

A Comparison of Scaffolding Media in a Learning System for Teaching Web Development

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Abstract: The purpose of this experiment was to compare two types of media scaffolds as a part of a learning system for teaching web development. Twenty students were given the task of creating an interactive web page using the web editor *Dreamweaver*[®]. They used a web-based tutorial to support this task. The tutorial included step-by-step text directions for how to complete the task, which were supplemented by media in the form of graphics for half of the students, and video for the other half. Those whose tutorials included videos performed better and rated the task more positively. In addition, students across both groups spent most of the time completing the task, as compared to viewing the tutorial, particularly the media. There was a strong positive relationship between time spent on the task and previous *Dreamweaver*^a experience, and a negative relationship between experience and time spent viewing the text directions.

Introduction

Rationale

Computer-based learning systems and the World Wide Web afford us an opportunity to move education to a new level, both to enrich traditional instruction and to provide instruction at a distance. However, research indicates that much of the promise of these systems has not been realized (Reeves, 2002). There are a number of reasons for this. A primary reason is that little thought or effort goes into design and research before the tools are implemented (Hall, Watkins, & Ercal, 2000). A fundamental characteristic of effective learning environments is that they promote and encourage active learning. Unfortunately, many web-based distance courses, and even elaborate multimedia simulations are simply used to display information. At the same time, research in hypermedia learning systems indicates that it is also very important to provide the learner with some level of guidance (Shin, Schallert, & Savenye, 1994), and this too is often lacking in these web-based systems. Finally, the ineffectiveness of these tools is almost surely partly due to the lack of systematic research (Dillon & Gabbard, 1998). The vast majority of web-based courses and modules have not been pilot tested or evaluated prior to their introduction into

the curriculum. In short, the full potential of web-based learning will only be realized through the application of systematic principles of instructional media design and iterative research (Eller, Hall, & Watkins, 2001).

Progressive-Scaffolding System

The prototype system used for this experiment was guided by two fundamental, and somewhat contrasting, design themes: problem-based interactivity; and progressive scaffolding.

In the proposed system, the core of each module is a problem, which requires that the learner actively integrate knowledge from multiple sources and apply basic methods and procedures for its solution. A large body of educational research indicates that learners learn most effectively when they are actively engaged in learning, as opposed to passively reading or listening (Brooks, 1997). Further, problem solving is at the core of meaningful learning.

“Progressive scaffolding” is the term we use to refer to a systematic method of providing learners with an optimal level of guidance (Hall, Watkins, & Eller, 2003). The system is designed in such a way that supporting materials are offered in a progressive fashion, from the most general and minimal guidance to the most specific and detailed. It is then up to the learner to select the tool at the necessary level for problem solution.

Pilot Experiment

We are currently developing a series of learning modules based on the system described above for teaching a Web Development class. The system is intended to support a face-to-face class at the University of Missouri-Rolla on this topic, but it is also intended to be appropriate as a component of a distance learning class.

As a part of this system, we created a prototype module, which is a step-by-step description for how to create a fairly elaborate web page, using the web development tool *Macromedia Dreamweaver*©. To create the page, the user must apply a number of general procedures including: setting up a site; adding tables & graphics; using tables for page layout; inserting text; creating hyperlinks; creating image rollovers; and creating a disjoint swap image behavior.

This initial prototype system is straightforward and was intended to examine the key components of the model posed above. The progressive scaffolding is provided in the form of different levels of information for displaying each step in the development process: a) Text; b) Graphics; c) Narrated Video. The system used for the pilot experiment can be viewed: http://campus.umr.edu/lite/web_dev_experiment

A pilot study was carried out using this system including detailed quantitative and qualitative analysis of participants using the system to create a basic web site (Hall, Digennaro, Ward, Havens, & Ricca, 2002). This pilot study addressed the following two questions:

1. To what extent do users utilize the different scaffolding options (text, graphics, and video)?
2. How does their use of the various options relate to performance?

With respect to our basic experimental questions, we found that users primarily utilized the most minimal (text) and elaborate (video) scaffolds, while they largely ignored the static graphics. In addition, we found that the amount of time spent viewing the text was positively related to performance; while the time spent viewing the videos was negatively related to performance. Other important findings emerged as well, independent of the experimental questions, based on the qualitative analysis. One of the strongest findings was that the previous content knowledge (experience level) of the user played an important role, with the more experienced users utilizing the more minimal scaffolds to a greater degree. This helped to partially explain the strong negative relationship between the amounts of time spent viewing the videos and performance. The videos most likely did not “cause” poor performance but were more useful to those with less experience. Unfortunately, this experiment did not allow for adequate evaluation of static graphics as scaffolds, since these were accessed so infrequently. Such an evaluation would have important practical implications, given differences in resources and complexity associated with the development and display of static graphics vs. video.

