British Journal of Educational Technology *Vol 38 No 4 2007* 623–636
doi:10.1111/j.1467-8535.2006.00670.x

The impact of instructional elements in computer-based instruction

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Abstract

This study investigated the effects of several elements of instruction (objectives, information, practice, examples and review) when they were combined in a systematic manner. College students enrolled in a computer literacy course used one of six different versions of a computer-based lesson delivered on the web to learn about input, processing, storage and output of a computer. The six versions of the program consisted of (1) a full version that contained information plus objectives, practice with feedback, examples and review, (2) a version without objectives, (3) one without examples, (4) one without practice, (5) one without review and (6) a lean version containing information only. Results indicated participants who used one of the four versions of the computer program that included practice performed significantly better on the posttest and had consistently more positive attitudes than those who did not receive practice. Implications for the development of computer-based instruction are explored.

Introduction

For many years, advocates of the systems approach to design have indicated that an effective instructional program includes elements such as pre-instruction, content presentation, learner participation and follow through (Dick, Carey & Carey, 2005; Reiser & Dick, 1996; Sullivan & Higgins, 1983). Pre-instructional activities are used to motivate learners and inform them of the objectives of a lesson. Content presentation provides learners with information and examples directly related to the objectives of the program. Learner participation allows students to practice skills and knowledge taught in the program and is usually combined with feedback. Follow-through activities such as a review of key information are used to help learners retain their new knowledge.

These elements represent desirable conditions in an instructional program and increase the probability of successful learner achievement. Each element has been the subject of a substantial body of research. However, many of these elements may produce a much different effect when they are studied individually than when they are combined into a more complete set. As Hannafin (1987) noted, some design strategies that have positive effects when used in isolation may be diminished or negated when used in combination with more powerful techniques.

A research design that incorporates the elements of instruction into a complete version of an instructional program, and then systematically deletes selected elements from other versions, has the potential to identify the elements that are effective in promoting student learning. That type of design was used in the present research. The elements that were directly incorporated into the present study were objectives, information, examples, practice with feedback and review. Research literature on each of these elements is briefly reviewed below.

Objectives

An instructional objective is a statement that describes an intended outcome of instruction (Mager, 1962). According to Ausubel (1968), stating an objective at the beginning of instruction will help the individual learners to structure their own learning. Reiser and Dick (1996) state that, 'At a fairly early stage, learners should be informed of what it is that they are going to be able to do when they finish the instructional process. By knowing what will be expected of them, learners may be better able to guide themselves through that process' (p. 48).

Some researchers have found that instructional objectives improve learning. Kaplan and Simmons (1974) reported that performance on information relevant to an objective was high when instructional objectives were used as orienting stimuli or as a summary/review upon prose learning. Staley (1978) found that the provision of objectives facilitated learning but that presenting objectives by subsets had no advantage over presenting the entire set at once. Research on effectiveness of objectives in computer-based cooperative learning indicated that students who received instructional objectives performed significantly better on posttest items than students who received either

advance organizers or no orienting activities (Klein & Cavalier, 1999). Studies have reported that objectives enhance learning of relevant content, but provide less assistance for incidental learning. (Kaplan & Simmons, 1974; Morse & Tillman, 1972; Rothkopf & Kaplan, 1972). Research has also indicated that inclusion of objectives resulted in more positive student attitudes (Staley, 1978).

Some researchers have found that objectives do not produce a significant difference in learning (Filan & Gerlach, 1979; Hartley & Davies, 1976). Hannafin (1987) found that when computer-based instruction was systematically designed, the presence of objectives did not make a difference but that it did influence performance in lessons that were not well designed. Research has also indicated that the benefits of objectives are reduced when a more powerful instructional element such as practice is included in computer-based lessons (Hannafin, 1987; Hannafin, Philips, Rieber & Garhart, 1987; Philips, Hannafin & Tripp, 1988).

Information

According to Forcier and Descy (2002), 'every learning environment has an implied method of information presentation' (p. 104). During this event of instruction, students encounter the content they will be learning either in a didactic form or through a discovery approach (Smith & Ragan, 1999). All models of direct instruction include strategies for presenting didactic information to students. A significant part of direct instruction involves presenting students with the necessary information for learning (Reiser & Dick, 1996). A designer or teacher determines the information, concepts, rules and principles that will be presented to students (Dick *et al.* 2005). Information that is necessary to perform the task stated in an objective is presented in a straightforward manner (Sullivan & Higgins, 1983).

