Investigating the Presentation and Format of Instructional Prompts in an Electrical Circuit Analysis Computer-Based Learning Environment

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Abstract—Research has shown that providing instructional prompts in computer-based learning environments designed to support example-based learning fosters learning. In computer-based environments, where learners interact only with a computer and do not have access to direct support from a teacher, learners need to be provided with instructional prompts or just-in-time help intended to encourage more active example processing during learning. This study investigated whether it was more beneficial to provide the learners access to on-demand (self-regulated) help after they committed an error in problem solving or for the learning environment to regulate the *presentation* of instructional help externally. 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 circuit analysis. Textual prompts facilitated practice problem solving notably better than pictorial prompts. Overall, textual-based prompts produced a large effect on near transfer. A significant format of prompts by academic ability interaction was discovered on near transfer. In particular, lower-ability learners scored significantly better when given textual prompts; whereas, their higher-ability counterparts performed equally well with both formats. Moreover, learners provided with externally regulated prompts reported significantly more positive attitudes toward the prompts in general compared to learners in the self-regulated conditions. Finally, continuous motivation was significantly stronger in learners who viewed textual prompts than in their counterparts in the pictorial prompt groups.

Index Terms—Backward fading, computer-based learning environment, electrical circuit analysis, external control, high school, instructional prompts, learner control, pictorial format, textual format.

I. INTRODUCTION AND RELATED WORK

THE computer-based instruction of electrical circuit analysis techniques has received a significant amount of interest over the last decade (see [1]–[7]). This literature contains 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. 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 often 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. To the best of the authors' knowledge 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.

This study is conducted in the context of a computer-based instructional module that introduces learners without any prior content-specific knowledge to the basic principles of parallel and series circuit analysis. The module is well suited for exposing and introducing high school students to electrical circuit analysis. The module's pedagogical features (i.e., the presentation and format of instructional prompts) are evaluated with high schools students. This evaluation is motivated by the increasing need to expose high school students [8] and home schooled students [9] to engineering in an effort to attract students to engineering programs at universities and colleges.

Following recent research [10], [11] on the structure of computer-based instructional modules, a backward fading structure is employed, which has been demonstrated to have a positive effect on learning. With the backward fading structure, the learner is initially presented with a fully worked-out example and in the next example all but the last of the problem sub-goals (solution steps) are worked out, and the learner is required to solve (anticipate) independently the solution of the missing problem sub-goal. In the subsequent example all but the last two problem sub-goals 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 sub-goals (independent problem solving). Recent research has also found that instructional prompts in computer-

based instructional modules foster learning (see [12], [13]) and that instructional prompts in conjunction with backward fading are beneficial for learning [14].

The issue of learner versus external control has so far been primarily investigated in the context of navigating hypermedia learning environments (see [15], [16]). The authors are not aware of a study on the impact of learner versus external control of the provisioning of instructional prompts within a given practice problem, which is the focus of this study. The pictorial and textual presentation formats of instructional content and the implications for the cognitive load have been extensively studied (see [17]–[19]). The impact of pictorial or textual *instructional prompts* in interactive learning environments with fading, however, has not yet been studied in detail.

II. STUDY METHODOLOGY

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

- What is the effect of different presentation and format of instructional prompts on the learner's performance?
- Do the different presentation and format of instructional prompts have a differential effect on the performance of higher and lower ability learners?
- What are the attitudes of learners toward the different types of presentation and format of the instructional prompts?

A. Participants and Design

The participants of this study were 51 students from a small charter high school in the Southwest. The experimental sample consisted of 26 females and 25 males. The participants ranged from eighth- to twelfth-graders (2 eighth-graders, 8 ninth-graders, 15 tenth-graders, 18 eleventh-graders, and 8 twelfth-graders; mean $M = 10.43$, standard deviation $SD = 1.06$). The participants had an average grade point average of $3.02 (SD = 0.84)$ and had not been exposed to formal instruction on electrical circuit analysis techniques before participating in this study. They were randomly assigned to one of the four experimental conditions (cells) as defined by a 2×2 factorial design with presentation (external versus self-regulated) and format (pictorial versus textual) of instructional prompts as factors. According to [20], the resulting per cell sample size was sufficient to detect a large effect (Cohen's $f = 0.40$), which was deemed to be substantively significant in the present study, based on a conventional alpha level of 0.05 (two-tailed) and statistical power of 0.80.

