Exploring the Presentation and Format of Help in a Computer-Based Electrical Engineering Learning Environment

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Abstract

This study investigated whether it was more beneficial to provide the learners in computer-based learning environments access to on-demand (self-regulated) help after they committed an error in problem solving or for the learning environment to externally regulate the presentation of instructional help. Furthermore, two different presentational formats—textual and pictorial—of instructional prompts were examined. This study was conducted with a computer-based learning environment that introduced high school students without any prior content-specific knowledge to the principles of parallel and series electrical circuit analysis. We found that textual prompts facilitated problem solving statistically significantly better than pictorial prompts. Moreover, the learners provided with externally regulated prompts reported statistically significantly more positive attitudes toward the prompts than learners in the self-regulated conditions. Finally, the continuing motivation was statistically significantly stronger in learners who viewed textual prompts than in their counterparts in the pictorial prompt groups.

Introduction and Related Work

The computer-based instruction of electrical circuit analysis techniques has received a significant amount of interest over the last fifteen years, (see for instance Coulon, Forte & Rivera , 1993; Hanrahan & Caetano, 1989; Yoshikawa, Shintani & Ohba, 1992). A wide variety of computer-based instruction and tutoring systems with the aim to teach circuit analysis techniques and to provide opportunities for practicing circuit analysis have been developed and evaluated. Many of the developed systems interact with the learner to aid in imparting the knowledge of the circuit analysis techniques and to provide feedback on learner input to practice problems. In the case of incorrect solutions the feedback is oftentimes accompanied by instructional prompts (help). These learner-program interactions are in the form of text and/or graphics and are controlled (presented) by the learner or the system. The impact of both the format and the control (presentation) of the instructional prompts in circuit analysis tutoring systems have not been previously examined in detail. This study extends the existing literature on computer-based instruction of electrical circuit analysis in that it examines the impact of the presentation and the format of the instructional prompts in electrical circuit tutoring systems.

Schnackenberg, Sullivan, Leader, and Jones, (1998) provide an extensive overview of different studies on the control approaches up to their time of writing. More recently, Brown (2001) found that leaving the navigation of computer-based training to the learner tends to interfere with the instructional integrity of the learning environment, which is counterproductive. Schnackenberg et al. (1998) found that with learner control, the learners tend to skip practice examples, which tends to negatively affect learning. In the context of the highly structured content domain of the present study, namely electrical circuit analysis techniques, it appears that program controlled instructional design and navigation would be beneficial (Lawless & Kulikowich, 1998). Furthermore, program control might be especially advantageous for learners with low levels of prior knowledge in the domain area (Shin, Schallert & Savenye, 1994). Against this background, it is reasonable to assume that both subject-matter novices as well as technology neophytes should benefit from a program-control design.

Overall, the issue of learner vs. external control has so far been primarily investigated in the context of navigating the instructional and/or practice material. We are not aware of a study on the impact of learner vs. external control of the *provisioning of instructional prompts* within a given practice problem, which is the focus of this study.

How should the highly structured content on circuit analysis techniques be presented to learners in order to foster their initial knowledge acquisition and to introduce them to structured, algorithmic problem solving associated with electrical circuits? One theoretical approach that offers some guidance in this area is cognitive load theory, which provides the general guideline that the limited capacity of the working memory has to be taken into account when designing an instructional module. One empirically validated instructional approach that is particularly well-suited to accommodate the limited capacity of learners is the use of worked-out examples. Specifically, research suggests that worked examples, consisting of problem formulation, individual solution steps, and final solution, foster initial learning of highly structured subjects such as algebra in Sweller and Cooper (1985) or statistics in Atkinson, Renkl and Merril (2003).