Gagne (1985) stresses the importance of emphasizing information presented to the learners. He indicates that distinctive features of what is to be learned should be emphasized or highlighted when the information is presented. Content presented should be chunked and organized meaningfully (Kruse & Kevin, 1999). In computer delivered instruction, information can be displayed using text and graphics and attention focusing devices such as animation, sound and pointers can be used (Wedman, 1986).

Practice with feedback

Practice is defined as the event of instruction provided to learners after they have been given information required to master an objective (Gagne, 1985). Practice involves eliciting performance from learners. It provides an opportunity for learners to confirm their correct understanding, and the repetition also increases the likelihood of retention (Kruse & Kevin, 1999). Practice is effective when it is aligned with the assessment in the form of a posttest and with the skills, knowledge and attitudes reflected in the objectives (Reiser & Dick, 1996).

Researchers have found that practice has a significant effect on performance. Hannafin (1987) reported a significant difference between practiced and non-practiced items on

the learning of cued and uncued information presented via computer-based instruction. Phillips, Hannafin and Tripp (1988) found a significant difference favouring practice over no practice in an interactive video in which practice items were embedded questions. Hannafin *et al* (1987) noted that practice effects were more pronounced for facts than for application items in computer-based instruction. Participants who received intellectual skills practice in a cooperative learning environment performed significantly better than those who received verbal information practice (Klein & Pridemore, 1994).

Practice provides an opportunity for feedback that confirms the student's answer as being correct or indicates that it is incorrect. This feedback strengthens the probability of correct responses and reduces the probability of subsequent incorrect responses (Philips *et al*, 1988). Simple forms of feedback are effective when learners are able to answer items correctly. More elaborate forms such as providing and explaining the correct answer and explaining why a wrong answer is incorrect are helpful when learners answer incorrectly (Kulhavy, 1977). Simple forms of feedback are most effective for simple verbatim and verbal information types of learning (Kulhavy, White, Topp, Chan & Adams, 1985).

Examples

Examples are verbal or graphical information that provides additional clarification of rules or information presented to learners. Kruse and Kevin (1999) include examples, non-examples, graphical representation and analogies as guidance strategies that can be used to further clarify new content ie presented.

Few studies have been conducted to examine effects of examples in a graphical representation form. Sullivan and Maher (1982) found a significant difference favouring the use of imagery over no imagery in prose learning by intermediate grade students. Walczyk and Hall (1989) reported a significant difference for participants who received examples over those who did not in comprehension assessments. Freitag and Sullivan (1995) found that adults who received examples in a training program significantly outperformed those who did not. A considerable amount of research has been conducted recently on the effects of worked examples as an instructional aid (Atkinson, Catrambone & Merrill, 2003; Atkinson, Renkl & Merrill, 2003; Renkl, Stark & Gruber, 1998).

Review

The review process typically provides an outline of the key information that was presented to learners. It is intended to reinforce learning, at the end of the instruction, often just before students are tested. Reiser and Dick (1996) cite the value of reviews to bring closure to instruction and to help reinforce the skills and knowledge that students should have acquired.

Research has suggested that reviews benefit learning of incidental material because instructional stimuli are introduced after the content has been presented and initially

processed (Kaplan & Simmons, 1974). The use of reviews to summarize salient information has been shown to enhance learning (Hartley & Davies, 1976). In studies on prose learning, reviews of relevant information yielded significantly better performance than when the information was presented without review (Bruning, 1968). Lee (1980) examined the effects of different types of review questions and found that difficult review questions can effectively facilitate the retention of these skills. Petros and Hoying (1980) examined the influence of review on delayed retention of prose passages and found that repetition of the original learning experience was the most effective review treatment.

The purpose of the current study

Many of the studies reported in the previous sections were conducted to examine a single instructional event. In general, these studies found that the presence of the event resulted in a positive effect on student learning. It was also noted, however, that the impact of some of these elements may be reduced considerably when they are combined with other elements into a more complete and generally more appropriate program of instruction.

The current study examined the impact of objectives, information, practice, examples and review when they were combined in a systematic manner in computer-based instruction in order to examine the effectiveness and efficiency of the design of the program. The primary research question was 'Which elements of instruction investigated in the study significantly affect student achievement and attitudes?'