Present Experiment

The present experiment built upon experiment 1, by extending the study in a number of ways. First, a new prototype tutorial was created based on a newer version of *Dreamweaver*[®]. Second, the number of students who participated was almost tripled (from 7 to 20). Third, and most fundamental, two experimental conditions were created, so that participants either used graphics as an adjunct scaffold to the text, or they used a video, rather than having the option to use both. This allowed for the direct comparison of graphics vs. video as a scaffolding technique. Fourth, a pre-questionnaire was used which assessed participants' experience with *Dreamweaver*[®] in particular and web development in general, which allowed for a more thorough examination of the role of user experience in its impact on the users' use of the tutorial and performance.

More specifically, the present experiment addressed the following experimental questions:

1. How does time allocation (as measured by time spent on text, media, and task performance) differ as a function of experimental condition (graphics vs. video)?
2. How does performance (as measured by quality, quantity, and ease-of-navigation) differ as a function of experimental condition?
3. How do users' subjective-ratings of the effectiveness and usability of the learning system differ as a function of experimental condition?
4. What is the relationship between degree of previous experiences and time allocation?
5. What is the relationship between degree of previous experiences and performance?

Method

Participants

The participants were 20 students recruited from a Visual Basic programming class and a Java programming class at the University of Missouri – Rolla in return for extra credit.

Materials

Students studied an online tutorial, in which they were required to develop a relatively complicated web page using the web editing tool *Dreamweaver*[®], which included: links, tables, graphics, layers, and behaviors. The tutorial consisted of four parts: introduction, setting up the table/layout, layers, and behaviors. Each part was on a separate web page with a link to the next part on the bottom of each page. The instructions were written in a step-by-step manner.

Two sets of materials were developed. The graphics set of materials included links to graphics files to illustrate the instructions and the videos set of materials included links to video files to illustrate the instructions. These instructional materials can be viewed on the web at: <http://campus.UMR.edu/lite/scaffolding2>

The experiment took place in the University of Missouri – Rolla's Laboratory for Information Technology Evaluation testing facility. The facility consists of two cubicles, one for the participant and one for the researcher. A video capture of the user's computer screen and a video of the user's facial expressions are collected and a picture-in-picture video is created for review via a mixer.

Procedure

Students completed the experiment one at a time. Upon arrival they were given a pre-questionnaire to complete. Students were required to respond to the following seven items using on a 10 point (disagree-agree) Likert scale.

1. I have used Dreamweaver often.
2. I have taken a class in which I learned Dreamweaver.
3. I have used the layers behavior in Dreamweaver.
4. I have used the table tool in Dreamweaver.

5. I have done a great deal of web development.
6. I have often used JavaScript in web development.
7. I have often used cascading style sheets (css) in web development.

Students were then told to sit at a computer that was set up, which had Dreamweaver open in the background and Internet Explorer open in the foreground, which was open to the tutorial's introduction. The introduction stated the following:

Your goal in this experiment is to build a web page that looks like [this](#). When you view the page, be sure to roll over the building names.

You will create this site using the web editor Dreamweaver MX. The program should be open now. If it is not, ask the experimenter to open it for you.

When you click on the link below, a tutorial will open which will guide you step by step through the process of creating the web page in Dreamweaver. The tutorial contains links to additional media, which you can use to aid your understanding of the instructions. The tutorial is divided into three parts. Complete all of the instructions in each part before moving on to the next.

When the experimenter tells you to do so, click the start button to begin. You will have 30 minutes to create as much of the web page as possible.

Students were then given thirty minutes to complete the web page using the tutorial. Their activity during the experiment was recorded as previously described. When thirty minutes had passed the experimenter told the participant that their time was up and to save their web page. The participant was then given a post-questionnaire. For the post-questionnaire, students were required to respond to the following seven items using on a 10 point (disagree-agree) Likert scale.

1. I found this tutorial to be very helpful.
2. I found the additional media helpful.
3. I found this task to be difficult.
4. I found this tutorial to be easy to use.
5. I learned a great deal about using Dreamweaver from this tutorial.
6. I found this tutorial to be frustrating.
7. I found this tutorial to be motivational.

Results

Scoring and Data Reduction

Time Allocation

In order to determine how participants allocated their time, videotapes were scored according to the amount of time that a user spent on three primary activities: 1) Reading text, 2) Viewing media (graphics or video), and 3) Creating the web page (task). Scoring was carried out such that all of the forty-five minutes that the user spent working had to be assigned one of these tasks. In cases where there was some overlap, such as when the participant was working on the web page, while a video tape was playing, the scorer made a determination as to what was the primary task being carried out at that time and time was then attributed to that task in scoring.