Two important factors found to influence the degree of learning associated with worked examples are their structure in Atkinson, Derry, Renkl and Wortham (2000) and the presence of self-explanation activities during example processing as in Chi (2000). One way to classify the structure of the worked examples in interactive learning environments is by the relationship to accompanying practice problems. For instance, presenting a fully solved example followed by a practice problem that requires the learner to independently solve all problem subgoals (steps) is called *example-problem* design. In contrast, in a *problem-example* design, the learner first encounters a practice problem and is subsequently presented with a fully worked example. In the fading approach, the learner is initially presented with a fully worked example and in the next example all but one of the problem subgoals are worked out and the learner is required to independently solve (anticipate) the solution of the missing problem subgoal. In the subsequent example all but two problem subgoals are worked out and the learner is required to anticipate the solutions to the two missing problem subgoals, and so on, until the learner is required to anticipate the solutions for all problem subgoals (independent problem solving). This fading design comes in two types: *forward-fading*, where the solution steps are omitted starting with the first problem subgoal, and *backward-fading*, where the last solution step is omitted first, then the last two, and so on. Recent studies found indications that fading, especially *backward-fading* has a positive effect on learning (Renkl, Atkinson & Grosse, 2004). Backward fading is therefore employed throughout this study.

In summary, we note that the usage of the pictorial and textual presentation formats of the instructional content and the implications for the cognitive load have been evaluated by several research groups. The influence of pictorial or textual *instructional prompts* in interactive learning environments with fading, however, has not yet been studied in detail. It is interesting and important to understand the impact of pictorial vs. textual prompts on the learner's performance as well as the impact on the learner's motivation. At the same time it is worthwhile to study these effects in conjunction with learner vs. external control (presentation) of the prompts.

Study Methodology

The present study manipulates two independent variables, namely the *presentation* (external vs. self regulated) and *format* (pictorial vs. textual) of instructional prompts. The study addresses the following research questions:

- What is the effect of the different presentation and format of instructional prompts on the learner's performance?
- What are the attitudes of the learners toward the different types of presentation and format of the instructional prompts?

Participants and Design

The participants in this study were 51 students from a small charter high school in the Southwest. The participants were recruited from a regularly scheduled computer class. The experimental sample consisted of 26 females and 25 males. The grade level of the participants ranged from eight to twelve (2 eighth-graders, 8 ninth-graders, 15 tenth-graders, 18 eleventh-graders, and 8 twelfth-graders). The participants had a mean grade point average of 3.02 (SD = .84) and had not been exposed to formal instruction on electrical circuit analysis techniques before participating in this study.

Participants were randomly assigned to one of the four experimental conditions as defined by a 2 x 2 factorial design with presentation (external vs. self regulated) and format (pictorial vs. textual) of instructional prompts as factors. The resulting conditions were: (1) self-regulated textual prompts, where participants could exercise control over the use of text-based instructional prompts (textual descriptions), (2) externally regulated textual prompts, where the computer program automatically provided textual prompts, (3) self-regulated pictorial prompts, where participants could exercise control over the use of prompts (diagrams), and (4) externally regulated pictorial prompts, where the computer program automatically presented pictorial prompts.

Pencil-Paper Materials

The participants were administered a set of pencil-paper materials consisting of a demographic questionnaire, a pretest, an overview of parallel and series electrical circuits, a posttest, and an attitude survey.

Demographic Questionnaire

The questionnaire collected basic demographic data (grade level, gender, ethnicity), as well as the participants' GPA and standardized test scores (Arizona Instrument to Measure Standards (AIMS) or Stanford 9 math and reading scores). The questionnaire also asked the participants whether they had ever learned about electrical circuit analysis before.

Pretest

The pretest was designed to assess the participants' prior knowledge in the area of electrical circuit analysis. It was composed of six multiple-choice questions relating to the basic physical meaning of electrical current, voltage, and resistance and elementary properties of electrical circuits. The participants could select from four response choices for each question.