Method

Participants

Participants were 256 freshman and sophomore undergraduate students enrolled in a computer literacy course at a large university in the south-western US. The students enrolled in this course had varied background knowledge on computers and were from different majors including education, communication, journalism and others.

Materials

Six different versions of a computer-based lesson on the topic 'input, processing, storage and output (IPSO) of a computer' were developed using Dreamweaver. IPSO explains the primary operations of the computer. An introduction section was included before the primary operations were explained in detail. This section introduced what a computer is and classified it based on size, power and generation. It also explained the IPSO cycle. The next four sections described the concepts of the IPSO operations in a computer and explained the function of the different components associated with that operation. The content used in this study was part of the required content for the course. The computer-based lesson was pilot tested with five students before it was used in the study.

The material was designed in six different versions that included various combinations of instructional elements. The six versions consisted of (1) a full program

(information + objectives + practice with feedback + examples + review), (2) a program without objectives, (3) a program without examples, (4) a program without practice, (5) a program without review, and (6) a lean program (information only). The screens included for each of these instructional elements are briefly described in the following sections.

Objective screens

The five objective screens, one screen per section, listed the objectives for each section of the lesson. The objective screens ranged from 79 to 82 words per section with an average number of 80 words per screen.

Information screens

A total of 14 information screens contained the knowledge for understanding the hardware of the computer (computer classification, IPSO cycle, IPSO operations). The information screens ranged from 223 to 576 words in length with an average of 344 words per screen.

Example screens

The examples were graphical representations of the knowledge on the hardware of the computer that was explained in words in the information screen. These example graphics were inserted into each of the information screens.

Practice screens

The practice screens provided students with an opportunity to practice the content they were learning. There were a total of five practice screens, each of which contained five four-choice multiple-choice questions. The student received immediate feedback after each response to a practice item. Students had the option to practice until they got the right answer. One practice screen was presented after each information screen. The practice screens ranged from 135 to 203 words, with an average of 164 words. One example from the five items on a practice screen is shown in Figure 1.

Review screens

The review screens contained a short description of the information from the information screens. One review screen was placed after each practice screen. The review screens ranged from 102 to 172 words, with an average of 130 words.

Procedures

Eighteen sections of students ($n = 256$) enrolled in the computer literacy course were randomly assigned to the six treatment groups based on pretest scores. The pretest, which took approximately 15 minutes to complete, was administered three weeks prior to the study. The classes were blocked into three groups (high, medium and low) based on their mean pretest scores, and one class within each block was randomly assigned to each of the six treatments.

