the changes in attributions occurring over time, their study still supports the short-term modifiability of attributions as a possible result of treatment variables.

Within J.M. Keller's *ARCS* model (1983, 1987a, 1987b), both attribution theory and learner-control would potentially play a useful roles when attempting to improve student *Confidence*. In some strategies, Keller suggests, students might receive attributional feedback to enhance the feeling of that "they can do it." Additionally, they could be given some degree of control over their learning situation to enhance feelings of their own self-efficacy. The attributional feedback would seem to apply mostly to situations under learner-control where students are asked to choose performance-related options. These options could include the selection of such specific instructional events as optional practice items, feedback, test situations, and possibly remediation or review following test conditions.

However, J.M. Keller's model is fairly non-specific about the types of attributional feedback which should be offered to students, and under which circumstances it would function optimally. Milheim and Martin (1991), too, suggest the utility of attribution theory for explaining the mixed effects found in the learner-control literature, but they, too, offer few specific suggestions for possible instructional design strategies which incorporate the theory.

Manipulations directed toward attaining these treatment goals would seem to fall into three classes of instructional strategies: 1) those affecting an entire lesson condition; 2) those preceding specific choice situations, taking the form of guidance, advice, or recommendations; and 3) those immediately following performance situations, taking the form of interpretations and attributions of success or failure generated by instruction.

In the first strategy class are included attempts to adapt instruction to whatever overall attributional style a person seems to possess. Here, diagnosis of attribution levels would take place once, prior to the start of the lesson. All instruction might by subsequently modified accordingly in the manner of an ATI.

Additionally in this class, instruction could at the outset inform the learner that they have control over what they see, and that their performance will be determined by how much they try. Given this, it would be necessary that the instruction monitor performance throughout the lesson and adjust task difficulty so as to minimize the discouraging effects of frequent failure.

Also in this class are manipulations related to task- or ego-involvement, as described earlier. Suggestions of norm-referencing (ego-involvement) could accompany students with high success rates. Examples would be general statements that a student's performance will be compared to others, or perhaps comments to the students that they did better than most people on a particular task. Low performing students might be best placed under task-involved conditions which encourage value placed on task improvement.

The second class also subscribes to a typical adaptive instruction paradigm, although here we are dealing with micro-instructional adaptations of task-specific attributions. In particular, strategies in this class are forward-looking, and include encouragement and advisement techniques such as those mentioned in the earlier section on achievement motivation. Some specific techniques might include recommending to the student they choose a task of hard (medium, easy) difficulty level depending upon what the student's current performance level and attributional tendencies are at the moment. They might also include such motivating statements such as "try harder on this one ...," or "the next task is an easy one ..." Another possibility might be to describe a subsequent task in terms compatible with the student's attributional style, but again on a very local level.

In the last class of instructional manipulations, the instruction could make evaluative and interpretive comments on a student's performance immediately following the success or failure of the task. The goal of these reflective or backward-looking instructional strategies is to intentionally alter attributions. Comments to the student might attribute failure to not trying hard enough, or when appropriate, to a task being difficult. Successful performance would always be attributed by the instruction to an internal factor. A study by Carrier et al. (1986) gave students a variety of backward-looking encouraging feedback (though not attributionally related) and found positive effects for task persistence. It is expected that feedback engineered more specifically to counteract maladaptive attributional patterns in the students would be even more fruitful.

A doctoral dissertation conducted by this author (Williams, 1992), examined the impact of attributionally related feedback on learners of differing attributional tendencies (or styles) within learner- and program- controlled conditions. The type of feedback employed in the study was specifically intended to affect a student's temporary perceptions of the causes of their learning successes and failures, that is their *attributions* of their performance outcomes, so to minimize the dysfunctional behaviors of learners with maladaptive attributional styles. Providing specific attributionally-related feedback to learners in an attempt to temporarily alter attributions has a well-established research base (Andrews & Debus, 1978; Barker & Graham, 1987; Borkowski, Weyhing, & Carr, 1988; Dweck, 1975; Fowler & Peterson, 1981; Graham & Barker, 1990; Medway & Venino, 1982; Meyer and Dyck, 1986; Schunk, 1982, 1983, 1990a; Schunk & Cox, 1986) which had hitherto not been investigated in a computer-based context.

