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An Interactive Multimedia Instructional Program on Statistics: An Instance of Design-Based Research

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Abstract

Students demonstrate slow progress in research methods and basic statistics classes if they struggle with identifying types of variables. A web-based multimedia instructional program to bring students up to speed on this concept was designed and evaluated with 90 undergraduate students at a Midwestern University. In order to make the design engineering process (Bryk & Gomez, 2008) easy, the program was designed both as a teaching tool and a research platform for testing potentially effective program features and instructional design strategies. In addition to the evaluation of the overall effectiveness of the program, the effectiveness of two types of potentially effective feedback was tested in this study. The results demonstrated the effectiveness of the program with either type of feedback.

Introduction

Computer technology has altered our ability to manage information. Multimedia has shortened the distance between people and information because it allows the computing to move from text to natural presentation of information through graphics, sound, images and video. Using multimedia provides multi-sensory experience for the learner in online environments. The benefits of multi-mode instruction are highlighted by Jensen and Sandlin (1991). Multimedia mirrors the way in which the human mind thinks, learns, and remembers by moving easily from words to images to sound, stopping along the way for interpretation, analysis, and in-depth exploration (Jensen & Sandlin, 1991).

Web-based multimedia instructional programs have additional benefits such as self-paced learning at a convenient place and time. The programs can be used by students both for regular classroom instruction and at home for remedial purposes. In addition, multimedia instructional programs that support interactivity and assist students in customizing instruction to their needs can provide additional benefits to learners. “The key features of multiple media, user control over the delivery of information and interactivity, can help learners come to a deeper understanding through supporting conceptualization and contextualization of the new material being presented”(Cairncross & Mannion, 2001, p. 162).

On the other hand, for the program to be effective instructional principles must be consistent with what is known about how people learn. "By maintaining overlapping theoretical and practical goals, researchers can derive instructional principles that are both grounded in theory and supported by evidence from authentic tasks" (Mayer, 2008).

Also, effective instructional design is typically based on a design-engineering-develop approach to innovation (Bryk & Gomez, 2008). If researchers engage in classroom-based research, the observed learning behaviors can be sources of data that inform next steps in the project. In this way, attention to knowledge use could be incorporated into the early stages of their work.

The purpose of this study was to demonstrate the design engineering of a web-based interactive multimedia instructional program for teaching types of variables (referred to here as the Program) that combined both the benefits of web-based interactive multimedia and effective pedagogy underlying the design and the choice of program features. Two program features, feedback and the format of problem scenario presentation (text-based scenarios augmented with animation, text-based scenarios augmented with still images, and text-only scenarios), were investigated in detail.

Feedback has been extensively identified as an important instructional strategy (Mory, 2003). Multimedia applications offer a particular valuable opportunity for feedback because it provides opportunities for students' self-assessment. The effects of different types and forms of informative feedback have been investigated in multiple instructional contexts and provided inconsistent findings (see reviews by Azevedo & Bernanrd, 1995; Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Butler & Winne, 1995; Clariana, 1993; Mory ,1992, 1996; Mason & Bruning, 2001).

As a part of program design engineering process, the researchers tested two types of potentially effective feedback for teaching concepts, single try and multiple try. In previous research, *single try* feedback has been compared to *answer until correct* (AUC) feedback (Clariana, 1993). This research study specifically compared *two tries* with *single try* feedback. The assumption was that the type of feedback that was the most helpful for both low prior knowledge students (LPK) and high prior knowledge students (HPK) would be implemented in the final version of this program.

Several studies have suggested that learning is enhanced in computer-based animation environments (Park, 1994; Tversky, Bauer-Morrison and Betrancourt, 2002). Animation appears to be most effective when presenting concepts of information that students may have difficulty envisioning (Betrancourt, 2005). On the other hand, in many studies dealing with abstract, scientific or technical content animation did not turn out beneficial compared to static pictures (Tversky, Bauer-Morrison, & Bétrancourt, 2002). Clark & Mayer (2007, p.72) recommend "using static illustrations unless there is a compelling instructional rationale for animation."

In this study, animation augmented eight text scenarios, still images augmented the next eight scenarios; the other four scenarios were text-only. In the first eight scenarios, the animations were used to show the concept of change in a dependent variable when independent variable was changed. These animations ended in still images showing the completed state of the process change. In addition, the learner had an option to replay the animation. This strategy allowed the learner to perceive functional relations between variables by watching the animations. At the same time, watching a still image would compensate for the fact that "human perceptual equipment is not very efficacious regarding processing of temporally changing information"(Betrancourt, 2005, p. 290).

Moreover, Lowe (2003) showed that low prior knowledge students are often more focused on perceptually salient rather than thematically relevant features of animation. To lower this tendency, arrows, highlighting, and labels were implemented to guide students' attention to important features of the animation. Other potential program features were compared during the design study experiment. The insights on how this approach contributed to the design process are provided in this dissertation.

Another critical condition for learning is prior knowledge (Clark & Mayer, 2007), defined here as the student's preexisting attitudes, skills, experiences, and knowledge of the concepts at hand, in this study types of variables (independent, dependent, controlled variables and levels of independent variable). In this study, students' experiences with the Program were analyzed in regards to their prior knowledge.

Program Design

A low cost web-based interactive multimedia instructional program was developed in order to facilitate undergraduate students' learning of types of variables. The Program consists of 20 scenarios for identifying different types of variables. It takes students approximately half an hour to complete it. Since the scenarios come from various contexts, the program can be used both in basic statistics and various research methodology courses. All the performance aids except for the feedback are incorporated in the Program as pop-ups and can be used when needed.

The instructional design decisions and the choice of multimedia program features were grounded in the findings from theory and empirical evaluations from the previous research. As an example, the methods for teaching the concept of variable types were verified based on previous research. According to Richards and Goldfarb (1986), "concept reasoning may be based on central tendency information, logical rules, or single episodes, depending upon which of these is activated in a particular task situation" (p.1). As these authors further explain:

> Improved performance on concept assessment tasks can be attributed to two sources - the establishment of a progressively more extensive network of episodes involving the concept (increasing the association between defining features and the concept compared to characteristic features and ensuring that exceptions to the universality of particular features are available to serve as counterexamples), and the evolution of an increasingly sophisticated series of procedures for answering questions and determining category membership. Direct teaching, of course, is also implicated (Richards & Goldfarb, 1986, p.34).

