Introduction

As the information age progresses and new technologies facilitate the development of sophisticated graphic content, the role of visual communication in our society rapidly gains priority and import. Although communication studies have historically privileged the written word in the examination of how people come to develop and transmit meaning, graphic design and information graphics content is quickly taking center stage in studies that explore the intersections of “visual literacy” and “textual literacy” when we learn.

Information graphics have been common supplements to word-driven texts for years, and few would argue with the notion that the combination of words and visuals can make for very powerful communications tools. In fact, news organizations, such as newspapers, have employed information graphics as a main storytelling device for many years. Likewise, digital learning has become exceptionally appealing to numerous universities because of its consumer-centric approach to delivery (Larkin & Belson, 2005), its ability to be highly interactive, and its capability to reach a large audience with a consistent message (Fearing & Riley, 2005). And as the information age progresses and new technologies facilitate the development of sophisticated graphic content, the role of visual communication in our society rapidly gains priority and importance as scholars explore the intersections of “visual literacy” and “textual literacy” when we learn.

As these trends change the way we teach and learn, many educators experimenting with and introducing new kinds of multimedia tools in their classrooms. Furthermore, as educators, researchers, and policymakers continue to press for updated learning models that will move us out of the 1950s approach to education, electronic learning is becoming viewed as one way to meet the needs of a changing and complex world (McCombs & Vakili, 2005). And as graphically driven, animated, interactive applications offer educators new opportunities for shaping course content, new avenues for research arise as well. Along with these developments comes a need to study the effectiveness of the individual tools at our disposal as well as various methods for integrating those tools in a classroom.
setting. This study focuses on the intersections between Web usability, interactive information graphics, and the effects of both on student enjoyment, engagement, and perceptions of learning through the lens of a multimedia text driven by graphic animations and audio.

**Literature Review**

It is nearly impossible to develop a thorough, informative literature review for a study like this without exploring a number of areas because multimedia as a concept is by nature quite multifarious. There are cognitive, emotional, and evaluative responses to multimedia, as well as pedagogical issues that surround using multimedia for an educational purpose. Likewise, information graphics research, visual-verbal associations, cognitive activities, and information graphics as storytelling devices equally inform this study. Thus the review that follows represents an effort to bring all of these areas into the discussion and show how they can inform one another.

In recent years, researchers have increasingly focused on multimedia teaching and learning tools and models for their implementation. Cognitive learning theories, for example, have been used to emphasize that students obtain a deeper level of understanding through the use of multimedia tools that, by nature, combine a variety of formats for words and visuals than is possible with single media forms of content (Mayer, 2002). Others have noted that the affective, emotional experience of individuals engaging with any new technology is a major component in their ability to adapt to it (Marcus, Neuman, & MacKuen, 2000; Plutchik, 1980). According to Bucy (2003), interactivity presents a complex paradox: “During Web browsing or hypermedia searching, emotions may be evoked both by content that is novel, compelling, or surprising as well as navigation that is difficult or unsuccessful” (p. 6). Thus, researchers have engaged in exploring usability as it relates to learning outcomes must carefully navigate the wide range of responses directed at the equally wide range of content types that multimedia presents.

For example, disorientation is a common problem with hypermedia environments (Conklin, 1987; Thuring, Hannemann, & Haake, 1995) as users often struggle to determine where they are and where
they have been in a single presentation (Eveland & Dunwoody, 2001; McDonald & Stevenson, 1996). Sundar (2000) reported that the presence of audio, video, and other visual imagery often has a negative effect on a user’s perception of coherence. At the same time, participants in Sundar’s study reported those elements to be some of the site’s best content. Likewise, a number of studies have shown that as disorientation increases, learning is likely to suffer (Beasley & Waugh, 1995; Tripp & Roby, 1990). Thus, the design of multimedia material needs as much attention as the content itself.

Additionally, the pedagogical implications for multimedia educational tools are vast and complex, and the issue of quality often depends upon subject matter, relevance, implementation, technology, and the media type (i.e. video, audio, graphics, text, animation, games, etc.), to name a few. Cillay (2005) listed a number of factors driving discussions of quality, including the abundance of “interactive, media rich, simulating learning activities,” opportunities for activities not possible in a traditional lecture hall setting, and the potential for 3D, computer-based simulative programs. Cillay also noted that “games, simulations, and animations can be powerful learning tools that move student understanding well beyond what occurs in a traditional classroom lecture environment” (p. 206).