Findings from the study generally support the notion that, overall, certain types of attributional styles are maladaptive. That is, students who exhibit such motivational patterns tend not to exert as much effort or mental investment in their learning activities, and thus are prone to perform poorly.

Additionally found in the study, the granting of a relatively small degree of learner-control within the CBI lesson succeeded in improving the performance of students who otherwise showed certain types of maladaptive motivational patterns. Also, students showing one type of generally maladaptive attributional style showed markedly improved performance when given such feedback following their on-task performances. In other words, giving attributional feedback moderated the maladaptive tendencies of these students.

A final finding from the study is more complex, but still interesting. Within program-controlled conditions, the inclusion of attributional feedback had the effect of improving learning for who normally exhibit dysfunctional attributional styles, but providing such feedback seems to have a deleterious effect on those who otherwise had functional attributional styles. Attributional feedback given to student under learner-control showed no such interactive effects; that is, students classed as having maladaptive styles performed, as expected, poorly and those with functional attributional styles performed well.

To summarize, the previous section posits that the general ineffectiveness of learner-controlled CBI can be explained, at least in part, by the fact that some learners have acquired maladaptive motivational tendencies, and as a result exhibit dysfunctional or suboptimal choices (e.g., showing low persistence or perseverance or terminating a lesson early). There is some evidence, although scant, that one particular motivational theory, namely attribution theory, can be exploited to improve the on-task motivational behaviors for learners within learner-controlled situations. The goal is to increase both motivation to achieve where such motivation is low and motivational patterns are maladaptive, and to help the student to optimize their selection of instructional support.

Summary

This paper has reviewed many studies comparing various forms of learner-controlled computer-based instruction with program-controlled CBI. These studies had been theoretically predicted to show learner-control superior to program-control. However, empirical findings related to these predictions have been disappointing.

A closer examination of these studies showed that a number of mediating factors were likely responsible for the poor performance under learner-control. It was found that many students simply were not capable of making good use of the control they were given. Two large categories of individual difference variables were suggested to be important in identifying these students: rationally-cognitively oriented variables and emotional-motivational variables.

In particular, both student prior knowledge and ability were found to predict student success under learner-control. Prior knowledge was found to be related to the capacity of the students to estimate the amount of instructional support they would need. (Students with low amounts of knowledge were not able to effectively monitor their comprehension.) Additionally, student ability was viewed as related to the learning strategies individual students bring to bear when faced with a learning problem. (Low ability students typically do not have the repertoire of learning strategies available to them that higher ability students do.) Some suggestions were offered for accommodating these differences within learner-controlled instruction.

The student's level of motivation was also found to be a potentially important variable in explaining the overall effects of learner-control. In particular, attributional theory was offered as an example of a well-grounded framework for understanding motivated student behaviors and effort and for adapting instruction to meet the needs of students with maladaptive attributional patterns.

In addition, this paper supports the utility of the adaptive instruction paradigm of Gehlbach (1979). In this framework, unlike the classic ATI approach of Cronbach and Snow (1977), students who are deficient in some relevant aptitude are administered an instructional treatment intended to "correct" the difficulty, not accommodate it. In the current case, students who exhibit suboptimal motivational patterns are provided with appropriate feedback in an attempt to encourage more healthy emotional self-perceptions and hence more functional behaviors.

Recommendations for future research

I believe it is now time to stop asking the research question "which is better: learner- or program-controlled CBI?" It seems that enough research has been produced to date to justify the conclusion of "take your pick." Rather, I would like to suggest that future researchers fundamentally alter the question to read, "How can I make learner-controlled CBI effective?" A study by Santiago and Okey (1992) which investigated various forms of advisement conditions all under learner-control provides a good example of how research might be conducted with the aim of improving learner-controlled instruction. Other specific issues which might be pursued include the following:

1. What specific instructional events are most or least amenable to providing or withdrawing learner-control? That is, of the many instructional strategies, methods, activities, and events from which designers may draw upon to build lesson designs, which ones are most promising? Theoretical work by Laurillard (1987), Milheim and Martin (1991), and Steinberg (1989) go a long way toward providing prescriptive guidelines for designers; however, more specific recommendations need to be explored. I would also like to strongly concur with Milheim and Martin's (1991) suggestion to conduct more empirical and theoretical work on the nature and role of learner motivations in learner-controlled CBI settings.

