What does the Literature Say about the Effectiveness of Learner Control in Computer-Assisted Instruction?

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Abstract

Each year, a substantial portion of educational institutions' budgets are allocated to supporting the integration of computers into instruction under the assumption that computers benefit teaching and learning, and can improve student academic performance. Educational research and practice, however, demonstrate that different ways of integrating computer technology and the context in which computers are used have varied effects on student learning. This article explores computer-assisted instruction (CAI), a learning environment that supports a one-on-one interaction between a learner (or several learners) and a computer program. It also demonstrates how the two polar characteristics of CAI, which indicate whether the learner or the program has primary control over the content and direction of instruction--learner control (LC) and program control (PC)--affect instructional delivery and outcomes. While trying to explain the inconsistency of research findings, the article argues that LC theory needs a stronger theoretical framework in order for LC studies to yield more definitive conclusions about the effectiveness of LC and CAI in general.

The Nature of Learner Control

Concerned about the quality of American education, researchers and educators have evaluated existing educational practices and are interested in exploring new instructional methods. Technological advances and the relatively low cost of computers and software make computers a reality for many American classrooms (U.S. Department of Education, 2000). This technology "invasion" raises the issue of how to effectively apply the technological advances in teaching and instruction. Computer-assisted instruction (CAI), the focus of this article, is one of the most common forms of integrating computers into the instructional process. CAI is a learning environment that supports a one-on-one interaction between a learner (or several learners) and a computer program (Hoska, 1993). CAI is frequently used to remediate or advance student knowledge and skills (e.g., "self-learning" and encyclopedic programs; "drill-and-practice" and simulation software) or to entertain them (e.g., computer games) (Schwier & Misanchuk, 1993).

Different types of educational software used in CAI vary, however, in the amount of learner control (LC), the characteristic of a computer program that allows learners to make instructional choices (Filipczak, 1996; Schnackenberg & Hilliard, 1998). For instance, "drill-and-practice" software usually does not facilitate learners' initiative and creativity because learners have to do the same types of assignments repeatedly until a targeted skill is mastered. In contrast, some types of simulation software and other types of interactive programs provide a "rich" LC environment. Freedom to modify screen design and text density, to choose or omit specific topics (including control over the amount of instruction), to sequence material, to apply learner advisement strategy (taking a test immediately and omitting a topic review or reviewing first and then taking the test) are all instructional choices or LC options (Chung & Reigeluth, 1992; Large, 1996; Niemiec, Sikorski & Walberg, 1996). Thus, non-linearity and flexibility are distinctive characteristics of LC (Burke, Etnier & Sullivan, 1998; Lawless & Brown, 1997).

While much research has been done to investigate the impact of LC on learning, very little is known about its nature (Chung & Reigeluth, 1992; Milheim & Martin, 1991). According to Zazelenchuk (1997), LC is one of the six ingredients or components of interactive multimedia [1], programmed web-based features that adequately respond to students' inquiries. Two other researchers, Lawless and Brown (1997), emphasize that LC is only one of the types of control in CAI. In particular, they distinguish two types of control--external (program control or PC) and internal (learner control or LC)--and refer to the former as the specific limits set by a multimedia computer program with which all users have to deal.

It is commonly accepted in the field that there are no completely intelligent computer programs (El-Tigi & Branch, 1997; Gilbert & Moore, 1998; James, 1998; Kirsh, 1997) or, in other words, none of the existing computer programs gives full LC to its users. All computer programs that are currently available on the market integrate elements of both LC and PC. Thus, computer programs differ only in the types and amount of LC they utilize (Hannafin, 1989; Reeves, 1993).

In this regard, it appears important to examine whether LC is beneficial for students, especially for their academic performance and motivation, and in what amount. To answer these questions, the researcher consulted an extensive number of resources devoted to LC. Because technological advances opened new horizons in LC and because "LC hardly seems a fixed or static idea" (Niemiec, Sikorski & Walberg, 1996, p. 157), this article relies on the most recent LC literature to examine the major attributes of the LC concept and LC research findings.