Likewise, Kelly (2005) notes that the heavy implementation of computer-based interfaces, such as games, simulations, and other interactive items, could provide students with a better learning environment and help them more fully enjoy the learning process. He notes that computer simulations could allow users to play with cell structure and chemical processes, thus giving them not only access to the material, but also allowing them to experiment with ideas and find solutions to complex problems. Simulations could give students a chance to engage in problem-solving activities by applying learned theoretical knowledge to practical problems. Likewise, in terms of human cognition, text and images serve a reciprocal function in which each relies on the other to inform the memory (Paivio, 1971). Thus, interactive information graphics approaches to teaching and learning can be powerful teaching and learning tools.

Concepts of literacy and even basic “reading” in a multimedia environment are also changing as researchers have begun to delve into issues related to the development of new computer-interactive
(Adoni, 1985) and visual literacies (Wileman, 1993; Heinich, Molenda, Russell, & Smaldino, 1999; Sinatra, 1986). Wileman (1993) defines visual literacy as “the ability to ‘read,’ interpret, and understand information presented in pictorial or graphic images” (p. 114).

The literature suggests that graphical displays and other visual images in education generally lead to positive learning outcomes for students. The integration of these types of teaching and learning tools is increasing in textbooks, presentations, and computer-driven course materials (Benson, 1997). Stokes (2001) asserts that we are approaching “a visualization movement in modern computing whereby complex computations are presented graphically, allowing for deeper insights as well as heightened abilities to communicate data and concepts. Visualization helps make sense of data that may have seemed previously unintelligible.” Stokes also provides a detailed collection of sources for a wide range of exploration into the increasing role of visuals in teaching and learning.

A number of studies have already reported that visual teaching tools and strategies can often be more successful than traditional lectures and text-driven techniques. Notable studies have included the use of interactive graphics in mathematics courses (West, 1997); the affects of color vs. black and white graphics in learning activities (Kleinman & Dwyer, 1999); the levels of effectiveness of simple vs. complex graphics (Myatt & Carter, as cited in Heinich et al., 1999); variations in types of still graphics used in instruction (Roshan & Dwyer, 1998); and comparisons of multimedia graphics to their text-driven equivalents in knowledge retention (Mayer, Bove, Bryman, Mars, and Tapangco, 1996). Mayer et al. found that the multimedia model was more effective than the text-based model and that better learning is promoted with text-visual combinations than with text alone.

In that same vein, Chanlin (1998) explored how course exercises with no graphics, still graphics, or animated graphics influenced students with different prior knowledge levels. The study found that both still and animated graphics were better than text-only models for learning descriptive facts when students’ prior knowledge was low on a particular topic. In addition, animated graphics were more effective when students’ prior knowledge of the subject was high. This could suggest that more complex multimedia models are more successful in upper-level courses or courses that cover content
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students have come into contact with in previous courses. The study also found that animated graphics might even be distracting in certain situations. Yet, a subsequent study (Chanlin, 1999) found that the ability to interact with and control the pace of animated graphics enhanced learning. Mackey and Ho (2008) examined students’ perceived learning in the design and implementation of Web-based tutorials for a Web design course. In this study researchers developed 26 tutorials used as supplements to face-to-face meetings with students through two consecutive semesters of the same course. Through survey methodology similar to the one used for this study, they found that students responded favorably to most of their usability factors and that there was a distinct correlation between usability and students’ perceptions of their own learning.

Several researchers also have noted a number of additional consequences related to e-learning and publishing. Pettersson (1989) notes that as the volume of available information in digital formats increases, it may become more and more difficult for people to find desired information. In this regard, it’s more important than ever that we research, test, and perfect organizational formats for information (graphics content included). Additionally, Pettersson notes that products like books are increasingly being replaced by “content services” that provide the same kinds of information books do in digital formats.

This review of relevant literature suggests that the wide variety by which e-learning modules may be requires a better understanding for both the usability factors that influence their success or failure and students’ perceptions related to their experiences with them.