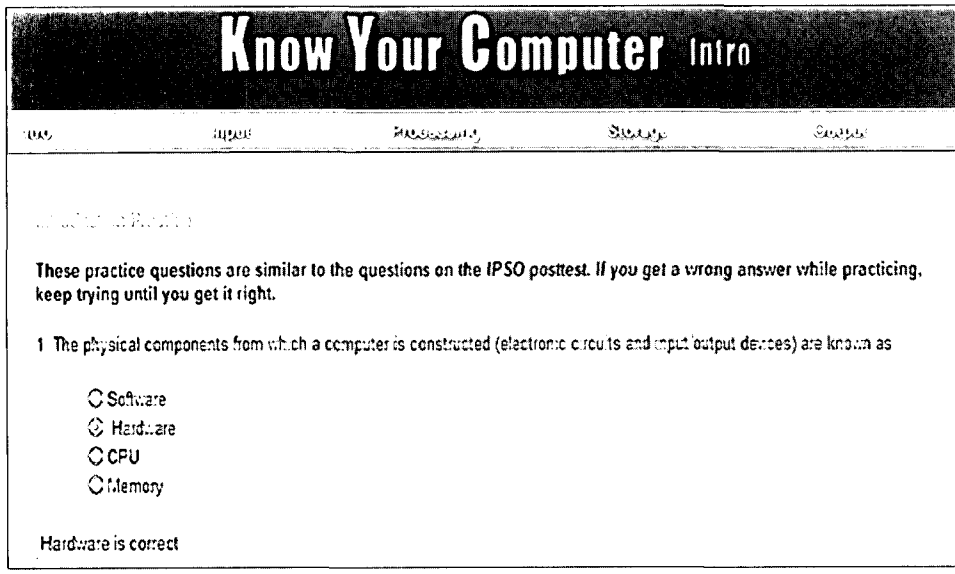

Figure 1: Practice screen in the IPSO web lesson

The participants used the computer-based IPSO lesson during the sixth week of the semester. Participants met in a regular computer lab for instruction and were directed by the instructor to the web address for the instructional program. Each class was routed directly to its treatment version of the program. Students worked through the program at their own pace, averaging approximately 1 hour. Then, they took the posttest and the attitude survey online. All six treatment groups followed the same procedure. Thus, the experimental differences in treatments occurred exclusively in the materials themselves and not in the procedure.

Criterion measures

The criterion measures consisted of a posttest and a student attitude survey. In addition, a pretest was used to assess subjects' knowledge of the content prior to the instruction and to randomly assign classes within ability blocks to treatments.

Pretest

The pretest consisted of 20 multiple-choice questions covering the content of the lesson. The overall mean score on the pretest was 8.68 or 43%, indicating that participants were not very knowledgeable about the content prior to instruction. A one-way analysis of variance (ANOVA) revealed that there were no significant differences across the six treatment groups in pretest scores.

Posttest

The posttest consisted of the same 20 multiple-choice questions that were on the pretest. It was judged to be unlikely that the pretest would have an effect on posttest scores

that could be a threat to validity because of the three-week interval between test administrations and because feedback was not given on the pretest. The reliability of the posttest was 0.65.

Attitude survey

The attitude survey assessed student attitudes towards the instructional program and the presence or absence of the instructional elements. The survey included 12 Likert-type questions that were rated *strongly agree* (scored as 4) to *strongly disagree* (scored as 0). The survey also included two open-ended questions that asked the participants what they liked best and least about the program. The survey was administered after the lesson and the posttest were completed. The reliability of the attitude survey was 0.98.

Data analysis

A one-way ANOVA was conducted to analyse the posttest data for statistical significance. A multiple analysis of variance (MANOVA) was conducted on the 12 attitude questions. Both analyses revealed significant differences. Therefore, Scheffe tests were performed for both data sets to test for significance between groups. Alpha was set at 0.01 for all statistical tests because of the large number of comparisons.

Results

Achievement

Table 1 shows the mean scores and standard deviations by treatment for achievement on the posttest. The table shows that the mean scores for participants in four of the treatments (full program, program without objectives, program without examples and program without review) were above 17 items correct, whereas the scores for participants in the other two treatments (program without practice and lean program) were below 15 correct. The table also shows that the mean posttest score across all six treatments was 16.44 items correct.

A one-way ANOVA conducted on the posttest data yielded a significant difference between the treatment groups on the posttest, $F(5, 250) = 11.689$, $p < 0.01$. Follow-up Scheffe tests revealed that each of the four groups with means scores above 17, as listed above and shown in the table, scored significantly higher than the two groups

Table 1: Means and standard deviations (SD) for posttest scores by treatment

Treatment	*Mean*	*SD*
Full program	17.61	1.99
Program without objectives	17.36	1.75
Program without examples	17.16	2.34
Program without review	17.17	2.76
Program without practice	14.98	2.66
Lean program	14.73	3.21
Total	16.44	2.75

Note. Maximum possible score was 20.

identified above that scored below 15. There were no significant differences between the four groups scoring above 17 or between the two scoring below 15.

Attitudes

Table 2 shows means for responses to the 12 Likert-type items on the attitude survey. The items were rated on a 5-point Likert scale from *strongly agree* (scored as 4) to *strongly disagree* (scored as 0).