B. 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 post-test, and an attitudinal survey.

1) Demographic Questionnaire: The questionnaire collected basic demographic data (grade level, gender, ethnicity),

and the participants' GPA and standardized test scores (Arizona's 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.

2) 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.

3) Introductory Overview: The four-page overview of parallel and series electrical circuits introduced the participants to 1) the physical meaning and units of electrical current and voltage; 2) 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; 3) the physical meaning and units of resistance and Ohm's Law; 4) the calculation of the resistance of a parallel circuit; and 5) 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., $R_{\text{tot}} = R_1 + R_2 + \cdots$ for series circuit and $1/R_{\text{tot}} = 1/R1 + 1/R2 + \cdots$ 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.[1] In particular, for the parallel circuit, the participants were presented with the voltage provided by the battery and resistance values of the individual resistors. For the calculation of the total resistance of the parallel circuit, the participants were instructed to proceed through the following three steps. First, the participants observed that the voltage is the same over each individual resistor and were presented with the calculation of the value of the current flowing through each individual resistor using Ohm's Law. Second, an example showed the calculation of the total current flowing in the circuit by summing up the currents flowing through the individual resistors. Third, the total resistance of the parallel circuit was calculated by dividing the voltage provided by the battery by the sum of the currents determined in step 2.

The instruction for evaluating the resistance of the series circuit was analogous.

4) Post-Test: The post-test 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.

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[1]These properties are described by Kirchhoff's Current Law and Kirchhoff's Voltage Law.

Fig. 1.   Screen shot of computer-based learning environment showing statement of a parallel circuit problem, completed first solution step, and pictorial format of instructional prompt for second solution step.

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 had learned in the computer-based module.

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 parallel circuit problems the participants were provided with the resistance values of the individual resistors and the current flow through one of the resistors and were asked to calculate the total current in the parallel circuit (battery current). To solve this problem, the participants first had to apply Ohm's Law to the resistor for which the current was provided to determine the voltage over the resistor. The participants then had to observe that the voltage is the same over all resistors and had to calculate the currents through the other resistors by applying Ohm's Law to each individual resistor. Finally, the participants had to sum up the individual currents to determine the battery current. The far transfer problems for the series circuit were structured analogously. In summary, the far transfer problems required the participants to apply the same basic principles (Ohm's Law, basic properties of voltages and currents in parallel and series circuits) as in the practice problems, but the sequence in which these principles were applied and the circuit element to which Ohm's Law was applied differed from the practice problems (and the solution steps presented in the introductory overview).

5) Attitudinal Survey: A 14-item attitudinal 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 continuous 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 participant attitude on the overall effectiveness was evaluated with six items such as: "I learned a lot from this instructional unit" or "The information was presented effectively." The participant attitude on the format of the instructional prompts was evaluated with four items, such as: "The instructional explanations (hints) helped me to learn." The participant attitude toward continuous motivation was assessed with three items, such as: "I would like to learn more about electrical circuits."

C. Computer-Based Learning Environment

The module was developed using the Director MX [21] 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-out (solved) examples to the participants and to scaffold their learning by progressively reducing the number of worked-out 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 cover story from one of the instructional examples that were shown to the participants on the computer screen during the learning phase is shown in the top box in Fig. 1.

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
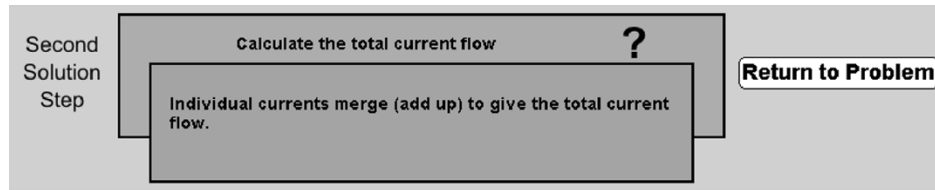
Fig. 2. Excerpt of screen shot showing textual format of instructional prompt for second solution step in parallel circuit problem.

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 two sets of four problems was fully solved (worked-out), whereas in the subsequent problems the worked-out steps were backward faded, and the participants had to anticipate the correct solution to the missing steps. Specifically, the participants had to solve independently 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, as illustrated for the second step in a parallel circuit problem in Fig. 2.

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, as illustrated in Fig. 1 for the second step in a parallel circuit problem.