Research Questions

This study is based on four key assumptions: 1) in an increasingly visual society in which today’s students are bombarded with numerous types of visual media from video games, to television, to interactive web applications, traditional teaching and learning tools such as printed texts and instructor-led lectures may be losing impact; 2) these same students are so accustomed to using
interactive digital applications in their daily lives that such activities have become commonplace and in many ways preferred; 3) students’ enjoyment of the learning experience is driven by the level of control they have over it; 4) graphic animations may be viewed as more informative more accessible, and easier to understand than traditional word-driven explanations. Based on these assumptions, we arrived at two hypotheses and two main research questions for this study:

- **Hypothesis 1:** The ease of interface, level of engagement and sense of learning engendered by interacting with the multimedia module will predict an individual’s enjoyment of the experience.
- **Hypothesis 2:** The ease of interface, level of engagement and sense of learning engendered by interacting with the multimedia module will predict an individual’s stated willingness to take a course using a digital text similar to the module as the course’s primary text.
- **Research question 1:** Do any specific features of a multimedia text (i.e., graphics, text, audio, animation, non-linear navigation) predict an individual’s enjoyment of a multimedia module?
- **Research question 2:** Do any specific features of a multimedia text predict an individual’s stated willingness to take a course that uses an interactive multimedia module as a primary text similar to the one used for this study?

**Method**

The development of instruments for this study was twofold. First, a graphically-driven, interactive module about photosynthesis titled “The Living World” was developed. (Note: This module was developed for use as a research tool only and is not currently in use in any course.) We chose this topic because it was one that students at this university would be required to learn as part of one of their core curriculum courses. Thus, while not all of the students would be required to major in a biological science, it would be a topic familiar to them. It’s important to note that researchers felt it necessary to create a module from scratch because we wanted complete control over the types of graphics presented
therein, and we felt we had a unique idea for the presentation and packaging of content on a single topic. Numerous sources (websites, books, etc.) were referenced in the development of the text and are cited in the multimedia module. Second, we developed a survey instrument intended to gauge aspects of the user experience with the text.

The multimedia tool: The module is comprised of three sections, “Cycle of Life,” “Nature of Light,” and “Lives of Leaves.” The module also contains a section of keywords and definitions, an interactive quiz, and an “Ask the Expert” link that allows users to submit questions to the site administrator related to the content in the module. Figure 1 shows the introduction page that contains the main chapter navigation, which is present at all times. Each section contains a text-based introduction and sub-categories that contain small chunks of text (no more than 315 words) and multiple animations, some instructive and some narrative with audio voice over (See Figure 2). Mackey and Ho (2008) neatly cite a number of Web usability standards that were the foundation for our work: 1) content, file size, and response time; 2) screen size; 3) user control (p. 390-1).
Figure 1: The user can navigate the three chapters of the text using buttons on the left-hand side of the module. These master navigation buttons are always present so the user can jump from section to section in a non-linear fashion.

Figure 2: Small chunks of text begin each section and are followed by an interactive graphic or animation accompanied by audio voice over that explains the process at hand.

Quick response times are maintained by externally loading individual sections into a shell that contains main navigation. This development technique offers the appearance of a single file, when, in fact, the entire module is comprised of multiple Flash files loading into the shell when the user clicks on main navigation buttons. Thus, only two smaller files load at a time instead of a larger, complete module. Although a monitor resolution of 640 x 480 pixels is still a common standard (Nielsen, 2006), we chose to develop our photosynthesis module at 800 x 600 pixels to give a bit more space for graphics.

Throughout the module are a number of features that are intended to enhance user control. First, we maintain simple site architecture, with main section navigation always present.
form to the left of the dynamic content area. And all content appears in a visually dominant portion of the page, approximately 640 x 480 pixels. Once the user is inside a category, sub-categories are displayed prominently across the top of the content area. There are a total of seven interactive graphics in the module, three in the first section and two each in sections two and three. Each graphic employs varying degrees of user control from the ability to simply click through each instructional section of a graphic, to the ability to explore various parts of an illustration in whatever order the user chooses, to the ability to turn audio explainers off and on and make explanatory captions appear or disappear as a narrative unfolds. Figure 3 offers an example of an instructive graphic the user can explore by rolling over the different parts of the internal structure of a leaf. Likewise, the user can explore a glossary of keywords that cross-references repeated words through the click of the mouse; take a quiz that randomizes questions in content and order each time the user engages it; and communicate via email with a site administrator regarding questions about the module. Students receive responses to those questions within 24 hours of submitting them.
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Figure 3: Information graphics provide the user with visualizations they can explore and/or narrated animations of complex processes. In this sense, graphics are used to simplify complicated information and appeal to visual learners.