A MANOVA conducted on the overall attitude data revealed a significant overall difference on the 12 attitude questions, F (60, 1188.48) = 12.98, $p < 0.01$. Follow-up univariate analyses indicated significant differences on 11 of the 12 attitude survey items at the $p < 0.01$ level. The only item that did not show a significant difference at

Table 2: Attitude scores by treatment

Attitude	*Questions*	*FP*	*NO*	*NE*	*NR*	*NP*	*LP*	*Total*
1	The goals of the program were clear to me.	3.34	3.40	3.22	3.34	3.17	2.77	3.21
2	I knew what I was supposed to learn at the start of each section of the program.	3.07	3.16	3.11	2.98	2.96	2.68	2.99
3	The program included enough pictures and examples.	3.20	3.38	2.41	3.10	3.06	2.43	2.93
4	The graphics helped me understand the content well.	3.17	3.32	2.30	3.12	2.83	2.36	2.85
5	The review at the end of each section helped my learning.	3.63	3.74	3.43	3.39	3.17	2.68	3.34
6	The program had enough opportunity to review the content.	3.17	3.18	3.07	2.76	2.77	2.48	2.91
7	The practice in the program helped me learn the content.	3.34	3.52	3.28	3.05	2.15	2.39	2.96
8	The program gave me enough opportunity to practice what I was learning.	3.05	3.20	3.04	2.56	2.13	2.25	2.71
9	I learned a lot from this program.	3.02	3.22	2.91	2.88	2.63	2.64	2.88
10	I would recommend this program to other students.	3.07	3.30	2.72	2.83	2.52	2.45	2.82
11	I would enjoy using other computer programs like this one in future lessons.	2.85	3.26	2.80	2.56	2.58	2.36	2.74
12	The overall quality of the program was good.	3.20	3.34	3.11	2.98	2.88	2.70	3.04
	Average	3.18	3.34	2.95	2.96	2.74	2.52	2.95

Note: 4 = strongly agree; 3 = agree; 2 = neither agree nor disagree; 1 = disagree; 0 = strongly disagree.
FP, full program; NO, no objectives group; NP, no practice group; NE, no examples group; NR, no review group; LP, lean program.

this level was 'I knew what I was supposed to learn at the start of each section of the program'.

The 11 items on which significance was obtained were further analysed to identify significant differences between treatment groups on these items. Table 3 provides a summary of the significant differences found when follow-up Scheffe tests were conducted at the 0.01 level. These data show that participants who used the program without objectives had the most positive attitudes towards their treatment with 17 significant comparisons. Participants who used the lean program had the most negative attitudes towards their treatment with 21 significant negative comparisons. Those who used the program without practice had 10 significant negative comparisons.

On the attitude items regarding practice—'The practice in the program helped me learn the content' (Item 7) and 'The program gave me enough opportunity to practice what I was learning' (Item 8)—participants in each of the two treatments that did not include practice had significantly lower attitudes than those in each of the four treatments that included practice. On the attitude items related to examples—'The program included enough pictures and examples' (Item 3) and 'The graphics helped me understand the content well' (Item 4)—participants in the two treatments that did not include examples had the lowest attitudes compared to those in the treatments that provided examples. However, on the attitude items regarding objectives—'The goals of the program were clear to me' (Item 1), and 'I knew what I was supposed to learn at the start of each section of the program' (Item 2)—participants in the program without objectives gave the highest overall ratings of all six groups, although not significantly higher than most groups.

The attitude survey also included two open-ended questions that asked the participants what they liked best and least about the program. The most frequent responses for what participants liked best were the review section ($n = 63$), the practice ques-

Table 3: Summary of significantly higher and lower differences for student attitudes

Treatments	**Significantly higher*	***Significantly lower*
Full program	10	
Program without objectives	17	
Program without examples	5	7
Program without review	5	
Program without practice	1	10
Lean program		21

*indicates the number of between-group comparisons of mean scores across the 12 attitude items that were significantly more positive for each group; **indicates the number of between-group comparisons of mean scores across the 12 attitude items that were significantly more negative for each group.

tions ($n = 59$), examples or graphics ($n = 37$), and easy to use or usability ($n = 33$). The most frequent responses for what was liked least were lots of information ($n = 54$), length of the program ($n = 39$), and inability to go back to the previous screen ($n = 10$). Twenty-four participants mentioned that there was nothing they disliked about the program.

Discussion

This study examined the effects of instructional elements (information, objectives, examples, practice and review) on achievement and attitudes. College students enrolled in a computer literacy course used a computer-based lesson delivered on the web to learn about IPSO of a computer.

Results indicated that among the instructional elements, practice had the most impact on both learner achievement and attitudes. Participants who used one of the versions of the computer program that included practice (full program, program without objectives, program without examples and program without review) performed significantly better on the posttest than those who did not receive practice (program without practice and lean program). Furthermore, students who received practice in their program had consistently more positive attitudes than those who did not receive it.