Based on the above integrative viewpoint, the Program was designed as a set of 20 scenarios, "extensive network of episodes involving the concept" (Richards & Goldfarb, 1986, p.34). Students needed to identify independent variable (IV), dependent variable (DV), controlled variable or constant (CV) and the levels of independent variables (LIV). Also, theory explanation pop-ups (brief explanation of each variable type with examples) were available on each screen (Figure 2) for the learner to develop their concept reasoning based on "central tendency information, logical rules" (Richards & Goldfarb, 1986, p.34).

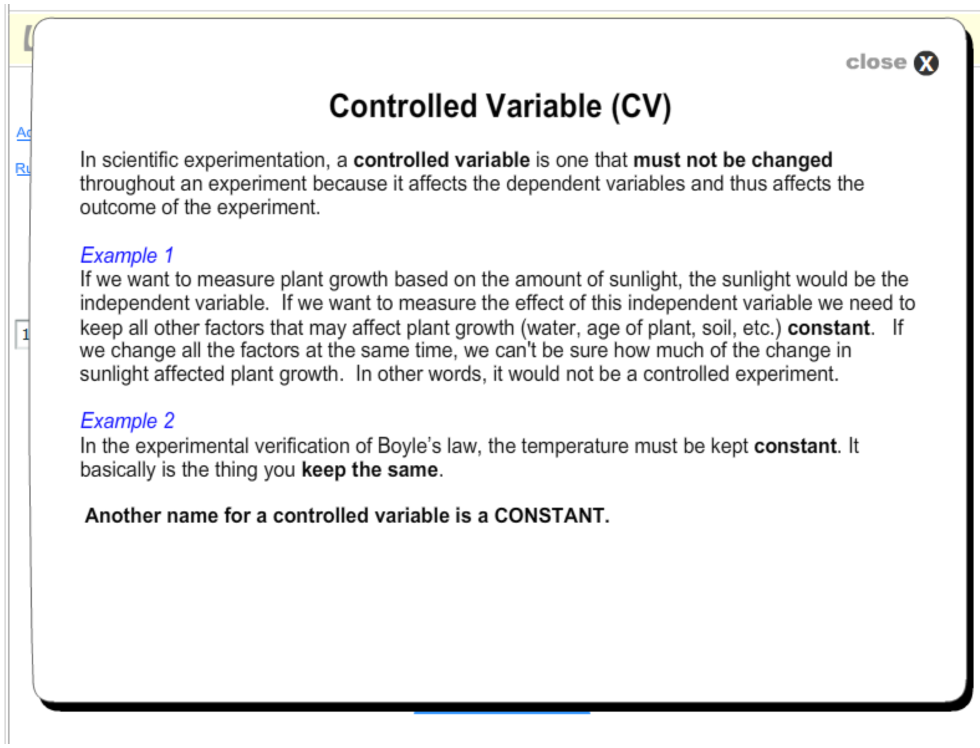

Figure 2. A screenshot of a theory explanation pop-up.

The 20 scenarios were designed to make students use the strategy of elaborative rehearsal. According to Baddley (1997) elaborative rehearsal involves the formation of connections between the new information and information already known. Educational research has confirmed the value of elaboration as an instructional practice (Ritchie & Karge, 1996). Wood et al. (1993) found that elaboration improves learning in adults and long-term retention by as much as one standard deviation. Each of the 20 problems was taught in a different context, which made learners retrieve the knowledge of the target concepts from long term memory for the application in a new scenario 20 times in a row.

Also, it is common knowledge that working memory is limited in capacity and in duration when dealing with novel information. It can combine, contrast or manipulate no more than four information elements at one time (Miller, 1956). As Litchfield (1987) stated, usually a set of concepts is presented simultaneously, and the attributes of different concepts are easily confused. But at the same time, this kind of presentation makes students compare, contrast, and clarify individual concepts (Litchfield, 1987). For the above reasons, four types of variables, independent, dependent, controlled (constant), and levels of independent variables, were taught through the Program at the same time.

In addition, the types of variables in the problem scenarios were manipulated in such a way, so that that an item classified as an IV in a particular scenario was a CV in the next scenario (Figures 3 and 4).