We have also operationalized definitions for a variety of interactive graphic forms and developed them with some standard Web usability principles in mind. Using Nichani’s and Rajamanickam’s (2003) classification system for interactive graphics, we developed this module to provide a number of “interactive visual explainers” that fall into one of four main categories: instructives, narratives, simulatives, and exploratives. An instructive generally explains a topic by allowing the student to sequentially step through a topic. Effective instructive graphics explain how to do something or how something occurs in a step-by-step format. A narrative involves very little interactivity and is more closely related to a television broadcast in that it provides a relatively passive viewing experience. Strong narrative graphics are those that combine interesting audio voiceover with graphic depth and rich animation. A simulative is usually a representation of some kind of real-world experience. Simulative graphics are generally the most immersive of the four categories because they imitate a real experience as closely as possible. Quizzes also fall into the simulative category in that they allow users to test their knowledge after interacting with educational content. Finally, an explorative allows the student to discover content in a non-linear fashion. Like instructives, exploratives are also highly interactive, however, the main difference is that exploratives tend to be a bit deeper and may include multiple illustrations, audio and video clips, photo slide shows, etc., in a single graphics package. Thus, the researchers would classify interaction as such that it offers instructive and narrative interactive graphics in a non-linear explorative fashion with mild simulations such as simulative animations and quizzes.

We drew a sample of students from a large (20,000 student) Midwestern university and asked them to engage with the multimedia module. Participants were asked to work through the module for 20 to 30 minutes, moving along at the pace that was most comfortable to them and navigating through
the material as they saw fit. The specified time was not rigorously enforced, as it was not a key element of this study, however, it was ample time for the participants to access all of the features, based on the outcomes of several individuals who tested the module for us prior to the study.

Survey instrument: After they finished engaging with the module, participants received a link to an online survey and were asked to provide feedback regarding their experience. Participants were asked to rate a series of statements based on the level to which they agreed or disagreed the particular item. Of our sample of 160 students, 17 either declined to partake in the survey or failed to complete at least half of it, thus leaving us with 143 data cases for statistical analysis.

The survey first asked participants to rate their level of technological acumen and to what degree they preferred textbooks and digital tools while engaging in a learning endeavor. Each variable was defined with a three-item index, with technology savvy (alpha = .82), digital learning preference (alpha = .79) and textbook learning preference (alpha = .78) all registering satisfactory alpha levels of .7 or higher (See Appendix A for a full list of the items used to create the variables in this study).

The second portion of the survey asked participants to rate their experiences with the multimedia module in three areas: how easily they felt it was to interact with the module, the level of engagement they felt with the material, and to what degree they felt the module’s approach to the material helped them learn. The ease of interface variable consisted of five items (e.g. “The multimedia text was easy to navigate,” alpha = .81). The engagement variable consisted of four items (e.g. “The multimedia text was engaging,” alpha = .79). The learning variable consisted of three items (e.g. “The fact the text offered information in a variety of forms helped me learn better,” alpha = .85). Each variable was created by summing the items and dividing that score by the total number of items used to comprise the variable, thus, allowing for standard measurement across the variables.

Students were also asked specific questions that pertained to various aspects of the module. Single-item variables were used to assess to what degree the participants felt audio files, animations and the non-linear path of the module helped them learn. Single-item variables were also used to measure how much the participants enjoyed the experience of using the module and whether they
would enroll in a course that used modules like this one in place of a traditional text book.

Demographic information, including gender and year in school was also collected.

Results

**Descriptive statistics:** On the whole, this group was technologically savvy (M=5.62) and was more likely to want to learn from computers and other digital options (M=5.48) than from traditional textbooks (M=3.54). In the three basic areas we asked them to rate, they rated the ease of the interface best (M= 5.89), with the level of engagement (M= 5.36) and sense of learning (M= 5.11) close behind. Of the three individual items we asked them to speak to, they gave the highest ratings to the animations (M= 5.28), while non-linear path control (M= 5.06) and audio files (M= 5.05) also received favorable marks.