Once the request for the instructional prompt was detected, 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).

D. Procedure

Groups of 8–15 participants attended one of the five scheduled experimental sessions. The average duration of each session was approximately 60 min. 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 and instructed to work independently of his/her 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 post-test. Finally, they indicated their responses on the attitudinal survey.

III. RESULTS

This section presents the scoring protocol and the results for achievement (post-test performance), en route practice, instructional time, and participant attitudes. Cohen's f statistic was used as an effect size index where f values of 0.10, 0.25, and 0.40 correspond to small, medium, and large values, respectively [20].

A. Scoring

The participants' performance on the pretest, practice problem solving during the computer-based instruction, and the post-test (near and far transfer problems) and their responses to the attitudinal survey were scored. The computer-based learning module automatically recorded the en route practice (accuracy of solving the missing steps) and instructional time on 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 of the proportions for the first and second anticipations ranged from 0 to 1. The eight post-test problems had three distinctive solution steps each, thus resulting in a maximum score of three points for each problem, equaling a maximum total score of 24 (12 points each were associated with the performance on the near and far transfer problems, respectively). On the attitudinal survey, a rating of strongly agree received a score of 5, agree a score of 4, neither agree or disagree a score of 3, disagree a score of 2, and strongly disagree a score of 1.

TABLE I
POST-TEST SCORES BY FORMAT AND PRESENTATION OF PROMPTS. THE TEXTUAL PROMPT FORMAT RESULTED IN SIGNIFICANTLY HIGHER NEAR TRANSFER AND TOTAL POST-TEST SCORES. BOTH SELF- AND EXTERNAL PROMPT PRESENTATIONS WERE EQUALLY CONDUCIVE TO LEARNING

| | 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	0.78	1.09
Post-test Total	10.13*	2.86	7.89	3.80	9.83	3.24	8.15	3.67

*$p = .01$

TABLE II
POST-TEST SCORES BY FORMATS OF PROMPTS AND ABILITY LEVEL. HIGHER-ABILITY LEARNERS PERFORMED EQUALLY WELL WITH BOTH FORMATS OF PROMPTS. THE LOWER-ABILITY LEARNERS ACHIEVED SIGNIFICANTLY HIGHER NEAR TRANSFER AND TOTAL POST-TEST SCORES WITH THE TEXTUAL PROMPTS

| | Post-test Total Format of Prompts | | | | Near Transfer Format of Prompts | | | | Far Transfer Format of Prompts | | | |
| | Textual | | Pictorial | | Textual | | Pictorial | | Textual | | Pictorial | |
Ability level	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Higher ($N = 25$)	9.77	3.14	9.67	2.64	8.54	2.50	8.75	2.90	1.23	1.36	0.92	1.38
Lower ($N = 26$)	10.55	2.58	6.47	4.05	9.73	1.90	5.40	3.66	0.82	1.47	1.07	1.03

B. Achievement

The overall post-test data (near transfer and far transfer combined) were analyzed with 2 (textual or pictorial format of prompts) $\times$ 2 (self- or external presentation of prompts) analysis of covariance (ANCOVA), using the pretest as a covariate ($\alpha = .05$). The mean scores M and standard deviations SD for each treatment group on the near and far transfer post-test problems and the overall post-test are shown in Table I. The ANCOVA revealed that there was no significant difference between the two levels of the presentation factor (self versus external regulation) on the overall post-test total, F ratio $F(1, 46) = 3.38$, mean square error $MSE = 11.20$, significance level $p = .07$. The ANCOVA also showed that there was a statistically significant difference when comparing the two different formats of prompts (pictorial versus textual). Specifically, on the overall post-test, participants presented with text-based instructional prompts scored significantly higher than their counterparts provided with pictorial-based prompts, $F(1, 46) = 6.51, MSE = 11.20, p = .01$. Cohen's f statistic for these data yields an effect size estimate of 0.38 for the total post-test, which approaches a large effect. Further analysis revealed that on the near transfer post-test problems, participants in the two textual prompt groups ($M = 9.08$, 76% mastery level) significantly outperformed participants in the two pictorial prompt groups ($M = 6.89$, 57% mastery level); $F(1, 46) = 7.00, MSE = 9.76, p = .01$. Cohen's f statistic for these data yields an effect size estimate of 0.39 for the near transfer post-test problems, which corresponds to 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.