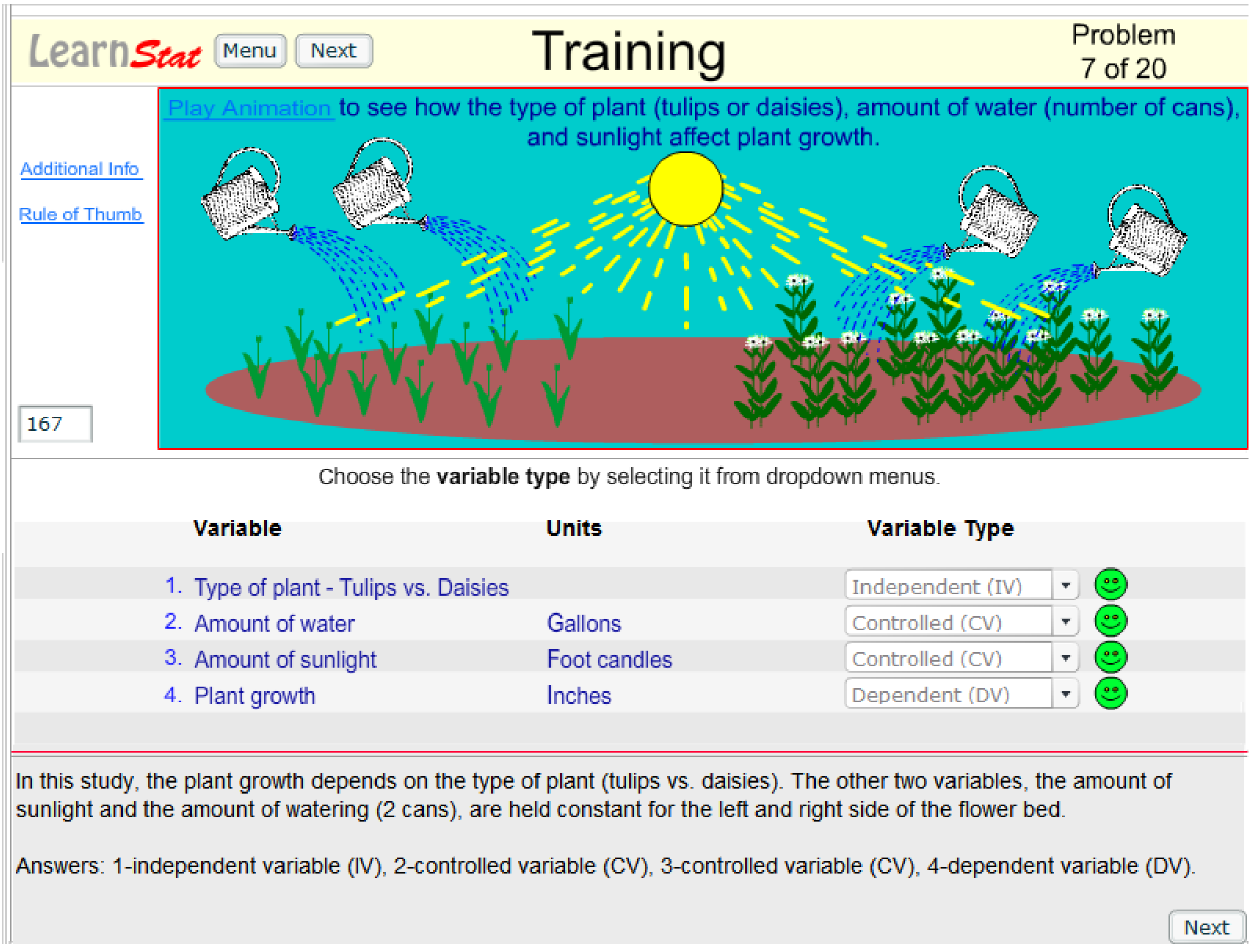

Figure 3. A screenshot of a problem scenario: type of plant (IV), amount of water (CV).

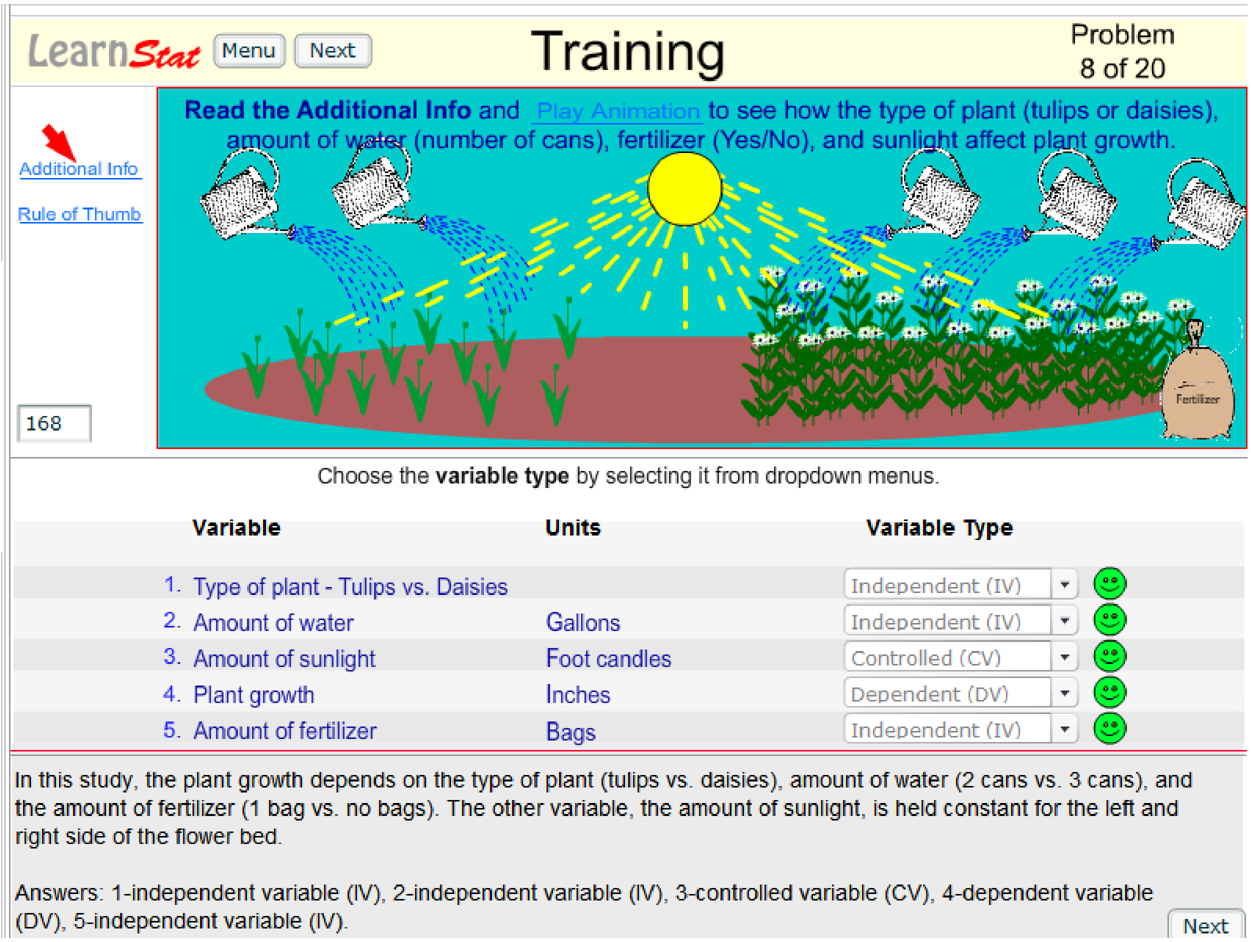

Figure 4. A screenshot of a problem scenario: type of plant (IV), amount of water (IV) (it was CV in the previous problem scenario).