In order to establish reliability, a random set of ten videos was selected with the constraint that half were from each of the two experimental conditions. Two scorers rated each of the ten tapes independently. Three Pearson's correlations were computed relating the two sets of scores for time spent reading text, viewing media, and creating the page (task) and these were $r = .94$, $r = .99$, and $r = .97$ respectively.

Performance

In order to assess participants' performance, the raters also rated the user's final web page in terms of quality and quantity (amount completed). In addition, the user's ease of navigation within the tutorial was rated. Again, reliabilities were computed by correlating (Pearson's r) the scores for two raters on a randomly selected set of ten participant videos (5 from each experimental condition). The reliabilities for quality, quantity, and navigation were $r = .96$, $r = .96$, and $r = .80$ respectively.

Pre-test of User Experience

In order to examine the relationship among the seven pre-test questions on user experience, and to reduce these into a more practical number of measures, a Principal Components factor analysis was computed on the seven pre-questionnaire items, with a Varimax rotation. The number of factors extracted was based on the criterion that the eigenvalue was greater than one. Based on this criterion, two factors were extracted. These factors were labeled "dreamweaver experience" and "web development experience". The factors in the rotated solution accounted for 53% and 38% of the variance with eigenvalues of 3.73 and 2.68 respectively. The items that loaded on each factor and the loadings are displayed in Table 1.

Item	Experience Factor	
	Dreamweaver	Web Development
Used Dreamweaver Often	.84	(.41)
Taken class with Dreamweaver	.94	(.31)
Used Layers tool in Dreamweaver	.97	(.21)
Used tables tool in Dreamweaver	.97	(.21)
A great deal of web development experience	(.28)	.82
Use JavaScript often	(.14)	.97
Use Cascading Style Sheets often	(.41)	.84

Table 1: Pre-questionnaire items and factor loadings

Based on this factor analysis, two factor scores were created for further analyses by averaging a participant's response on the four items that primarily loaded on the Dreamweaver Experience factor and the three items that primarily loaded on the Web Development factor (bold items in Table 1).

Experimental Condition

Time Allocation (Experimental Question 1)

In order to compare the two experimental conditions on time allocation, a 2 X 3 mixed analysis of variance was computed with experimental condition (graphic vs. video) as a between subjects independent variable and activity (task vs. text vs. media) as a within-subject independent variable. Percentage of time spent on given activity was the dependent variable. There was a significant main effect for activity $F(2,36) = 169.80$, $p < .001$, $eta^2 = .90$. There were no other significant effects or effect sizes that reached the criterion for medium effect size based on Cohen's criteria (Cohen, 1969). The means associated with this analysis are displayed in Figure 1.

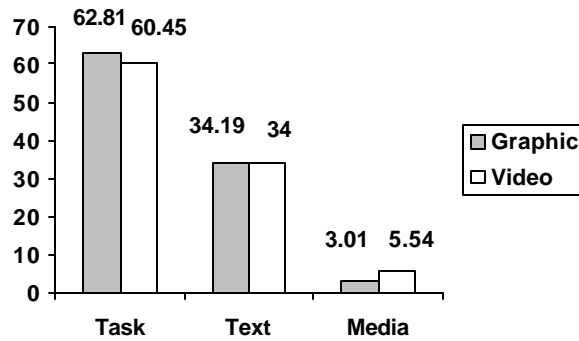


Figure 1: Percentage Time Spent as a Function of Activity and Experimental Condition

Performance (Experimental Question 2)

In order to compare the experimental conditions on performance, a one-way multivariate analysis of covariance (MANCOVA) was computed with condition (video vs. graphics) as the independent variable, the three performance measures (quantity, quality, and navigation) as dependent variables, and the two user experience factors (dreamweaver and web development) as covariates. This MANOVA was not statistically significant, though the effect size was medium to large $L(3,14) = .89, p = ns, \eta^2 = .11$. The means for the three dependent variables as a function of experimental condition, adjusted for experience ratings, are displayed in Figure 2.

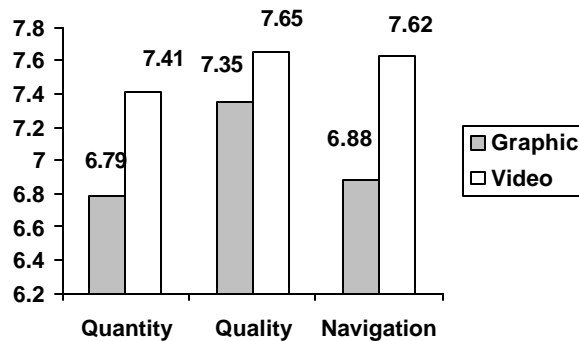


Figure 2: Performance Ratings as a Function of Activity and Experimental Condition (means adjusted based on pre-questionnaire experience ratings)

Post – Test Ratings (Experimental Question 3)

In order to compare the experimental conditions on post-test ratings, a series of seven, one-way analyses of variance (ANOVAs) were computed, with condition (graphic vs. video) as the independent variable and one item from the rating scale as the dependent variable on each. The means, statistical significant, and effect size criteria are displayed in Table 2.