Analysis of Research Findings: Do Students Benefit from LC?

Formal research of LC started at the end of the 1950's and has generated a large body of work. Developmental and cognitive psychologists, instructional technologists, and educators have studied LC in a variety of learning environments such as presentation, collaborative and navigation settings (Chung & Reigeluth, 1992), and with different populations: secondary school students (Burke, Etnier & Sullivan, 1998; Rubincam & Olivier, 1985), college students (Becker & Dwyer, 1994; Crooks, Klein, Jones & Dwyer, 1996; Murphy & Davidson, 1991; Schnackenberg & Sullivan, 2000) and adults (Shute, Gawlick & Gluck, 1998). However, only some of these studies (e.g., Chung & Reigeluth, 1992; Crooks et al., 1996; Friend & Cole, 1990; Milheim & Martin, 1991; Schnackenberg & Sullivan, 2000) controlled for specific LC components/variables (content, sequence, pacing, internal processing, advisory). In addition, a few other studies, including one by Cho (1995), merely focused on comparing LC instructional approaches with traditional teaching approaches.

Generally, research indicates that LC may be an excellent tool for adapting a learning environment to students' needs (e.g., Friend & Cole, 1990), that LC can empower learners (Schweier, 1993), and that students whose learning style preferences were matched by a computer or a teacher achieved higher test scores, had better understanding, retained their knowledge and skills longer and were highly motivated to succeed (Friend & Cole, 1990; Schnackenberg & Hilliard, 1998; Spoon & Shell, 1998). These optimistic findings should, however, be interpreted with caution. LC is not uniform; its three major components--content, sequence and advisory control--vary in their effects on student performance and motivation.

Content Control

Content control may benefit students in multiple ways. For example, Chung and Reigeluth (1992) discern that content control enables students to set their own learning objectives. They emphasize that students with advanced knowledge or greater ability may be bored with repeating what they have already mastered, and that these students benefit more if they are allowed to choose content that is relatively new and appealing to them. Students who need some extra time to work on a topic or need to review previous topics can also find content control useful because it allows learners to establish better connections between relevant topics (Chung & Reigeluth, 1992). Thus, one of the major advantages of content control is that it supports on-demand, self-paced learning.

LC literature identifies two primary approaches to integrating content control in multimedia instruction: full-minus and lean-plus types of control. In the former approach, a computer program allows students to bypass some topics, while in the latter, a program initially offers few topics but learners have the opportunity to add some or all "optional" topics (Crooks et al., 1996). In Crooks et al.'s (1996) and Schnackenberg and Sullivan's (2000) studies, full-minus and lean-plus types of control were compared with regard to their effect on student test scores and task engagement (motivation).

In Crooks et al.'s study (1996), 128 undergraduate education major students were randomly assigned to one of the four groups based on a 2 x 2 cross-factorial design. The groups varied in instructional methods (cooperative and individual) and two approaches to LC (full-minus and lean-plus). The two major findings of that study were that lean-plus students utilized more LC than their full-minus counterparts (while lean-plus students selected 56% of the optional elements, full-minus participants bypassed only 17% of optional elements) and that full-minus learners performed significantly better on a practice test than lean-plus learners. However, students' post-test scores were not found to be statistically significantly different for either LC mode or instructional method. Also, the study did not discern which of the two LC approaches benefited students more in the long run.

Schnackenberg and Sullivan (2000) also used a randomized 2 x 2 factorial design with two conditions (LC, PC) and two instructional models (full, lean). In their study, 202 college students who used a full-minus program performed significantly better on the post-test than those who used a lean-plus program. Like Crooks et al. (1996), they found that LC promotes the exploration of more optional screens. In Schnackenberg and Sullivan's (2000) study, lean-plus learners explored 68% of the optional screens and full-minus learners viewed only 35% of them. Their study also revealed that students valued more LC than PC.