Introductory Overview

The four-page overview of parallel and series electrical circuits introduced the participants to (*i*) the physical meaning and units of electrical current and voltage, (*ii*) electrical circuit elements and their graphical representations, such as light bulbs and batteries, and the way circuit elements are connected with wires in the two main forms of electrical circuits, namely parallel and series circuits, (*iii*) the physical meaning and units of resistance as well as Ohm's Law, (*iv*) the calculation of the resistance of a parallel circuit, and (*v*) the calculation of the resistance in a series circuit. These last two sections on calculating the resistance of series and parallel circuits were not focused on deriving the formulas for calculating the total resistance of the circuit from the resistance values of the individual circuit elements (i.e., $R_{tot} = R_1 + R_2 + \ldots$ for series circuit and $1/R_{tot} = 1/R_1 + 1/R_2 + \ldots$ for parallel circuit).

The instructional goal was not to teach the participants to use these formulas. Instead the participants were taught to calculate the total resistance from basic principles, namely Ohm's Law and the properties of current and voltage in the electrical circuits. In particular, for the series circuit, the participants were presented with the resistance values of the individual resistors in the circuit and with the value of the current emitted by the battery into the circuit. The participants were then instructed to proceed in the following three steps in the calculation of the total resistance of the series circuit. First, the participants studied that the current flowing through each of the circuit elements is equal to the current emitted by the battery and the calculation of the voltage over each individual resistor is done using Ohm's Law. Second, the participants were shown examples where the calculation of the total voltage over the series arrangement of resistors is carried out by summing up the voltages of the individual resistors. Third, the examples presented the calculation of the total resistance of the series circuit by applying Ohm's Law to the entire circuit, i.e., the calculation of the total resistance of the series circuit as the sum of the voltages determined in step 2 divided by the current emitted by the battery. For the parallel circuit, an analogous solution strategy was presented.

Posttest

The posttest contained eight complex problems, more specifically, four problems (two for each type of the electrical circuits, parallel and series) to measure the performance on near transfer and four problems (two for each type of the electrical circuits, parallel and series) to assess the far-transfer learning.

The near-transfer problems had the same underlying structure but different surface characteristics from the practice problems encountered during the learning (computer) phase. They required the participants to perform the same tasks (e.g., calculating the individual voltage or current respectively, determining the total voltage or current respectively, and finally computing the total resistance) as they learned in the computer-based module. Despite having the same structure and requiring the same solution steps as the practice problems from the learning phase, the near-transfer problems appeared different since they had different cover stories and current, voltage, and resistance values.

The far-transfer problems had different underlying structure and surface features as compared to the computer-based practice problems. In particular, in the far-transfer series circuit problems the participants were given the individual resistance values and the voltage over one of the resistors. The far-transfer series circuit problem asked the participants to calculate the battery voltage. To solve this problem, the participants had first to use Ohm's Law to calculate the current in the series circuit from the resistance value of the one resistor for which the voltage was given. The participants then had to notice that the current is the same in all resistors and had to calculate the voltages over the other resistors in the circuit from the current determined in the first step and the values of the individual resistors using again Ohm's Law. In the third and final solution step, the participants had to sum up the voltages over the individual resistors to obtain the total voltage (battery voltage) over the circuit. The far-transfer parallel circuit problems were structured analogously.

Attitude Survey

A 14-item attitude survey was used to collect data on participant attitudes and motivation. The survey pertained to the overall effectiveness of the computer-based program, the format of the instructional prompts, and participant continuing motivation. The individual items were five-choice Likert-type questions. The response choices were assigned ratings of strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. The attitude items were grouped into three categories, namely instructional effectiveness (7 items), role of instructional prompts (4 items), and continuing motivation (3 items).

Computer-Based Learning Environment

The module was developed using Director MX (by Macromedia, Inc. (2002)) software, which is an authoring tool for creating rich multimedia programs. The module was programmed to operate in one of four modes that corresponded to the four experimental conditions of the current study.