2. What exactly is the nature of a learner's mental processes as he or she proceeds through learner-controlled instruction? If we can better understand both the rational-cognitive thought processes and the emotional-motivational states of the learner, we might be able to devise means to encourage optimal processes and perhaps attempt to alter or at least compensate for dysfunctional processes. This type of investigation has been suggested before (Clark, 1984; Robson, Steward, & Whitfield, 1988) but has not yet been adequately pursued, perhaps because of the inherently qualitative nature of the data and the lack of comfort with such methodologies by learner-control investigators.

3. Related to the previous suggestion, it is time investigators more closely examined the social nature of learner-controlled activities. Anyone who has observed classroom situations where students navigate through instruction has informally noticed that there can be a great deal of discussion between students, both sitting at separate computers and working at the same computer. Rather than attempt to eliminate such interactions in order to investigate the "pure" effects of learner- or program-control, researchers may wish to adopt methodologies closer to field-studies or naturalistic inquiry to study how learners can feed off each other during instruction.

4. Learner-control should be much more closely investigated under other common or developing types of computer-based environments, such as: simulations; hypermedia and other online databases (such as electronic encyclopedias); online help and other support tools; and distance education. All of these contexts (possibly excepting distance education), by definition, intrinsically allow learner-control to a greater or lesser degree. And it is likely that these types of computer-based experiences will soon be more frequent experiences for students than standard tutorials. However, very little research has been conducted to sort out the peculiar learner-control factors in each which need attention or support.

5. There needs to be a greater link make between learner-controlled CBI research and a growing body of literature on the topic of *self-regulated learning*. Briefly, this research, developed by

McCombs and associates (McCombs, 1982, 1984; McCombs & Marzano, 1990) and by Zimmerman and associates (Zimmerman, 1990; Zimmerman & Martinez-Pons, 1986, 1988, 1990), conceptualizes students as "metacognitively, motivationally, and behaviorally active participants in their own learning processes" (Zimmerman & Martinez-Pons, 1988, p. 284). Although the research so far has primarily focused on understanding on a rather macro level the mental strategies occurring during successful self-regulated learning, this literature has clear implications for the inclusion of motivational variables in the design of learner-controlled instructional systems. In fact, some investigators have recently begun to explicitly address motivational variables operating in self-regulated learners (e.g., Schunk, 1990b; Zimmerman & Martinez-Pons, 1990). Additionally, there is beginning to emerge an interest in the application of self-regulated learning models to other formats of CBI, such as computer programming (Armstrong, 1989).

Conclusion

Lepper and Chabay (1985) succinctly summarize the problem of differentially providing learners with control over their own instruction, "It is unlikely that any choice of level of control will be optimal for all students, or even that the same level of control will be optimal for a single student for all activities or in all situations" (p. 226). Of the many approaches for accommodating differences among learners, one is to allow them to adapt the instruction themselves to meet their own needs as they see fit. Instruction would not be linear and lockstep; that is, all students could receive different instructional events. This strategy is not as highly prescriptive or determined or complicated as branching or other adaptive schemes sometimes found in computer-based approaches. Rather, learner-control is a way of allowing individual differences to exert a positive influence without trainer control or intervention based on these individual differences. However, great care needs to be exercised by designers in constructing their learner-controlled lessons to optimize effectiveness for *all* types of learners.

In sum, after all that has been written about the virtues of giving trainees control over their own learning, such activities alone offers no guarantee of successful learning. This might have been forecast by Dewey, that strong proponent of experiential education, who voiced concerns about unconditional learner self-management, "The ideal aim of education is creation of the power of self-control. But the mere removal of external control is no guarantee for the production of self-control." (1938, p. 64).

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