Question	Experimental Condition	
	Graphic	Video
tutorial helpful.***	6.9	9.1
media helpful.	7.6	6.0

task difficult.	4.1	3.6
tutorial easy to use. ^{(*)+}	6.9	8.9
learned a great deal ^{*+}	5.5	7.9
tutorial frustrating	3.6	3.9
tutorial motivational. ⁺	3.8	5.2

(*) $p < .10$, * $p < .05$, +medium-large effect size, ++large effect size

Table 2: Mean responses on post-experimental questionnaire items as a function of experimental condition

Previous Experience (Experimental Questions 4 and 5)

In order to examine the relationship between participants experience and both time allocation and performance, the two experience factors scores (Dreamweaver Experience and Web Development Experience) were correlated with the three measures of time allocation and the three measures of performance. These correlations, statistical significant, and effect size (based on Cohen's criterion – (Cohen, 1969)) are displayed in Tables 3 and 4.

Time Allocation	Experience Factor Score	
	Dreamweaver	Web Development
Text	-.36 ⁺	-.00
Media	-.01	.02
Task	.34 ⁺	.07

⁺medium – large effect size

Table 3: Pearson Correlations of Time Spent on Activities with Factor Scores

Performance	Experience Factor Score	
	Dreamweaver	Web Development
Quantity	.34 ⁺	.36 ⁺
Quality	.33 ⁺	.23
Navigation	.41 ⁺	.42 ⁺

⁺medium – large effect size

Table 4: Pearson Correlations of Performance with Factor Scores

Discussion

With respect to the first experimental question, there was very little difference between the two experimental conditions in terms of the amount of time they spent on the different types of scaffolds. It appears that the type of supportive scaffold that students have, in addition to traditional text, does not have much impact on how they go about using these tools. In fact, the much more powerful effect yielded by the time allocation analysis was the dramatic difference in the time spent on the different types of scaffolds across both groups. Students spent very little time using the supportive media, whether it was graphical or video. Rather they spent the majority of their time focusing on the task and most of the rest of their time reading the directions. It appears then that students instinctively utilize the most familiar and simple text scaffold, unless they find a need for more elaborate assistance. However, it is important to note that the degree to which they accessed different types of scaffolds was partly mediated by their previous experience with the content material, which will be discussed below.

With respect to the second experimental question, the bulk of the evidence indicates that those who had the video as a supplemental scaffold performed better than those who had the graphic screen shots. In fact, the effect may have been stronger had the participants spent more time, in general, using these supplemental media scaffolds. This finding would be consistent with the notion that including a temporal element in the examples adds to the realism of performing the task, since the video explicitly display the steps in time sequence. Of course, the videos

are also more directly representative of the specific task the user is performing. This is particularly interesting, given that the scaffold of choice (the text) was the most abstract with respect to exactly what the user was to do. Perhaps this indicates that, if a user needs to rely on additional media, more rich and representative media is preferred.

The difference between the conditions in subjective ratings from post-test questionnaires constituted the third experimental question. This analysis indicated that, even more strongly, the video was preferred in comparison to the screen shots. Students in the video group gave notably higher ratings than those in the graphic group, as indicated by statistical significance tests and effect size estimates on four of the seven questions. More specifically, those in the video group found the tutorial more helpful, easier to use, more motivational, and also felt they learned more, which is consistent with their performance measure. The consistency of these subjective ratings with the performance adds further support for the idea that richer and more representative media provides the best supplemental support for text directions.

The fourth question addressed the impact of previous experience on time allocation. As anticipated, user experience played a role in the way that students used the videos. A reasonably strong positive relationship was found between experience with *Dreamweaver*[®] and time spent on the task, while a strong negative relationship was found between *Dreamweaver*[®] experience and the time spent reading the text directions. Not surprisingly, as experience ratings increased, users tended to focus more on the task and less time reading directions. Interestingly, there was no relationship between this experience measure and time spent on the media. However, it is very likely that this latter finding is in part an artifact of the small amount of time that users spent viewing the media in general (approximately 4%), resulting in a small amount of variance in the time-spent-on-media measure.

The fifth and final experimental question focused on the relationship between previous experience and performance. Consistent with expectations, the impact of user experience on performance was consistently strong. Across all measures, those with more experience performed better. This was particularly true with respect to ease of navigation, which can be explained to some extent by the experienced users' focus on the task. These more experienced users were not required to navigate to the same degree. In general, the results with respect to experience indicate that it's important to take into account the knowledge level of the participants when designing a scaffolded system such as the one used in this experiment. The more experienced users appear to rely more on the task at hand rather than supporting scaffolding.

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