The goal of the computer-based learning environment was to deliver instruction on the principles of calculating resistance in parallel and series electrical circuits. The aim of the program was to present worked (solved) examples to the participants and to scaffold their learning by progressively reducing the number of worked solution steps and increasing the amount of independent problem solving by the participants. The environment presented two sets (parallel and series) with four problems each, constituting a total of eight problems. The following is the cover story from one of the instructional examples that were shown to the participants on the computer screens during the learning phase:

> *To operate an aquarium you wire the pump with a resistance of R_p = 20 W and the aquarium light with a resistance of R_l = 40 W in parallel. You connect this parallel circuit to a battery with a voltage of V_b = 5 V. What is the total resistance R_{tot} of this parallel circuit?*

Each problem had exactly three solution steps. Each step was clearly labeled and visually distinguished from the other steps. The computer module revealed one step at a time after the participants clicked the "Next" button, thus allowing the participants to control the pace of their learning. The participants proceeded through the module by clicking on the "Next Problem" buttons after inspecting all three steps in each problem. The navigation was linear and the participants could not return to previous steps and problems once they finalized their answers.

The first problem in each of the sets of four problems was fully solved (worked), whereas in the subsequent problems the worked steps were backward faded and the participants had to anticipate the correct solution to the missing steps. Specifically, the participants had to independently solve one step (the last one) in the second problem of each set, two steps (the last two) in the third problem of each set, and were responsible for independently solving all three steps in the last problem of each set.

In the case of incorrect anticipation, the computer-based learning environment offered an instructional prompt that was either externally regulated or requested by the participant, depending on the treatment condition. Participants in the externally regulated groups were always presented with the instructional prompt if they made a mistake while solving the individual steps. On the other hand, the decision to view the instructional prompts was solely at the discretion of the participants in the self-regulated conditions. They were offered the option to receive the instructional prompt but could refuse the help.

The instructional prompts were presented in two different formats, depending on the treatment condition. In the textual-based prompt groups, the prompts were verbal reminders of Ohm's Law and the properties of currents and voltages in series and parallel circuits. These reminders were tailored to the individual problem steps. The pictorial-based prompts were presented as drawings illustrating the current flow and voltages in series and parallel circuits, as well as Ohm's Law tailored to the individual problem step.

Once the request for the instructional prompt was entered, the prompt appeared on the screen next to the solution step that needed to be solved. The participants were given two attempts at solving each missing step. The correct solution was then displayed on the screen. The solved steps remained visible on the screen after the final answer was presented, allowing the participants to study the entire solution (worked example).

Procedure

Groups of 8 to 15 participants attended one of the five scheduled experimental sessions. The average duration of each session was approximately 60 minutes. The participants took part in the study in a computer lab in their high school. Each participant was seated in front of a Windows-based desktop computer. The experimenter instructed the participants to work independently of their peers. The participants first filled in the demographic questionnaire. Next, they answered the pretest. The participants proceeded to study the introductory overview on electrical circuits. After studying the introductory instructional text the participants worked through the problems in the computer-based learning environment. During this phase the experimental variation took place. Immediately after completing the computer-based instructional program the participants were administered the posttest. Finally, they indicated their responses on the attitude survey. Each participant completed this entire procedure in one session.

Scoring

The participants' performance on the pretest, practice problem solving during the computer-based instruction, and the posttest (near- and far-transfer problems) as well as their responses to the attitude survey were scored. The computer-based learning module automatically recorded the en route practice (accuracy of solving the missing steps) and time on the computer. The maximum pretest score was 6, one point for each correctly answered multiple-choice question. There were a total of 12 unsolved steps in the computer-based learning environment. The participants were given two attempts at solving each of the 12 unsolved steps. For each correctly solved step, one point was awarded, thus producing a maximum score of 12 for each of the solving attempts, i.e., the first and second anticipations. (A score of zero was assigned for the second anticipation if the first anticipation was correct.) The individual scores for each of the anticipations were summed and divided by 12 in order to obtain the proportion of problem steps that were correctly solved on the first/second anticipation. The values for the first and second anticipations ranged from 0 to 1. The eight posttest problems had three distinctive solution steps each, thus resulting in a maximum score of three points for each problem, equaling to a maximum total score of 24 (12 points each were associated with the performance on the near- and far-transfer problems, respectively). On the attitude survey, a rating of strongly agree received a score of 5, agree a score of 4, a rating of neither agree or disagree equaled to 3, disagree was scored as 2, and a rating of strongly disagree received a score of 1.

