Effects of differential text formats on adult conceptualization of science: evidence from three disciplines

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Abstract:
The World Wide Web (Web), the largest multimedia system in existence, has been heralded by many as the perfect tool for lifelong learning. One topic mentioned in this regard is science, since many adults have little prior knowledge about it and the field is constantly changing. Yet little empirical research has been done to examine how web documents may actually affect the learning process. This article looks at learning theories that point to the importance of affective attributes of messages that may be particularly applicable to the mixed medium that is the Web and then focuses on the effects of textual elements on the learning of science from both static and interactive texts.

Article:
At its core the World Wide Web (Web) is a hypermedia system; simply one that is vast, growing, and completely lacking in structure and design (Baeza-Yates & Ribeiro-Neto, 1999). In addition it has a multi-purpose nature, that is, it is a combination of an entertainment medium, a commercial source, and an information source (Barnes, 2003). This mix of roles makes it a difficult phenomenon for study and one which attracts researchers from many disciplines. The present article considers only the Web's role as a source for information and learning. It focuses on only a small part of the problem--how the text read from a web site differs from traditional static texts in terms of adult learning, and looks at only one topic area, science. It also speculates, and calls for more research, on the way the Web juxtaposes contradictory and refutational texts and the impact that has not only on cognitive decision-making but on the beliefs and affective responses to information sources about science topics. Although there will be some work described here that is pertinent to structured web environments such as e-learning sites, the focus of this review is the use of the open Web for text utilization. It will begin with a short description of why this issue is particularly important to the learning of science, look at two models of learning that bear directly on the issues, and then proceed to a consideration of how texts in general promote science conceptual change, and finally look at the special case of texts on the Web.

Science and Adults
There are many adults who leave formal schooling without a strong understanding of many basic science concepts. Research in science literacy has shown that nonexpert or lay adults do not have enough basic information to understand the complexities of policy questions surrounding issues like global warming, stem cell research, and genetically modified agricultural products (National Science Board, 2004). One reason for this lack of science understanding by adults may be that during their education their alternative conceptions, or misconceptions, were not adequately confronted. Science education researchers, Pines and West (1986), have used an analogy of two vines for describing the problem, suggesting that in the best cases, spontaneous, or everyday, knowledge will intertwine with formal, or instructionally presented, knowledge and become inseparable. There is great variability in the success of this process. Certainly, work with undergraduates who were science (Posner, Strike, Hewson, & Gertzog, 1982) and nonscience (Alvermann & Hynd, 1989) majors indicates that members of both groups retain a number of alternative conceptions common in young children. These conceptions have survived through years of schooling and remain a basis for understanding newly encountered information about science questions. The reasons for the persistence of misconceptions is a subject

of much debate in science education and will not be discussed further here (Chinn & Brewer, 1993; Smith, DiSessa, & Roschelle, 1993); rather the focus will be on the many processes that contribute to helping a conceptual change (Dole & Sinatra, 1998) and the role that the Web may play in that process.

The problem of science literacy is not simply a matter of cognitive deficit; affective issues are also important. For instance, whether one has a supportive attitude, or opinion, toward the use of genetic modification for improving agricultural products is a mix of understanding how the science works (cognitive factors), buying such products (behavioral factors), and being afraid of potential adverse effects (affective factors). Learning about these topics, or indeed any topic, has a certain element of persuasion attached to it. As stated long ago by social psychology researchers, "We assume that opinions, like other habits, will tend to persist unless the individual undergoes some new learning experiences. Exposure to a persuasive communication which successfully induces the individual to accept a new opinion constitutes a learning experience ..." (Hovland, Janis, & Kelley, 1953, p.10). A learning experience requires a restructuring of a person's concepts about the world, or conceptual change, and persuasion involves a restructuring of the attitudes that underlie those conceptions. Both are confronted when new information is presented in some format and perhaps changed, therefore, the key in both processes is the person's reaction to new information being received.