This strategy was used in response to the need of further research on the strategies that would make the learner reflect on feedback (Clark & Mayer, 2007). It put students in a situation when the probability of answering with the correct answer was low. In other words, the high level of discrepancy between student's confidence level and the correctness of their response was very likely. According to Kulhavy and Stock's (1989) certitude model of feedback, learners who are informed that their answers are wrong when they are confident that their answers are correct will "exert much effort to find out what was remiss in their thinking" (Mory, 2003, p. 749).

The effects of different types and forms of informative feedback have been investigated in multiple instructional contexts and provided inconsistent findings (see reviews by Azevedo & Bernanrd, 1995; Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Butler & Winne, 1995; Clariana, 1993; Mory ,1992, 1996; Mason & Bruning, 2001). Decisions on feedback content, presentation format, and timing were made while creating the Program. Without going into too much detail, regarding *feedback content*, the Program uses response-contingent feedback to provide both verification (knowledge of result –KR- feedback presented as smiley faces) and item-specific elaboration (elaborative feedback –EF presented as text) (Figures 3 and 4).

In relation to feedback presentation format, a *single try* feedback and a *two tries* feedback were tested. The *single try* feedback consisted of KR and pre-determined EF feedback. The *two tries* was composed of KR feedback on the first try and the KR feedback combined with the EF feedback on the second try. In regards to the *feedback timing*, immediate feedback vs. delayed feedback, the designers followed the Keller's recommendation (1983, p. 426-427) "to improve the quality of performance, provide formative (corrective) feedback when it will be immediately useful, usually just before the next opportunity to practice."

As a final step in program feedback engineering, two potentially affective formats of feedback presentation, *single try* and *two tries,* were tested in two experimental conditions (Condition 2 and Condition 3 correspondingly) with the goal in mind to identify the most effective feedback presentation format for the Program.

In addition, student's perceptions on how the Program features supported their cognitive processing of the target concepts were also gathered using two surveys: Survey 1 administered after the teaching session with the Program and Survey 2 administered after the delayed post-test (administered five days after using the Program). This strategy allowed the researcher to get an insight into the helpfulness of the Program features by a particular cognitive process: recall of the target information (Figure 5), understanding of the concepts (Figure 6), and maintaining students' attention (Figure 7). Moreover, students' overall impressions of their educational experiences with the Program were collected through Survey 1 and 2.

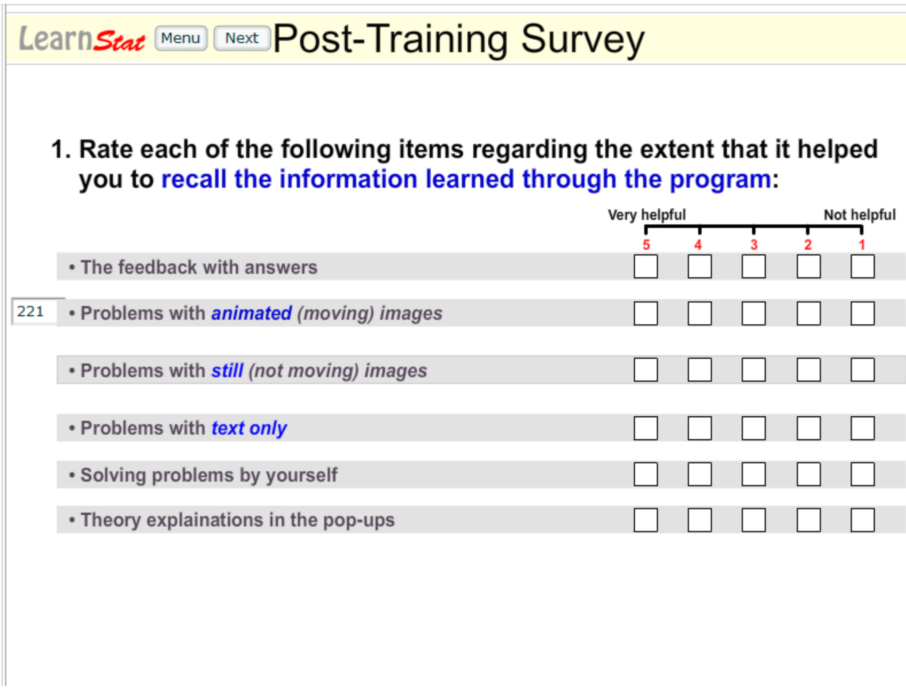

Figure 5. A screenshot of Survey 1: item #1 collects data about how different program features help students recall the information learned through the program.

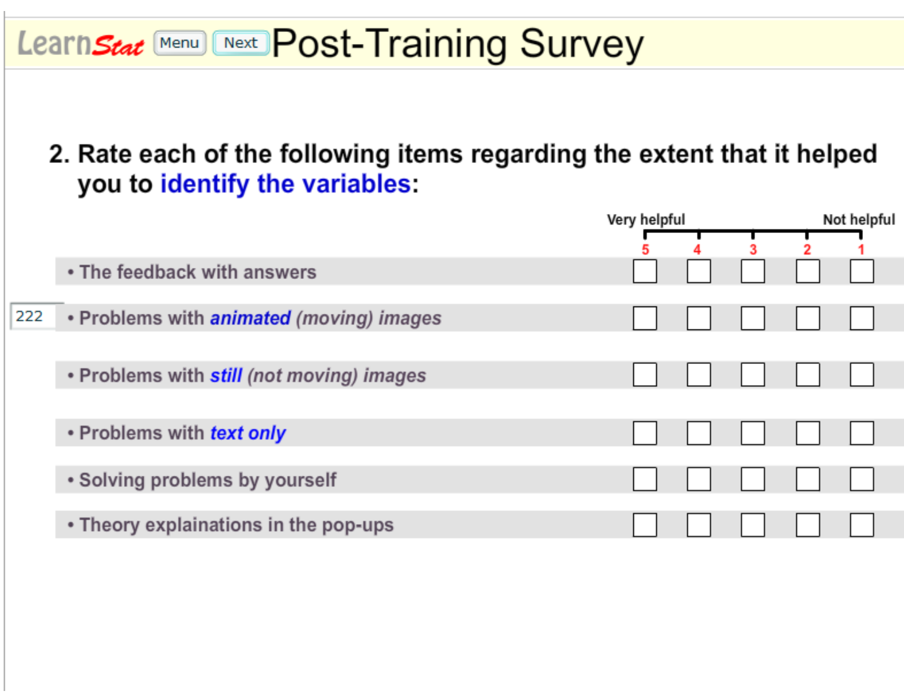

Figure 6. A screenshot of Survey 1: item #2 collects data about how different program features help students understand the information learned through the program.