Sequence Control

Sequencing is a very common type of LC, especially for multimedia programs. Sequence control allows learners to navigate/choose in what order they prefer to study subtopics, and therefore it may be perceived as promoting flexible and inventive thinking and supportive of students' intrinsic interest for a subject they study (Cho, 1995). Empirical research provides, however, mixed findings with regard of sequence control affecting student learning. In Gray's (1988) study, for example, while learners who used multimedia with a high level of the sequence LC performed better than those who used more PC multimedia with a low level of sequencing, their knowledge retention was virtually the same. Furthermore, students from the LC group showed a more negative attitude toward CAI than those from a control group. In Burke, Etnier and Sullivan's (1998) research, study participants--89 5th grade students who were randomly assigned to one of the following conditions: navigation aids with LC, navigation aids without LC, LC without navigation aids and PC without navigation aids--also preferred moderate amounts of sequential control. More particularly, their study demonstrated that students favored more the program that enabled them with LC and provided navigation aid. The researchers did not find any statistically significant difference in post-test scores and the time spent for instruction for these four experimental groups.

These two studies demonstrate that student knowledge retention and time on task (in this case, time spent on using a computer program) are not affected by sequence LC, and that better post-test scores or attitudes toward CAI associate with modest amounts of sequence control in CAI.

Advisory Control

Two distinct approaches exist for defining advisory control. According to Niemic, Sikorski and Walberg (1996), advisory control means that a program advises students of their progress and suggests a course of action, which may be adopted or ignored by learners. Murphy and Davidson (1991) used this definition for their study in which 44 nursing students were randomly assigned to one of the following conditions: LC, adaptive LC strategy (in their paper, adaptive LC was defined as PC) and learner advisement strategy. The study indicated that students who used LC strategy spent less time to complete their instruction. However, no significant difference was found in the immediate recall, intermediate and long-term retention of the concepts that were studied by the students.

Rubincam and Olivier (1985) offered a different interpretation of the advisory control concept. They perceived advisory control as an option for learners to select learning objectives and to start from instruction or a test. For their study, Rubincam and Olivier chose six classes of high school students who were taking a mathematics course on coordinates and transformation. The results of the post-test did not provide evidence for LC improving student performance in CAI. However, students who were consistent in selecting the strategy scored significantly higher than other students.

Although both studies demonstrated that students who use advisory control needed less time to complete instruction, they did not confirm that students under advisory control performed better or have better retention. The personal characteristics of students may perhaps predict higher test scores better than LC conditions.

LC and Students' Academic Performance and Motivation: Is there any Effect?

Academic Performance

The dispute on the effectiveness of LC to improve academic performance (mainly test scores) has not been settled. Indeed, there is some evidence that CAI has a positive impact on students' academic performance. For example, Schacter (1999) disclosed the findings of Kulik's (1994) meta-analysis of 500 studies on CAI. Kulik found that the test scores of students who used CAI were at the 64th percentile compared to the 50th percentile for students who did not use computers in the classroom and that CAI allowed students to learn more in less time.

Since LC is only one of the many attributes associated with CAI, it is unjustified to conclude that LC has a positive impact on students' academic achievement. This conclusion can be warranted only if shown that LC consistently improves students' scores. The studies reviewed in this article do not show this consistency. While the studies conducted by Crooks et al. (1996), Burke, Etnier and Sullivan (1998), and Rubincam and Olivier (1985) did not find any influence on the post-test performance of students, Schnackenberg and Sullivan (2000) and Gray (1988) indicated students' post-test scores significantly improved. Thus, the impact of LC on students' academic performance is not as clear.

Motivation and Attitude toward Learning

In 1998, Silivan-Kachala used 219 research studies on CAI for a meta-analysis. The meta-analysis revealed that CAI improved students' attitudes toward learning and their self-conceptions (cited in Schacter, 1999). Again, this fact does not allow us to generalize that LC itself motivates students. Perhaps, the increase in motivation and the improvement of self-conception are caused by other factors associated with CAI, not with LC. Therefore, it is important to examine whether other studies were able to detect shifts in motivation and attitude toward learning in LC environments.