Practice was clearly the instructional event that had the strongest positive effect on achievement among the elements manipulated in this study. Participants in all four treatments that included practice scored significantly higher on the posttest than those in the two conditions that did not include it. Whereas the removal of practice from the full program resulted in a significant decline in posttest performance, the removal of any one of the three other elements (objectives, examples, review) did not have such an effect.

Practice of the type in this study is effective because it gives learners the opportunity to perform a similar or identical learning task to that assessed on the posttest. This practice combined with feedback, as it was in the present study, enables learners to confirm their correct understanding and to identify their incorrect ones. Thus, the probability of retention of correct responses is increased and the probability of incorrect responses is reduced when the practice is aligned with the subsequent posttest assessment (Philips *et al*, 1988; Reiser & Dick, 1996). Practice also has the advantage of eliciting overt responses from the learner, a form of active participation not directly provided by the other elements of instruction investigated in this study.

Whereas practice elicits overt responding from learners, the other elements investigated in the study either provide information that is additional to that contained in the information screens (ie, the objectives) or that is supplementary (examples) or primarily redundant (review) to the information. The absence of each of these elements individually in one of the three different treatments in the present study (program without objectives, without examples or without review) consistently yielded a posttest score between 17.16 and 17.36 that varied only slightly and non-significantly from the score

of 17.61 for students in the full program. Thus, there is no evidence from this study that any of these three elements individually contributed to increased student learning. Hannafin (1987) noted that when computer-based instruction is systematically designed, the presence of objectives for students may not increase their achievement. Nevertheless, the presence of objectives may be essential for the instructional designer to design the instruction systematically.

Turning to attitudes, results revealed that most participants had a favourable impression about the computer-based lesson used in this study. In general, they agreed with statements such as 'I learned a lot from this program', 'I would recommend this program to other students', and 'The overall quality of the program was good'.

Results for attitudes were generally consistent with findings for achievement. When the items on the attitude survey were analysed to examine differences between treatment groups, the participants who used the lean program had the most negative attitudes towards their treatment followed by those who used the program without practice. Combined with results for achievement, this study suggests that practice not only increases learning, but the absence of it also diminishes students' attitudes towards instruction.

Student responses to the attitude survey showed that they were sensitive to the absence of some of the instructional elements investigated in this study. Participants who received practice in their program agreed significantly more with items related to the amount and helpfulness of the practice than students who did not receive practice. Furthermore, participants who received examples throughout the program agreed more with items related to the amount and usefulness of the examples than students who did not receive examples. These findings suggest that students are aware when practice and examples are left out of computer-based instruction and that excluding these elements has a detrimental effect on their attitudes.

However, this pattern was not found for the attitude items related to objectives. Students in the no-objectives treatment had the most positive responses to the two items related to the goals and objectives of the program. They also had significantly more positive attitudes towards their treatment when their results were compared with students in several of the other treatments. This finding suggests that students may be unaware of the absence of objectives when other elements such as practice are included in the program.

In addition, students may not always be aware of the absence of review in computer-based instruction. Participants in the no-review treatment and those in the lean treatment did not receive review throughout their program. Nevertheless, students in the no-review condition had significantly more positive response than those in the lean group on the item, 'The review at the end of each section helped my learning'. It should be noted that when asked what they liked best about the program, students most frequently listed the element of review.

This study has implications for the design and development of computer-based instruction. Practice was the only consistently effective instructional event for enhancing student achievement in the study. This suggests that it should be included in computer-based instruction especially when students are tested using items aligned with the objectives and practice items. We also recommend including objectives, examples and review in computer-based instruction as none of these elements are very costly in terms of writing time by the designer, amount of text space in the lesson, or length of reading time by the learner. However, a computer lesson that includes information only is not recommended if the goal is to increase student achievement and attitudes.

Future research should continue to focus on the impact of instructional elements in various instructional settings. Additional research should examine how instructional elements in computer-based instruction influence outcomes such as problem solving and complex learning tasks. Furthermore, the recent proliferation of web-based and Internet-based instruction suggests that studies should be conducted to examine the effect of objectives, examples, practice and review in these settings. As was done in this study, research in these settings should include measures of student achievement and attitudes. Studies of this nature will continue to inform designers about the influence of instructional elements on learning and performance.

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