In order to determine which format of prompts was the most beneficial to learners based on their academic ability a 2 (academic ability level: high or low) $\times$ 2 (format of prompts: textual or pictorial) analysis of covariance (ANCOVA), using the pretest as a covariate ($\alpha = .05$), was performed. Participant GPA and standardized test scores (AIMS math plus reading or

Stanford 9 math plus reading) were converted into Z scores and combined to create a general indicator of academic ability. The participants were blocked by their overall Z scores and equally distributed into higher-ability and lower-ability groups.

Table II presents the mean scores and standard deviations on the post-test by academic ability and format of prompts. There was a significant format of prompts by academic ability interaction for the post-test total, $F(1, 46) = 5.22, MSE = 10.48, p = .03$, and for the near transfer post-test problems, $F(1, 46) = 8.30, MSE = 8.36, p < .01$. This latter interaction is shown in Fig. 3. The format of prompts by academic ability interaction effect was analyzed using a simple main effect analysis. The format of prompts influenced the performance on the near transfer items for the lower-ability participants, $F(1, 23) = 12.30, p < .01$. However, the format of prompts did not influence the performance on the near transfer items for higher-ability participants, $F(1, 22) = 0.02, p = .90$.

C. Practice

The program automatically recorded the accuracy of practice problem solving within the computer-based learning environment. The performance on en route practice problems was analyzed using 2 (textual or pictorial format of prompts) $\times$ 2 (self- or external presentation of prompts) analysis of covariance (ANCOVA), with the pretest as a covariate ($\alpha = .05$). The scores for the first and second attempt at solving the practice problems are presented in Table III. The ANCOVA revealed a significant main effect on first anticipation for format of prompts, $F(1, 46) = 15.45, MSE = 0.01, p < .01$, where participants presented with text-based prompts outperformed their counterparts presented with pictorial prompts. Cohen's f statistic for these data yields an effect size of 0.58 for accuracy of anticipation for solving the practice problems on the first trial, which corresponds to a large effect. The differences on accuracy of anticipations on the first anticipation between the self and external approach to presentation of prompts were nonsignificant as was
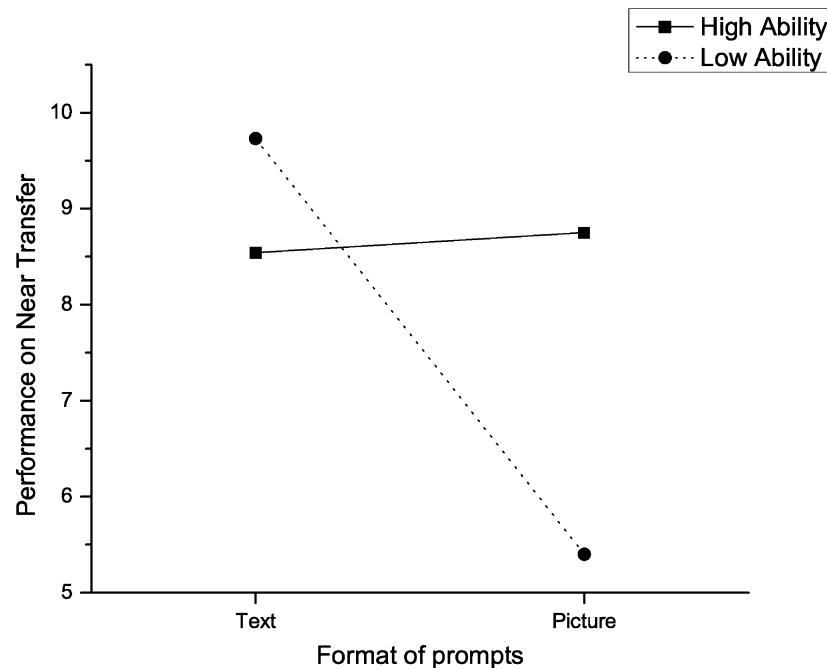
Fig. 3.   Format of prompts by academic ability interaction on near transfer post-test problems. Higher ability learners performed equally well with both formats of prompts while lower ability learners performed significantly better with textual prompts.