Becker and Dwyer's (1994) study investigated the impact of increased LC on students' intrinsic motivation for a learning task. The participants of the study, 44 students majoring in accounting, management, or in both completed two self-paced sessions in which they used two multimedia programs. The multimedia programs allowed learners to choose their own paths. The study found that students who used hypertext programs were more self-determined and their intrinsic motivation was higher than those students who used paper-based resources to study.

In contrast, Cho's (1995) study, in which 20 undergraduate students used a HyperCard environment, found no overall difference in cognitive processes between students in LC and PC groups. Moreover, it also confirmed the hypothesis that multimedia materials embedded with a high degree of LC could be inappropriate for low ability students.

Thus, the analysis signifies that there is no consistency in the way LC influences students' motivation and attitudes toward learning. Generally spoken, the studies can be divided into three groups: those that did not find any effect of LC on students' motivation and attitudes toward learning (e.g., Cho, 1995), those that found a positive effect (Becker & Dwyer, 1994), and those that found a negative effect (e.g., Gray, 1988).

One may argue that for this literature review, the author purposely chose controversial studies but, in reality, the studies that showed a positive effect of LC on all sorts of learning outcomes outnumber other studies. Indeed, many researchers who report their studies tend to review only those studies that show a positive effect of LC, but many of them then fail to replicate the results (e.g., Shute, Gawlick & Gluck, 1998). In fact, in a meta-analysis Niemiec, Sikorski and Walberg (1996) summarized 24 studies of LC which had all of the necessary parameters reported. The studies were grouped according to subjects' gender, grade level, ability, type of LC (e.g., sequencing, pacing, reviewing, feedback, additional instruction and practice), and type of outcome (e.g., post-test, retention). However, neither of these categories had an overall positive significance at the .05 level. Thus, the research studies on LC fail to confirm or disconfirm anything. Consequently, there are no right answers on whether LC is beneficial for students and whether a higher degree of LC implied in a computer program improves instructional effectiveness.

Explaining the Inconsistency of LC Research Findings

Analysis of the literature has revealed that the theory of LC is unfinished (Large, 1996), and that research findings are controversial. Becker and Dwyer (1994, p. 169) discerned three possible explanations of why so many studies failed to find positive effects of LC. They stressed that LC is often presented to students improperly, and therefore is not helpful to them; that some students do not realize that they have LC available to them; and that students may not know how to take advantage of LC options. For instance, Chung and Reigeluth (1992) recognized that LC of content is unsuitable when all topics of instructional presentation are required in order to successfully pass the final test, or when the sequence in which material is learned is important to understanding the entire topic. They also did not recommend the use of sequence control for topics in which learners have no prior knowledge. As Large (1996, p. 104) stated, "while some students may gain educational benefit from this freedom, others may suffer as a consequence of being handed such control over their learning". Lawless and Brown (1997) also found student prior knowledge influencing the effectiveness of LC. They argued that "all students appear to benefit from LC opportunities, but those with higher content domain experience and/or ability may benefit the greater" (p. 120).

An excessive targeting of younger and inexperienced learners is one of the drawbacks of empirical studies on LC. Research suggests that the age of participants may relate with how LC affects instructional outcomes. In fact, slightly more research shows a negative effect of LC when it is utilized in teaching elementary students as opposed to older students and adults

(Large, 1996). Perhaps younger learners cannot adequately respond to LC because their developmental level is not ready to comprehend LC features. Large (1996) referred to the study by Hannafin (1984) who reported that younger and inexperienced learners often lack focus and are distracted from learning objectives and that LC impedes rather than improves their learning outcomes.

Many studies on LC were done under the assumption that the positive effect of LC is so obvious and powerful that even a brief experience with LC in CAI will benefit learners. Reeves (1993) condemned researchers for designing studies in which students worked under LC conditions for less than an hour, and for choosing classrooms in which LC and CAI were not common attributes of instruction.