Data Analysis

There was no significant difference in the pretest scores between the participants randomly assigned to the textual and pictorial prompts groups $F(1,47) = 1.70$, $p = .20$. Similarly there was no significant difference in the pretest scores between the participants randomly assigned to the self-regulated and externally regulated prompts groups $F = .01$, $p = .94$. The near transfer and far transfer posttest scores were analyzed using 2 (Prompt Format: Textual and Pictorial format) x 2 (Prompt Presentation: Self-regulated or Externally regulated) x 2 (Posttest Problem Type: Near-transfer and Far-transfer posttest scores) analysis of variance (ANOVA). Prompt format and prompt presentation were between-subjects variables in the analysis and posttest problem type was within-subjects variable. En route data on performance on practice problems in the computer-based learning environment was also collected and analyzed. Attitude data were analyzed using 2 (textual or pictorial format of prompts) x 2 (self or external presentation of prompts) x κ (number of attitude items for each of the three item categories: overall effectiveness of instruction (κ=7), effectiveness of prompts (κ=4), and continuing motivation κ=3) multivariate analyses of variance (MANOVA).

Results

Achievement

The unadjusted mean scores and standard deviations for each treatment group on the near- and far-transfer posttest problems are shown in Table 1.

Table 1: *Posttest scores by format and presentation of prompts.*

	Format of Prompts				Presentation of Prompts			
	Textual (N = 24)		Pictorial (N = 27)		Self (N = 24)		External (N= 27)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Near Transfer	9.08*	2.29	6.89	3.70	8.54	3.24	7.37	3.26
Far Transfer	1.04	1.40	1.00	1.18	1.29	1.43	.78	1.09

*p=.01

An ANOVA revealed that there was no significant difference between the two levels of the presentation factor (self vs. external regulation) on the overall posttest total, F ratio $F(1,47) = 3.43$, mean square error $MSE = 11.20$, significance level $p = .07$. There was a statistically significant difference when comparing the two different formats of prompts (pictorial vs. textual). Specifically, on the near-transfer posttest, participants presented with text -based instructional prompts scored significantly higher, achieving a mean score of 9.08 (76%), than their counterparts provided with pictorial-based prompts, who achieved a mean score of 6.89 (57%). This difference on the near transfer posttest scores was statistically significant $F(1,47) = 6.50$, $MSE = 9.69$, $p = .01$. Cohen's f statistic for these data yields an effect size estimate of .37 for the near-transfer posttest problems, which approaches a large effect. This advantage did not, however, extend to the performance on the far-transfer items. Finally, there was no significant interaction between the two factors.

Practice

The performance on en route practice problems was analyzed using 2 (textual or pictorial format of prompts) x 2 (self or external presentation of prompts) analysis of variance (ANOVA). The proportions (accuracy) of correctly solving the unsolved practice problem steps at the first and second attempt are presented in Table 2.