**Data analyses:** We began by examining a correlation matrix to assess to what degree, if any, the demographic data we gathered co-varied with any of our outcome variables. Of the demographics we examined, only gender was found to correlate significantly with several variables, including both dependent variables we wished to examine. Thus, we retained gender as a potential covariate for all future analyses. A second correlation matrix between the outcome variables and the individual’s technology savvy, digital learning preference and textbook learning preference variables revealed similar patterns in the data and thus, these variables were retained and controlled for in the following statistical analyses.

Hypothesis 1 predicted the ease of interface, level of engagement and sense of learning engendered by interacting with the multimedia module will predict an individual’s enjoyment of the experience. To test this hypothesis, we conducted a multi-step linear regression, with ease of interface, level of engagement and sense of learning serving as the independent variables and level of enjoyment serving as the dependent variable, all while controlling for gender, technology savvy and the two learning preference variables. The regression was strong and predictive (adj. R-square = .60, p <
Hypothesis 2 predicted the ease of interface, level of engagement and sense of learning engendered by interacting with the multimedia module will predict an individual’s stated willingness to take a course using a digital text similar to the module as the course’s primary text. We again conducted a multi-step linear regression, using learning, engagement, and interface as the independent variables and the intent to enroll item as the dependent variable, while controlling for the same four items as in the previous regression. The regression was again strong and predictive, (adj. R-square=.55, p < .0001). The learning variable was once again a significant predictor (beta = .49, p < .0001), however neither interface, nor engagement contributed significantly to the regression (both ps > .1).

To further assess this outcome, we created a correlation matrix using only the DV and the three IVs. While learning-willingness to enroll correlation remained the highest (r = .70), both the interface-willingness to enroll correlation (r = .44) and engagement-willingness to enroll correlation (r = .63) were both significant and strong (both ps < .0001). Furthermore, we conducted a second regression that excluded the learning variable, but retained all the other items outlined above. In that instance, the regression was again significant and strong (adj. R-square = .54) and both interface (beta = .18, p < .01) and engagement (beta = .62, p < .0001) were significant predictors. Hypothesis 2 was only partially supported.

Research Question 1 asked if any specific features would predict an individual’s enjoyment of the multimedia module. We selected the items that measured the participants’ level of approval of the audio clips, animations, and non-linear path control as the independent variables for this analysis. We chose those items because they deal with the features most germane to the module that also would be most different from traditional text. We again used a multi-step regression to analyze the data, with level of enjoyment serving as the dependent variable while controlling for the same four variables as we had in the prior analyses. The regression was strong and predictive (adj. R-square = .48, p < .0001),
with animation (beta = .47, p < .001) and path control (beta = .26, p < .001) as the significant predictors. The audio variable was not significant (p > .5).

Research Question 2 asked if any specific features would predict an individual’s stated willingness to take a course using a digital text similar to the module as the course’s primary text. We once again used the audio, animation, and non-linear path control items as the independent variables for the regression, with intent to enroll as the dependent variable. All previous covariates were controlled for here as well. The regression was again strong and predictive (adj. R-square = .60, p < .0001). Both animation (beta = .21, p < .05) and path control (beta = .55) were significant predictors, while audio was not (p > .5).

Discussion

Students who engaged with the multimedia module developed for this study were noticeably motivated by two important design factors. First, the majority reported that graphical animations used to explain complex processes were both engaging and easy to understand. Visualizations were considered easier to digest, understand, and remember, and information graphics left students feeling more satisfied with their experience than had it been delivered in a traditional, text-privileged format. Interestingly, since all of the students who engaged with this text had likely encountered instruction about photosynthesis before, these findings might concur with Chanlin’s (1998) report that animations were more positively received and had stronger learning outcomes when students had prior knowledge of the topic.

Second, the ability to control the path taken through the text in a non-linear form predicted students’ enjoyment of the module and an intention to take a course that makes use of a similar text. Thus, the organization of the content and design of the interface directly affected their enjoyment of the text and the sense that they learned something from the module. The audio explanations found in the module were less significant in that students felt less engaged by it. This may suggest that heavily
engaging both seeing and hearing simultaneously in a specific learning task may be too overwhelming to the senses. And because the graphics were certainly more stimulating than audio explanations, students were less likely to find the audio valuable and enjoyable as a learning tool.