Another reason why LC research is so severely criticized in the literature (e.g., Reeves, 1993) is that LC theory has problems defining and measuring LC. Currently, no valid and reliable instruments exist to assess the quantity and quality of LC (Goforth, 1994). If researchers had such instruments, they would be able to create a scale of the effects associated with various levels and types of LC. Indeed, all existing studies on LC have failed to control for quantity of LC. As argued by Reeves (1993), learners are not ready to absorb *any* level of LC. In fact, he and others found anecdotal evidence indicating that the need for LC varied for novices and experts in the subject matter, for inexperienced and advanced computer users and for students with different learning potentials. It was also found that students' personalities also affect the amount of LC they are able to absorb and benefit from (Barnard, 1992-93; Chung & Reigeluth, 1992; Friend & Cole, 1990; Goforth, 1994; Schwier, 1993).

As noted by Large (1996), learners are not homogeneous; their personal characteristics, prior knowledge, abilities, needs and goals are unique. Since the "effectiveness of LC in any study is particularly dependent on the profile of the learner population…." (Goforth, 1994, p. 1), "failure to match the learners' preferences with the type of LC which [students] were given" (Burke, Etnier & Sullivan, 1998, p. 193) may explain the inability of LC research to validate the effectiveness of LC.

Implications for future research and practice

The analysis of the existing literature about LC does not confirm that LC is beneficial for students and that a higher degree of LC implied in a computer program improves instructional effectiveness. The research findings range from the strong positive effect of LC to no effect or even a negative effect on learning outcomes, students' academic achievement and motivation. Contradictory findings were found for all of the three components of LC that were examined: content, sequence, and advisory controls.

The large variability of conditions in which studies were conducted makes the research findings difficult to compare (Goforth, 1994; Schacter, 1999). Study design (e.g., the length of intervention, control of independent variables), personal characteristics of students (e.g., age, ability, computer expertise), the subject area and other specifics of CAI, and the most important, researchers' theoretical standpoints with respect to how they define LC and its components, are all factors that have to be considered when analyzing studies on LC and its effectiveness on student learning.

LC should certainly be investigated further, but a stronger theoretical framework is needed in order for LC research to yield more meaningful conclusions about the effectiveness of LC. Perhaps, LC is not as effective as we would like. Moreover, it is more costly to design and implement LC than PC (Schnackenberg & Sullivan, 2000). However, if we determine the ideal conditions for implementing LC, we can discover that LC is cost effective. Until then, implementing LC in CAI should be done with some caution, but not at the cost of limiting the use of LC to those unimportant components of instruction that have little effect on instructional outcomes (Schwier, 1993). As indicated by Chung and Reigeluth (1992), "all instruction involves some LC, [and] our challenge is NOT whether or not learner control should be used, BUT rather *how* to maximize the learner's ability to use the LC available and to decide what kinds of LC to make available" (p. 19, original emphasis).

While developing stronger theoretical grounds for LC and conducting other studies in this area may take some time, it is also understood that those who use CAI in their teaching need immediate advice on how to use LC more effectively. The literature on LC does not provide a magic formula for that, but gives several recommendations. Perhaps one of the major conditions for the successful integration of LC in CAI is to have instruction carefully pre-planned (Burke, Etnier & Sullivan, 1998). According to Hannafin (1984), several conditions should be present in order for LC to have a greater chance for success: "the learners are older; the learners are more able; the educational objective is to impart a higher order of skills rather than factual information; the content is familiar, advisement is provided to assist learners in making decisions; learner control is used consistently within a lesson; it is possible to switch unsuccessful learners from LC to PC; and LC is combined with evaluation to facilitate the re-design of the program based on the paths chosen by effective learners" (cited in Large, 1996, p. 103). Finally, educators should recognize that students need to be taught to take advantage of LC that is implemented systematically in conditions that are natural and friendly for learners, in order for LC to promote better instructional outcomes.

Contributor

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Note

[1] The other five components of interactivity are active learning environment, feedback, multiple media, learner response option, and adaptability.