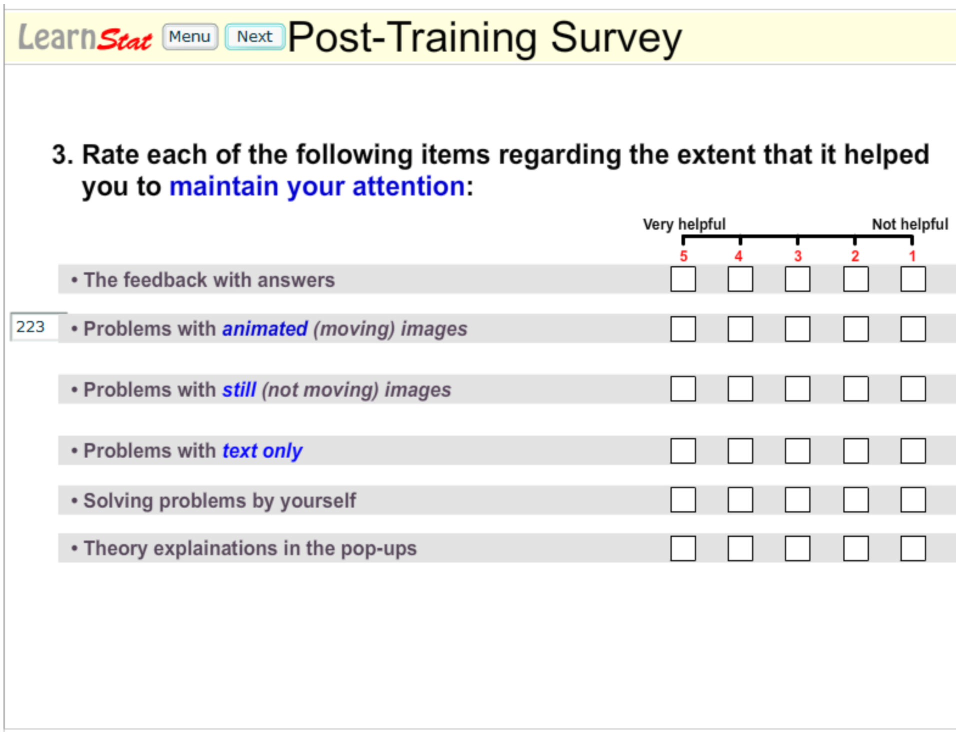

Figure 7. A screenshot of Survey 1: item #3 collects data about how different program features help students maintain their attention through the program.

Purpose of the Study

The aim of this study was, first, to evaluate the effectiveness of the design of the program with linear navigation and predetermined feedback, second, collect information about how different features in the program helped students memorize, understand, retain the information, and how they helped students maintain their attention. Two potentially effective types of feedback were compared and the most effective type was chosen.

Students' perceptions on how the design of different features in the program supported their cognitive and metacognitive processes were collected through two surveys. The obtained quantitative and qualitative data were considered in regards to students' prior knowledge. Data were collected from 3 perspectives:

1. students' (how different program features and instructional design methods help them learn)
2. multimedia instructional designer's (which features are used the most/the least, possible navigation and visual design problems)

3. instructors' (students' knowledge gain between pre-test and delayed post-test)

Research Questions

The following research questions were addressed:

Research Question #1: How well did the Program facilitate retention of the acquired concepts depending on the feedback type?

In this study, *single try* feedback was a response-contingent feedback consisting of the Knowledge of Results (KR) and the pre-determined Elaborative Feedback (EF). KR consisted of green and red smiley faces, and EF was a text explanation of the correct answers. The *two tries* feedback consisted of two steps. The users were presented the KR Feedback on the first try and the KR Feedback combined with EF after the second try (see Figure 2.1).