TABLE III
ACCURACY OF PRACTICE PROBLEM SOLVING 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
First Anticipation	0.93^*	0.08	0.82	0.13	0.86	0.14	0.88	0.11
Second Anticipation	0.05	0.07	0.13^*	0.09	0.09	0.09	0.09	0.08

$^*p < .01$

TABLE IV
INSTRUCTIONAL TIME (IN MINUTES) BY FORMAT AND PRESENTATION OF PROMPTS. THE INSTRUCTIONAL TIMES ARE NOT STATISTICALLY SIGNIFICANTLY
DIFFERENT AND THUS DO NOT ACCOUNT FOR THE DIFFERENCES IN POST-TEST SCORES AND ACCURACY OF ANTICIPATION

| | Format of Prompts | | | | | | | Presentation of Prompts | | | | | | |
| | Textual ($N = 24$) | | Pictorial ($N = 27$) | | | | | Self ($N = 24$) | | External ($N = 27$) | | | | |
Measure	M	SD	M	SD	$F(1, 47)$	MSE	p	M	SD	M	SD	$F(1, 47)$	MSE	p
Train. Time	11.87	3.26	13.07	4.53	1.14	15.87	.29	11.75	2.92	13.19	4.70	1.62	15.87	.21
Comp. Time	23.58	7.11	25.67	5.54	1.42	39.42	.24	23.21	5.92	26.00	6.54	2.51	39.42	.12

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, $F(1, 46) = 14.42, MSE = 0.01, p < .01$. Cohen's f statistic yields an effect size of 0.56, which corresponds to a large effect. However, there was no significant difference between the textual and pictorial format of prompts in the accuracy of the second anticipation given that the first anticipation was incorrect, $F(1, 36) = 1.40, MSE = 0.13, p = .25$. Moreover, there was no significant main effect for the presentation of prompts or interaction between the two factors.

D. Instructional Time

The overall average time spent on initial knowledge acquisition during the paper-based introductory training was 12.51 min ($SD = 3.99$), and 24.69 min ($SD = 6.35$) in the computer-based learning module across all participants. 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 post-test, an analysis of variance (ANOVA) was conducted on the instructional time. The analysis indicates that the advantage of the textual format of instructional prompts can not be attributed to the amount of instructional time. Table IV presents the average instructional time in paper-based training and in computer-based learning by format and presentation of prompts. Analyses of the training time participants spent studying the paper-based introductory training packet and

TABLE V
PARTICIPANT CATEGORIZED ATTITUDE SCORES BY FORMAT AND PRESENTATION OF PROMPTS. THE LEARNER ATTITUDES TOWARD THE PROMPTS WERE
SIGNIFICANTLY MORE POSITIVE WITH EXTERNAL REGULATION. THE CONTINUOUS MOTIVATION WAS SIGNIFICANTLY HIGHER WITH TEXTUAL PROMPTS

| | Format of Prompts | | | | Presentation of Prompts | | | |
| | Textual ($N = 24$) | | Pictorial ($N = 27$) | | Self ($N = 24$) | | External ($N = 27$) | |
Attitudinal Category	M	SD	M	SD	M	SD	M	SD
Instructional Effectiveness	4.05	0.48	3.78	0.54	3.91	0.49	3.92	0.57
Role of Instructional Prompts	4.01	0.75	3.93	0.65	3.73	0.75	4.18*	0.57
Continuous Motivation	3.83*	0.67	3.36	0.67	3.68	0.76	3.50	0.65

*$p < .05$

the computer-based learning time revealed that there was no significant main effect for format of prompts or presentation of prompts (see Table IV).

E. Attitudes

The overall mean score across all the 14 attitudinal survey items for all participants was 3.86 ($SD = 0.49$), a favorable rating suggesting the participants generally agreed with the positive statements about the computer-based instructional module and its components. The attitudinal items were grouped into three categories, namely instructional effectiveness, role of instructional prompts, and continuous motivation. The mean attitude scores by format and presentation of prompts for participant responses on the three main categories of attitudinal items on the five-point Likert-type attitudinal survey are presented in Table V. An analysis of variance (ANOVA) of the attitudinal category related to the role of instructional prompts revealed that there was a significant main effect for the presentation of prompts, $F(1, 47) = 5.40, MSE = 0.45, p = .03$. Cohen's f statistic for these data yields an effect size of 0.34, which corresponds to medium to large effect. Specifically, the participants who were assigned to the groups where the presentation of the instructional prompts was externally regulated had significantly more positive attitudes ($M = 4.18, SD = 0.57$) than their counterparts in the self-regulated groups ($M = 3.73, SD = 0.75$). In addition, a significant main effect was discovered on the continuous motivation attitudinal survey items for the format of prompts, $F(1, 47) = 6.36, MSE = 0.45, p = .02$. Cohen's f for these data yields an effect size of 0.37, which corresponds to medium to large effect. In particular, the participants who were exposed to the textual format of prompts expressed significantly stronger interest ($M = 3.83, SD = 0.67$) to continue learning about the content area and engineering in general than their counterparts in the groups with pictorial format of prompts ($M = 3.36, SD = 0.67$). The differences for the format and presentation of prompts on the attitudinal survey items relating to the instructional effectiveness were nonsignificant, indicating that all examined formats and presentations of prompts were perceived as equally effective.