Table 2: *Accuracy of practice problem solving by format and presentation on prompts*

	Format of Prompts				Presentation of Prompts			
	Textual (N = 24)		Pictorial (N = 27)		Self (N = 24)		External (N = 27)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
First Anticipation	.93*	.08	.82	.13	.86	.14	.88	.11
Second Anticipation	.05	.07	.13*	.09	.09	.09	.09	.08

*p<.01

The participants in the textual prompts groups solved on average 93% of the unsolved problems steps, i.e., 11.16 out of the 12 unsolved steps, at the first attempt, whereas the participants in the pictorial prompts group solved 82% of the unsolved steps at the first attempt. The ANOVA revealed that this difference corresponds to a significant main effect on first anticipation for format of prompts, $F(1,47) = 12.00$, $MSE = .01$, $p < .01$. The differences on accuracy of anticipations on the first anticipation between the self and external approach to presentation of prompts were non-significant as was the interaction between presentation and format of instructional prompts. There was a significant main effect for format of prompts on the second trial of solving practice problems. In particular, the participants who received pictorial-based prompts had a significantly higher probability of accurately solving the practice problems on the second trial as compared to participants who were assigned to the text-based prompts groups, $F(1,47) = 12.77$, $MSE = .01$, $p < .01$.

Table 3: *Participant attitude scores by format and presentation of prompts*

	Format of Prompts			Presentation of Prompts		
	Textual (N = 24)	Pictorial (N = 27)		Self (N = 24)	External (N = 27)	
	M	*M*	*F*	*M*	*M*	*F*

Attitude Category						
Instructional Effectiveness	4.05	3.78	3.18	3.91	3.92	.01
Role of Instructional Prompts	4.01	3.93	.19	3.73	4.18	5.40*
Continuing Motivation	3.83	3.36	6.36*	3.68	3.50	1.06
Role of Instr. Prompts Items						
The instructional explanations (hints) helped me to learn	4.04	4.11	.07	3.75	4.37	6.18*
Text-based instructional explanations (hints) were/would be helpful	3.83	3.37	2.40	3.29	3.85	3.60
Pictorial-based instructional explanations (hints) were/would be helpful	4.21	4.19	.01	4.13	4.26	.35
Having control over the instructional explanations (hints) was/would be beneficial for my learning	4.21	4.04	.52	4.00	4.22	.89
Continuing Motivation Items						
I would like to learn more about electrical circuits	3.79	2.93	12.34**	3.54	3.15	2.13
After completing the instructional unit, I find science more interesting	3.63	3.30	1.91	3.54	3.37	.50
I would recommend this instructional unit to others	4.08	3.85	.81	3.96	3.96	.00

*$p < .05$, **$p < .01$

Instructional Time

In order to test if the amount of time participants spent on acquiring initial knowledge during the paper-based training and learning in the computer-based learning environment influenced their performance on the posttest, an analysis of variance (ANOVA) was conducted on these times. No statistically significant differences between the different treatment groups were found.

Attitudes

The attitude items were scored on a five-point scale, ranging from 5 indicating strong agreement with the positive statements to 1 corresponding to strong disagreement. The overall mean score across all the 14 attitude items on the survey for all participants was 3.86 (SD = .49).

The attitude items were grouped into three categories, namely instructional effectiveness (7 items), role of instructional prompts (4 items), and continuing motivation (3 items). The mean attitude scores by format and presentation of prompts for participant responses on the three main categories of attitude items on the five-point attitude survey are presented in Table 3. Multivariate analyses of variance (MANOVA) of the attitude items related to the role of instructional prompts revealed that there was a significant overall main effect across the four items relating to the presentation of prompts, (M = 4.18 for externally regulated prompts and M = 3.73 for self-regulated prompts), $F(1,47) = 5.40$, $MSE = .45$, $p = .03$. Cohen's f statistic for these data yields an effect size of .34, which corresponds to medium to large effect. In addition, a significant overall main effect was discovered across the items relating to continuing motivation for the format of prompts (M = 3.83 for text-based prompts and 3.36 for pictorial-based prompts), $F(1,47) = 6.36$, MSE = .45, p = .02. Cohen's f for these data yields an effect size of .37, which corresponds to medium to large effect. The differences for the format and presentation of prompts on the attitude survey items relating to the instructional effectiveness were non-significant.