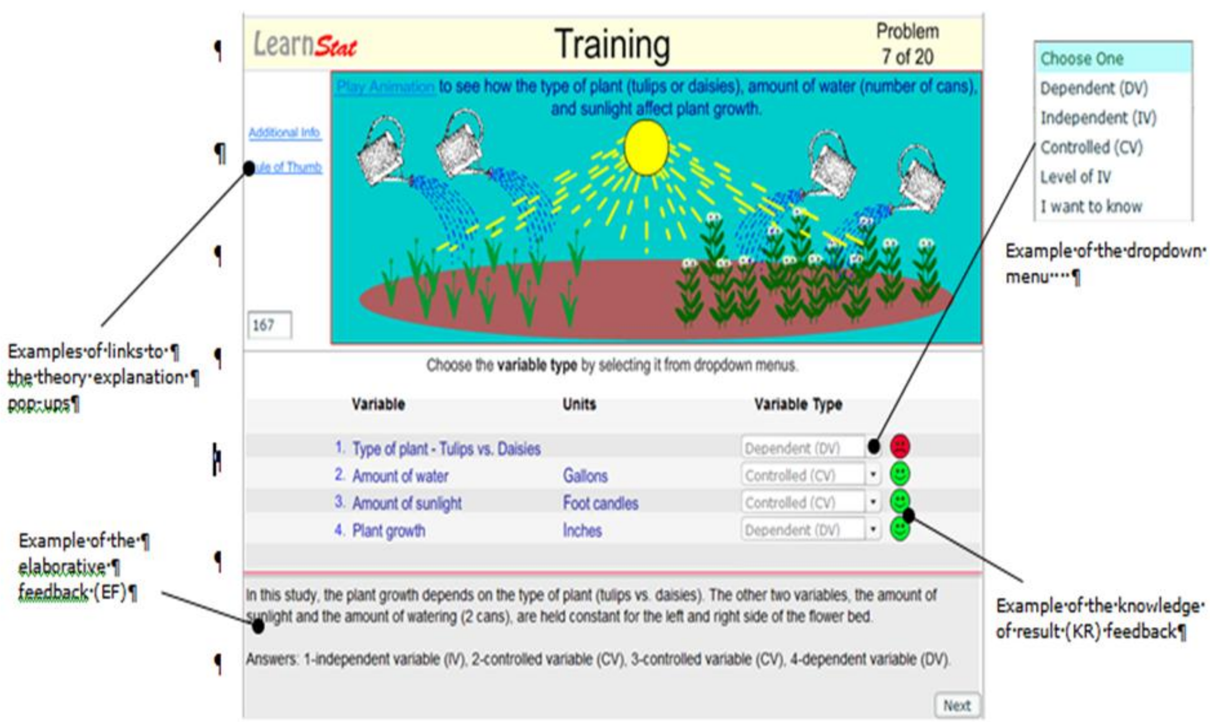

Figure 2.1 A screenshot of a problem scenario

It was hypothesized (Hypothesis 1a) that the program would facilitate retention of the concept of variables, and the average knowledge gain in the control condition would be statistically significantly lower than in each of the experimental conditions. The only difference between experimental conditions was feedback type, *single try* or *two tries*. Also, it was expected that the average knowledge gain differences between the two experimental conditions would be statistically significant (Hypothesis 1b). Since the only difference between the experimental conditions was feedback type, the higher knowledge gains would indicate the more effective type of feedback for this program.

Research Question #2: How different were students' experiences with the Program when their prior knowledge was considered?

It was expected that there would be a statistically significant difference in knowledge gain between the low prior knowledge (LPK) students across two experimental conditions (Hypothesis 2a). Similarly, a statistically significant difference between the high prior knowledge (HPK) students across two experimental conditions was expected (Hypothesis 2b).

Methodology

Data were collected in with 90 participants in two undergraduate Basic Statistics courses for non-statistics majors and an Educational Psychology course. The experiment followed a 2x2 design with the first factor as the between subjects factor and the last factor as the within subjects factor. The conditions tested included control condition and two experimental conditions, "single try" (ST) feedback and "two tries" (TT) feedback. Participants were randomly assigned to each of the three conditions, the equal number of students per condition. The between subjects factor was the type of feedback, ST and TT. The within subjects factor was the level of students' domain specific prior knowledge based on their pre-test score. The level of prior knowledge was determined according to the median split (Mdn=25) of participants' pre-test scores. Research questions and data collection instruments are presented in Table 2.1

Table 2.1 Research questions and data collection instruments

#	Research Questions and Hypotheses	Data Collection Instruments
1	How well did the Program facilitate retention of the acquired concepts depending on the feedback type?	1. Students' pre-test and delayed post-test scores stored in the database.
2	How different were students' experiences with the Program regarding their prior knowledge?	1. Students' pre-test and delayed post-test scores stored in the database. 2. Likert-scale survey

Data Collection

The participants received instruction through the multimedia instructional program at their convenience for 15-40 minutes without any help from the teachers. The pre-test, the training episode, and the post-test were done at students' own pace. The data collection process is presented in Table 2.2. Students' perceptions on how the feedback helped them recall and understand the information along with how it helped them maintain their attention were collected in a Likert-scale survey embedded in the program and administered after the training.

Table 2.2 Data collection

Time Schedule	Procedures
Day1	Pre-test, training episode, likert survey
Day5	Post-test

Data Analysis

Students' knowledge gain.

The knowledge gained during the training was assessed with a pre-test and delayed (5th day after the training) post-test. The pre-test and post-test were the same and consisted of ten scenarios. In each scenario, participants had to make five choices by selecting from five dropdown menus: independent variable, dependent variable, controlled variable, level of independent variable, and “I want to know”. The fifth choice “I want to know” was added to avoid random answers. Making the correct choices required conceptual knowledge, that is, coherent mental models of types of variables. Each correct answer was scored as one point. The maximum score was 50 points.

Students’ pre-test scores served as indicators of their prior knowledge of types of variables. The difference between delayed post-test scores and pre-test scores served as indicator of students’ retention of the types of variables concept. All the tests as well as the survey were embedded in the program and the students’ responses were captured in the database. All the items in the tests were designed to check the students’ ability to differentiate between independent, dependent & controlled variables as well as levels of independent variables.

Hypotheses 1a and 1b were validated by the pairwise comparison of the single try feedback condition and two tries feedback condition. As to the comparison of students’ performance in each of the experimental conditions in regards to students’ prior knowledge, non-parametric two-sample Wilcoxon rank-sum (Mann-Whitney) tests were computed within each prior knowledge level and the significance level was divided by two to avoid type I error (i.e., the value of the significance level was set at 0.025).

Students’ perceptions of the program and their use of performance aids.

Students’ ratings of different program features and instructional methods were examined in regards to their prior knowledge. Descriptive statistics was used for the analysis of the data. Means, medians and standard deviations of students’ ratings of their overall experience and the program features were calculated for each experimental condition and level of prior knowledge (for LPK and HPK students by condition).

Results and Discussion

The results of the evaluation provided evidence of the overall effectiveness of the Program for both high and low prior knowledge students (LPK and HPK students correspondingly), but there was no significant difference in their performance across conditions.

Research Question #1: How well did the Program facilitate retention of the acquired concepts depending on the feedback type?

A one-way between subjects ANOVA was conducted to compare the effect of overall program training on students' knowledge gain between the pre-test and delayed post-test for Condition 1 (no training), Condition 2 (training with a single try feedback), and Condition 3 (training with a *two tries* feedback). Tests of the three a priori hypotheses were conducted using Bonferroni adjusted alpha levels of .017 per test (.05/3). There was a significant effect of the program training on students' knowledge gain [(F(2,87)=34.18. p=0.000]. The results indicated that the knowledge gain was significantly lower in the control group condition (M = 1.9, SD = 2.52), than were those in both the *single try* feedback condition (M = 14.93, SD = 9.16) and the *two tries* feedback condition (M = 16.06, SD = 8.58). Hypothesis 1a was confirmed. The pairwise comparison of the *single try* feedback condition and *two tries* feedback condition was non-significant (0.838), [F (2, 87) =1.13, p=0.838]. Hypothesis 1b was rejected. The knowledge gain between the pre-test and delayed post-test (5 days after the training) in Condition 2 was 30.8% and in Condition 3 (30.0%).