IV. 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 anticipa-

tions 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 they were required to solve 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 groups advanced to the prompt and second trial, compared to 7% for the learners in the text-based prompt groups. However, there were no significant differences in the conditional probability of correct second anticipation given that the first anticipation was incorrect, indicating that both prompt formats are equally conducive to correct anticipation at the second trial given that the learner is incorrect at the first trial.

The textual prompt format led to significantly higher near transfer post-test 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 study revealed that the textual prompts were especially beneficial to lower-ability learners. On the other hand, higher-ability learners were able to perform equally well with both formats of instructional prompts. The significantly better performance of the lower-ability learners with the textual prompts indicates that the textual representation of the electrical analysis techniques is more suitable for novice learners. The lower-ability learners seemed to have difficulties relating the more abstract pictorial representations to the problems at hand. In contrast, the higher-ability learners were able to interpret the pictorial depictions as effectively as the verbal descriptions. This finding seems to indicate that higher-ability learners are capable of comprehending the more expert-like illustrations better than their lower-ability counterparts. The results suggest that all the learners, regardless of the treatment condition, encountered difficulties when attempting to solve the far transfer problems. Essentially, a floor effect was encountered on this measure. Therefore, one might consider testing the hypotheses with

learners who already possess some general engineering knowledge that would enable them to make the transition to the far transfer learning.

The results from the attitudinal survey indicate that the learners in the text-based group expressed significantly more positive attitudes toward the statements relating to the continuous motivation. This more positive attitude is consistent with the higher post-test scores of the learners in the text-based prompt groups. Indeed, the higher post-test scores suggest that these learners had acquired a better mastery of the instructional material, were more confident about their newly acquired skills, and had higher motivation for further study in the content area of electrical circuits. This difference in attitudes toward learning more about electrical circuits corresponds to a large effect, indicating that this difference has practical relevance. This practical relevance is especially significant in light of the ongoing efforts to attract high school students to engineering in general and electrical engineering in particular [8], [9]. While the studied learning environment was effective in fostering an interest in further study of electrical circuits in the high school students, the version with text-based prompts was significantly more effective in this regard. This finding suggests that instructional designers would be wise to consider using text-based prompts in learning environments developed for a high school audience.

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 result is interesting considering that both external and self-regulation of the prompts resulted in equal performance on the post-test and equal instructional time. Nevertheless, the learners in the group with the external control of the prompts expressed significantly more positive attitudes toward the role of the prompts. This difference, which had a medium to large effect, may be a result of the low level of prior knowledge of the learners about electrical circuit analysis. The learners with the low level of prior knowledge may have appreciated the system automatically presenting them with the helping prompts instead of being forced to decide for themselves whether or not they should view the helping prompts. Overall, the results of the attitudinal survey suggest employing text-based prompts and having the presentation of the prompts under the control of the instructional module when designing an instructional module on electrical circuit analysis for high school students without any prior exposure to this knowledge domain.

Several interesting avenues may be pursued in future research on computer-based interactive learning modules with instructional prompts. One avenue is to investigate the impact of text versus pictorial prompts on learners with a higher level of prior knowledge of general engineering analysis techniques, such as engineering college freshmen or sophomore students. These students are accustomed to abstract graphical representations of engineering problems and may, therefore, benefit more from the pictorial prompts. 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. Moreover, exploring the impact of animated pictorial prompts illustrating the flow of the electrical particles in the circuits would be worthwhile. These animated pictorial prompts would help the learners to visualize the circuit behavior, therefore facilitating performance on far transfer problems.

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