Univariate analysis of variance on the four items relating to the effectiveness of the instructional prompts by presentation of the prompts revealed significantly higher scores on the item "The instructional explanations (hints) helped me to learn" for the externally regulated prompts (M = 4.37 for externally regulated prompts and 3.75 for self-regulated prompts, $F(1,49) = 6.18$, MSE = .79, $p = .02$).

Univariate analysis of variance on the three items relating to the continuing motivation by format of the prompts revealed significantly higher scores on the item "I would like to learn more about electrical circuits" for the textual prompts (M = 3.79 for text-based prompts and 2.93 for pictorial prompts, $F(1,49)$ =

12.34, MSE = .77, $p < .01$).

Discussion

The two main research questions addressed in the present study focused on the impact of the format (textual or pictorial) and presentation (self or externally regulated) of instructional prompts on the learners' performance and attitudes. Significant differences were revealed for the accuracy of anticipations on practice problems during the learning phase in the computer-based environment. In particular, the learners assigned to the textual-based prompt groups were significantly more successful in correctly solving the individual solution steps at the first problem-solving attempt than their counterparts in the pictorial-based prompt groups. This finding corresponds to a large effect and is therefore of practical significance. The learners who were assigned to the treatment conditions with pictorial prompts, on the other hand, had a significantly higher success rate at the second anticipation compared to learners in the text-based prompt conditions. One way to account for the higher success rate of the learners with the pictorial prompts in the second attempt is that these learners had a significantly higher probability of advancing to the prompt and second trial because of their higher error rates at the first anticipation. In particular, for 18% of the solution steps the learners in the pictorial-based prompt group advanced to the prompt and second trial, compared to 7% for the learners in the text-based prompt group.

We also found that the textual prompt format leads to significantly higher near-transfer posttest performance compared to the pictorial prompt format. The advantage of textual prompts over pictorial prompts on the near-transfer learning yielded a large effect, which indicates this is also of practical relevance. The analysis indicates that the advantage of the textual format of instructional prompts cannot be attributed to the amount of instructional time. The significantly better performance with the textual prompts indicates that the textual representation of the electrical analysis techniques is more suitable for learners without prior exposure to electrical circuit analysis. The results suggest that all the learners, regardless of the treatment condition, encountered difficulties when attempting to solve the far-transfer problems. Essentially, we encountered a floor effect on this measure.

The results from the attitude survey indicate that the learners in the text-based group expressed significantly more positive attitudes towards the statements relating to continuing motivation. In particular the learners that had experienced text-based prompts had a significantly more positive attitude toward the survey item relating directly to future study of electrical circuit analysis. This more positive attitude is consistent with the higher posttest scores of the learners in the text-based prompt group. Indeed, the higher posttest scores suggest that these learners had acquired a better mastery of the instructional material, which may have made them more confident about their newly acquired skills, and had resulted in higher motivation for further study in the content area of electrical circuits. This difference in attitudes towards learning more about electrical circuits corresponds to a large effect, indicating that this difference has practical relevance.

The results for the learner attitudes toward the statements relating to the role of the instructional prompts indicate that the external regulation of the prompts is perceived as significantly more appealing than the self-regulation of the prompts. This is an interesting result considering that there were no significant differences for external vs. self regulation of the prompts in terms of the performance on the posttest and the instructional time. The learners with the low level of prior knowledge may have preferred that the prompts were automatically presented by the system instead of being forced to decide for themselves whether or not they should view them. Overall, the results of the attitude survey suggest that employing text-based prompts and having the prompts under the control of the instructional module are preferred by students in a module on electrical circuit analysis for high school students with little knowledge in this domain.

There are several interesting avenues to pursue in future research on computer-based interactive learning modules with instructional prompts. One avenue is to investigate the impact of text vs. pictorial prompts on learners with a higher level of prior knowledge of general engineering analysis techniques, such as college freshmen or sophomore engineering students. Another avenue is to study the impact of more complex and elaborate pictorial prompts that are designed to foster the acquisition of the more expert-like graphical representation common in electrical circuit analysis.

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