Taken as a whole, this seems to suggest that easy-to-use modules that provide students with interactive, animated visual content and a sense of control regarding the path an individual takes through the text all have positive and interrelated outcomes for learning, engagement, and enjoyment. We cannot ignore the fact that contemporary students, particularly those in higher education, have been raised with visual animations and interactive media, such as video games, Internet applications, websites, and television and the like, in their daily lives. Our ability to “reach” students in higher education could be dramatically impaired if we are not willing to keep up with the times, so to speak, and develop, collect, and transmit educational content in ways that students can effectively relate to. This study ultimately suggests that students find multimedia texts such as the one developed here to be more engaging and enjoyable, easier to understand and relate to, and better capable of helping them learn than traditional textbooks.

This study has a few limitations worth noting. First, the participants in this study engaged in a single-time interaction with the multimedia module as opposed to a longitudinal interaction. While the majority of the participants reported little difficulty with the module, many of the studies cited above note that repetition and familiarity with a multimedia tool can lead to decreased apprehension and improved interaction. To what degree repeated engagement would have altered the outcome of this work is unknown.

Second, we measured learning in a self-report fashion as opposed to measuring actual learning. While we presuppose that students at the collegiate level are likely to know whether they have gained knowledge during an interaction such as the one we provided, a quiz or a test at the end of the engagement to test actual knowledge gain was something we considered. We discarded this option, however, based on the first limitation (minimal interaction) and our minimal understanding as to how much they knew about the material coming in to this study. In other words, an English major who
learned a lot from the interaction with the module might score lower than a botany major who was frustrated by the navigation and confused by the graphics but had a larger cache of prior knowledge.

Future studies should consider ways to both engage in a longitudinal study and test actual knowledge. It’s also worth noting that a number of design or functional improvements could be made to the module to increase usability, including real-time evaluation and feedback in quizzes, a “loading…” animation at the start of animations that are sometimes slow to load, and more control over keyword navigation.

Even withstanding those limitations, we believe the work has merit as an opening gambit to a larger discussion about the value of multimedia learning tools. Participants who interacted with the material reported a high level of interest in learning from similar materials presented in a similar fashion in a subsequent learning environment. They also noted not just a sense that they learned something by working through this material but that the material was engaging. In addition, ease of use was significantly correlated with an intention to enroll in a class using a multimedia text and it significantly predicted whether the individual enjoyed the multimedia experience. This supports earlier work in both e-learning and multimedia research, which has demonstrated that navigation and response time are key to the quality of the user’s overall experience. Furthermore, although we did not parse out the different types of information graphics— instructives, narratives, simulatives, and exploratives — in specific survey questions related to their individual levels of effectiveness, we laid the groundwork for future studies that explore students’ specific reactions to these individual types of visualizations. Future research should seek to build on these issues, especially given the likelihood of a continued technological entrenchment in the classroom and a greater push for enhanced multimedia learning outside of it.

References


**Appendix: List of items used in this study, grouped by variable**

**Technology savvy**
- I consider myself to be fairly computer savvy.
- I adapt well to new technology.
- I have a lot of experience with course materials that are presented in digital formats

**Digital learning preference**
- I prefer to use technology, as opposed to printed materials like textbooks, when learning a concept.
- When seeking information, I prefer to use computer resources, such as the Internet.
- Using technology to learn is important to me.

**Textbook learning preference**
- I prefer to use textbooks, as opposed to computer resources, when learning a concept.
- When seeking information, I prefer to use traditional library materials, like textbooks.
- Using textbooks to learn is very important to me.

**Ease of interface**
- The multimedia text was easy to use.
- The design of the multimedia text was well organized.
- The multimedia text was easy to navigate.
- The type on the multimedia text was easy to read.
- The multimedia text was difficult to navigate. (reverse code)

**Level of engagement**
- The multimedia text was engaging.
- The multimedia text was boring. (reverse code)
- I enjoyed that I could control the path I took through the text.
- I enjoyed that the text offered information in a variety of forms (i.e. animation, illustration, text, audio, etc.)

**Sense of learning**
- I learned a lot from the multimedia text.
- The way the information was presented helped me learn better.
- The fact that the text offered information in a variety of forms (i.e. animation, illustration, text, audio, etc.) helped me learn better.