The Role of Affective Factors in Learning

Basing their work, in part, on theories developed in the field of science education by Posner et al. (1982) as well as others, Dole and Sinatra (1998) created the cognitive reconstruction of knowledge model (CRKM) that incorporated the social psychological emphasis on affective factors such as motivation, belief, and attitude into the prevailing model of conceptual change. Their contention was that traditional conceptual change research ignored these factors by focusing only on the content and structure of the knowledge that students were building. They attempted to reconcile factors that block the student from hearing the new information that is being presented and might lead to no, incomplete, or weak conceptual change. These changes have been identified by Chinn and Brewer (1993) as ignoring, rejecting, excluding some information, holding some in abeyance, reinterpreting, or simply a peripheral change.

One mechanism incorporated into the CRKM (Dole & Sinatra, 1998) is based on the elaboration likelihood model (ELM) developed by Petty and Cacioppo (1986). The ELM described the two routes to persuasion: one central and the other peripheral. The central route was achieved when a person interacted with a persuasive message and was motivated, able, and willing to elaborate on that message, to cognitively process the informational content and to, finally, be persuaded. That is, the person was open to conceptual change. The central route allows the person to engage with the arguments being presented and to evaluate the evidence contained therein. Persuasion by this route has a longer lasting effect than the second peripheral route that usually results in little or no cognitive restructuring. Instead, a change in attitude is made for reasons that may satisfy a simple heuristic or a pre-existing affective state. The arguments in the persuasive communication are neither engaged with nor elaborated upon, when the peripheral route is activated by a message. It is Dole and Sinatra's proposal that instructional methods should activate this central route and monitor opinions about science as well as the learning of facts. When the peripheral route is taken, then affective and cognitive elements in the attitude may be temporarily changed but the learning disappears quickly. When arguments are elaborated by the recipient of a persuasive or informative communication, as in the central route, conceptual change has occurred and lasts beyond the exposure to the communication.

Astleitner and Wiesner (2004) made a similar case for incorporating motivation into models for multimedia learning. In their model of multimedia learning and motivation, which they based on Mayer's cognitive theory of multimedia learning (Mayer, 2001; 2003) they include elements that are reminiscent of the CRKM, including, attention, engagement, and goal setting. The authors call for more research to understand how motivation operates during the use of multimedia systems. This may be particularly salient in studying interaction with web texts choices. The web site attributes that inspire a web document to be chosen, read, or learned may be connected to motivational factors.

The documents found on the Web are a mix of content and persuasive elements that might play into science conceptual formation in adults. In lay adults, science concepts are embedded in their attitude structures. In order for the public to understand new science information, especially when there is controversy among scientists themselves, it is important for them to both understand and to accept. This requires stimulation of both processes of conceptual change and persuasion.

It is primarily through texts that science information is communicated to both students and the public at large (Hand et al., 2003). Texts are not simply the static, traditional texts that are found in books, magazines, and newspapers, but also the interactive and multimedia rich ones found on the Web. The Web has promise for connecting people to the information that they missed during formal schooling or information that is new since they left school, in fact a recent survey found that when adults have been introduced to a science topic and want more information about it, 44% of them turn to the Web (National Science Board, 2004). Science communicators and educators need to understand the mechanisms, including the potential affective ones, which make web texts influential in learning processes in adults.

PROMOTING SCIENCE LEARNING USING TEXTS

In the learning models reviewed, the message factors are primarily content-based, including, plausibility, coherence, and comprehensibility. These would operate in the use of any text, whether from the Web or not. It is instructive to review the way that static texts can be designed to effect science conceptual change and then move to how the medium of the Web may change these effects.

Static Texts and Conceptual Change

The presentation of ideas to inform and persuade has been studied for millennia (Chambliss, 1994). Working in the social psychology domain in the 1950s, Hovland and many colleagues (Hovland et al., 1953) studied the persuasive effects of constructed texts and their order of presentation on a variety of attitudes. They found that many variables including order of the arguments, acknowledgement of counter-arguments, and motivation of the reader played a role in the effectiveness of the text to persuade the reader.

In a meta-analysis of instructional interventions used to promote conceptual change in science instruction, Guzzetti, Snyder, Glass, and Gamas (1993) found that refutational texts were useful in helping science students to correct their alternative conceptions. Refutational texts are designed to acknowledge commonly held conceptions that are then refuted by the scientific evidence. They have been studied in many different settings with quantitative as well as qualitative methods (Guzzetti, 2000). Refutational texts were found to be statistically superior in promoting conceptual change.