Research Question #2: How different were students' experiences with the Program when their prior knowledge was considered?

Since the distribution of low prior knowledge (LPK) and high prior knowledge (HPK) students' scores per condition was not normal, non-parametric tests were used to analyze the data about the effects of feedback type within each prior knowledge level. Two two-sample Wilcoxon rank-sum (Mann-Whitney) tests were computed within each prior knowledge level and the significance level was divided by two to avoid type I error (i.e., the value of the significance level was set at 0.025).

The results suggested that there was no statistically significant difference between the underlying distributions of the knowledge gain scores between low prior knowledge students in the *single try* feedback condition (Condition 2) (M=19.67, SD= 9.78) and the *two tries* feedback condition (Condition 3) (M=19.18, SD= 9.11) (z = 0.189, p = 0.8501).

As to the high prior knowledge students in Condition 2 (M=9.86, SD=4.88) and Condition 3 (M=12.29, SD=6.29), their knowledge gain scores were not significantly different either (z = - 0.761, p=0.447).

These findings contradict the findings from the previous research (Clariana, 1993) in which *single try* feedback was more effective *than multiple try* feedback for LPK students while *multiple* try feedback was more effective than *single try* feedback for HPK students. In Clariana's study(1993), the type of *multiple try* feedback was the *answer until correct* one. In our study, *two tries* feedback was not more effective for HPK students compared to LPK students.

Students' average survey ratings of the overall effectiveness of the program were high across both experimental conditions 2 and 3 and across both LPK and HPK students. The average rating given by LPK students was 4.76 for Condition 3 and 4.27 for Condition 2.The average rating given by HPK students was 4.64 for Condition 3 and 4.50 for Condition 2. In other words, low prior knowledge students valued the *two tries* feedback higher than *single try* feedback even though there was no significant difference in their knowledge gain. Learning through the program was easier (LPK: 3.84, HPK: 4.43) and more interesting (LPK: 3.97, HPK: 4.25) for HPK students.

In contrast, the ratings for the survey statement "The program helped me understand the difference between variables." were marginally the same (LPK:4.53, HPK: 4.57). The same is true about students' ratings of the statement "I would recommend the program to others." (LPK: 4.47, HPK: 4.43). It allows the designers to assume that the program was equally helpful for both LPK and HPK students and the program features addressed the needs of students with different levels of prior knowledge.

Table 2.3 Means (and SD) of students' survey ratings (1-strongly disagree, 5-strongly agree) of overall satisfaction with the program

Categories of student satisfaction with the program	**Condition 2**		**Condition 3**	
	LPK, n=15	**HPK, n=14**	**LPK, n=17**	**HPK, n=14**
	M (SD)	**M (SD)**	**M (SD)**	**M (SD)**
1. I would recommend this program to others	4.33 (0.72)	4.29 (0.61)	4.59 (0.51)	4.57(0.51)
2. The Program made me think	4.20 (0.68)	4.29 (0.61)	4.47 (0.51)	4.50 (0.65)
3. Learning through the Program was interesting	3.73 (0.80)	4.14 (0.36)	4.18 (0.64)	4.36 (0.74)
4. Learning through the Program was easy	3.80(0.56)	4.21(0.70)	3.88(0.60)	4.64(0.50)
5. The Program helped me understand the difference between variables	4.27(0.70)	4.50(0.65)	4.76(0.44)	4.54(0.50)

Note. LPK stands for Low prior knowledge students, HPK stands for high prior knowledge students, n stands for the number of students.

As to students' ratings of program features, the program feature that received the highest rating was feedback across both conditions. Interestingly, both survey items *Learning by using theory explanation* popups (deductive reasoning use) and *Learning by solving problems* (inductive reasoning use) were rated higher by high prior-knowledge students. In contrast, the item *Learning through feedback* received almost the same ratings.

Also, in both conditions, text scenarios augmented with animation were consistently higher rated compared to the ones with still images and text only. Scenarios with animation were the most helpful for maintaining attention. On the other hand, the ranges of ratings for all three items (animation, still images, text-only) are large (min: 1, max: 5), which means that the preferences may be related to students' individual differences related neither to prior knowledge nor to conditions.

Students' survey ratings by the kind of cognitive processing supported by the Program (the target concept recall, understanding, and maintaining attention during the training) are presented in Table 2.4.

Table 2.4 Means (and SD) of students' survey ratings (1-strongly disagree, 5-strongly agree) of problem scenario presentation format by type of cognitive processing

Types of cognitive processing	**Condition 2**		**Condition 3**	
	LPK, n=15 M (SD)	**HPK, n=14 M (SD)**	**LPK, n=17 M (SD)**	**HPK, n=14 M (SD)**
1.Helped me recall the concept of variables				
1) Learning by using theory explanation popups (deductive reasoning use)	3.73(0.96)	4.21(0.58)	3.88(0.99)	3.86(1.10)
2) Learning by solving problems (inductive reasoning use)	3.20(0.94)	3.64(1.01)	3.47(1.18)	4.07(1.27)
3) Learning through feedback	4.53(0.52)	4.50(0.65)	4.53(0.62)	4.43(0.65)
4) Problems as text with still images	3.67(0.98)	3.21(0.97)	3.94(0.90)	4.21(0.70)
5) Problems as text only	2.93(0.96)	3.07(1.00)	3.00(0.96)	3.73(0.96)
6) Problems as text with animation	3.73(0.96)	3.73(0.96)	3.73(0.71)	3.50(0.94)
2.Helped me identify variables				
1) Learning by using theory explanation popups (deductive reasoning use)	3.87(0.83)	4.14(0.66)	3.76(1.08)	3.79(1.25)
2) Learning by solving problems (inductive reasoning use)	2.87(1.06)	3.64(0.84)	3.71(1.05)	3.79(1.31)
3) Learning through feedback	4.53(0.64)	4.57(0.65)	4.41(0.71)	4.29(0.73)
4) Problems as text with still images	3.80(1.08)	3.64(1.01)	3.76(1.15)	4.07(0.73)
5) Problems as text only	2.73(0.96)	3.21(0.97)	3.12(0.86)	3.50(1.34)
6) Problems as text with animation	4.47(0.64)	4.07(1.27)	4.06(1.09)	3.93(1.27)
3. Helped me maintain attention				
1) Learning by using theory explanation popups (deductive reasoning use)	3.00(1.13)	3.64(0.50)	3.53(1.01)	3.36(1.60)
2) Learning by solving problems (inductive reasoning use)	2.53(1.19)	3.57(0.94)	3.47(1.33)	3.64(1.28)
3) Learning through feedback	3.80(1.01)	4.50(0.94)	4.18(0.95)	4.07(0.83)
4) Problems as text with still images	3.20(1.08)	3.93(1.00)	3.94(1.09)	3.71(0.91)
5) Problems as text only	2.13(1.36)	2.64(0.93)	2.82(1.19)	2.50(0.85)
6) Problems as text with animation	4.67(0.72)	4.50(1.16)	4.35(1.11)	4.43(1.16)

Conclusions

The multilayered nature of this research is an attempt to contribute both to the science of instruction (formative evaluation of the Program with the goal of identifying possible problems for further modifications and improvements) and the science of learning (the experimental testing of two types of feedback design grounded in cognitive theories and validating the feedback design using students' input on how the feedback in the Program helped them maintain attention, understand, and retain the target concepts). "By maintaining overlapping theoretical and practical goals, researchers can derive instructional principles that are both grounded in theory and supported by evidence from authentic tasks" (Mayer, 2008). It might be argued that for both experimental conditions - *single try* (ST) and *two tries* (TT) feedback – the Program facilitated retention of knowledge. There was no significant difference between conditions, which is in tune with Clariana's study (1993).

This work allowed the researchers to make conclusions about the overall effectiveness of the Program by comparing the students' knowledge gain in the control group with the students' knowledge gain in each of the experimental conditions. The knowledge gain was compared for both LPK and HPK students across the conditions to make sure that the Program met the needs of students with different levels of prior knowledge. Students' perceptions on how the design of different features in the program supported their cognitive and metacognitive processes provided information about the justification and helpfulness of the program features. Also, the data from this research study provided themes for the next stage of the program formative evaluation. One of the topics of interest in the next stage that emerged from this research was the comparison of different formats of problem scenario presentations: problem scenario augmented with animation, problem scenarios augmented with still images, and text only scenarios.

References

Azevedo, R., & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research, 13*(2), 111-127.

Baddeley, A. (1997). *Human memory: Theory and practice*. Revised edition. Hove, UK: Psychology Press.

Bangert-Drowns, R. L. Kulik, C. Kulik, J. A. & Morgan, M. T. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research, 61*, 213-238.

Betrancourt, M. (2005). The animation and interactivity principles in multimedia learning. In R. E. Mayer (Ed.). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Bryk, A. S., & Gomez, L. M. (2008). Ruminations on reinventing an R&D capacity for educational improvement. In F. M. Hess (Ed.), *The future of educational entrepreneurship: Possibilities for school reform*. Cambridge: Harvard Education Press.

Butler, D. & Winne, P. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational research, 65* (3), 245-281.

Cairncross, S & Mannion, M. (2001).Interactive Multimedia and Learning: Realizing the Benefits. *Innovations in Education & Teaching International, 38* (2), 156-164.

Clariana, R. B. (1993). A review of multiple-try feedback in traditional and computer-based instruction. *Journal of Computer-Based Instruction*, *20*(3), 67-74.

Clark R. C. & Mayer, R. E. (2007**).** *E-Learning and the science of instruction***:** *Proven guidelines for consumers and designers of multimedia learning* (2nd ed**.**)**.** San Francisco, CA: Pfeiffer & Company.

Jensen, R. E. & Sandlin, P. (1991). *Why do it? Advantages and dangers of new ways of computer-aided teaching/instruction*. San Antonio, TX: Department of Business Administration, Trinity University.

Keller, J. M. (1983). Motivational design of instruction. In C.M. Reigeluth (Ed.) *Instructional-design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum.

Litchfield, B.C. (1987). The effect of presentation sequence and generalization formulae on retention of coordinate and successive concepts and rules in computer-based instruction (Doctoral dissertation, Florida State University, 1987). *Dissertation Abstracts International, 49,* 486A

Lowe, R.K. (2003). Animation and learning: Selective processing of information in dynamic graphics. *Learning and Instruction, 13*, 157-176.

Mason, B. J. & Bruning, R. (2001). Providing feedback in computer-based instruction: What the research tells us. Retrieved from http://dwb.unl.edu/Edit/MB/MasonBruning.html

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *The American Psychologist*, *63*(8), 760–769.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*, 81-97.

Mory, E. (1992). The use of informational feedback in instruction: Implications for future research. *Educational Training Research and Development*, *40*(3), 5-20.

Mory, E. (1996). Feedback research. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology*. New York: Simon & Schuster Macmillan.

Mory. E. H. (2003) Feedback research revisited, in Jonassen, J. H. (Ed.): *Handbook of Research on Educational Communications and Technology*, MacMillian Library Reference, New York, pp. 745-783

Park, O. (1994). Dynamic visual displays in media-based instruction. *Educational Technology, 34*(4), 21-25.

Richards, D. D. & Godfarb, J.(1986). The episodic memory model of conceptual development: An integrative viewpoint. *Cognitive Development (1)*, 183-219.

Ritchie, D. & Karge, B. D. (1996). Making information memorable: Enhanced knowledge retention and recall through the elaboration process. *Preventing School Failure*, *41*(1), 28-34.

Tversky, B. Bauer-Morrison, J., & Bétrancourt, M. (2002) Animation: Can it facilitate? *International Journal of Human-Computer Studies*, 57, 247-262.

Wood, E., Willoughby, T., Bolger, A., Younger, J., & Kaspar, V. (1993). Effectiveness of elaboration strategies for grade school children as a function of academic achievement. *Journal of Experimental Child Psychology, 56*, 240-253.

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