Refutational texts may be efficient but they are not necessarily sufficient. Guzzetti (2000) described earlier work done with colleagues that used interviews with physics students exposed to carefully constructed refutational texts. These students indicated that they did not necessarily change their conceptions. The texts increased the students' cognitive conflict by showing both their misconception and the "right" answer but they were still inclined to hold onto their original ideas. The evidence for the use of refutational texts is based on studies where the texts were manipulated to state clearly that a nonscientific position is ill-conceived and the scientific viewpoint is correct (Hynd, 2001). Using noncontrived, naturalistic texts may cause problems for some readers. According to Chambliss (1994) typical readers interacting with these texts may not be able to distinguish claims in the text from the evidence presented. Without the authority of pointing out the "right" way multiple points of evidence may appear to support both positions. Some readers will take the presence of their alternative conception in the written text as being supportive of their position and disregard the evidence to the contrary.

The refutational texts discussed here have been found useful in changing people's science conceptions. The results raise interesting questions for researching the learning effects of documents on the Web. How do people, especially lay adults, make sense of the contradictory claims made on various web sites and documents? Are they simply guided by the peripheral cues given by the documents that they encounter or do they engage with the content and make cognitive decisions about its pertinence to them? Web documents are not simply content; they come in a particular mediated form. There has been some study of how the form changes the perception of messages. The next section will examine the way computerization has impacted the comprehension of message content about science by the reader.

Text on the World Wide Web: Effects on Learning

According to mass communication theories (Eveland & Dunwoody, 2002; Littlejohn, 1983) there is a difference in audience and user reaction to information presented in different media. The advent of hypertext and hypermedia produced a flurry of studies that looked at how learning was impacted by this new form of presentation. Work in education focused on the effects on cognition and found that although the node-link architecture should be more representative of cognitive schemas, and therefore an aid to learning, many empirical studies showed that learners, especially when novices to a topic, were not helped by hypertext systems (for a comprehensive review see Shapiro & Niederhauser, 2004). There are indicators, indeed, that the medium makes no difference if the instructional message is badly designed (Mayer, 2001; 2003) but this does not really answer the question of what happens when there is no design as would be the case in an open searching session on the Web. The Web is also much more than a large hypermedia system, nonetheless, some of the same difficulties with using hypermediated texts apply in this new medium. Investigation of the effects of web-based texts on attitudes and concept formation, especially towards science topics, has been understudied.

Studies focusing on learning from the Web are few in number, instead, web user studies have concentrated on better searching algorithms (Bar-Ilan, 2004), display characteristics (Baeza-Yates & Ribeiro-Neto, 1999), and Internet-based instructional technologies (Hill, Wiley, Nelson, & Han, 2004). Certainly, it is important to design better and easier to use systems; however, in the final analysis, users must be able to read and absorb the material being presented. In a review of the literature on the role that reading from the Web plays in learning, Kim and Kamil (2003) pointed out that most of the texts are expository, or nonnarrative, and they are at high reading difficulties. In addition, there are a number of features that the Web provides, such as hyperlinks, multimedia that needs to be opened with particular software, and pop ups, that constitute seductive details. It had been shown that in previous research (Harp & Mayer, 1998) that these details can detract from attention given to the main text and may constitute force the learner into the peripheral route.

To understand the learning impact of web-based text, one of the most basic questions is whether a difference can be detected in the persuasive qualities of the exact same text presented either in paper or on a computer screen. Murphy, Long, Holleran, and Esterly (2003) used two naturally occurring texts, that is, two actual articles from Time magazine that were two-sided and refutational, and concerned social science topics, to a group of college students. Preknowledge was judged by answers to fact-based questions and topic beliefs were assessed. Both of these factors were measured again postreading along with article reaction variables such as author credibility, persuasiveness, understandability, emotional reaction, and article interest. There were few differences in the effects of the medium of delivery; both media were effective in changing self-reported beliefs. There were differences, however, in the ease of understanding the article, the perceived persuasiveness of the argument, and the credibility rating of the author when the article was read in paper format. In each case, the paper format was more effective. Perhaps, the computer presentation is discounted solely because of its format.

Somewhat similar findings were obtained in a study by Eveland and Dunwoody (2002). In this study, college students were asked to evaluate two different versions of the same story, about the causes of wildfires from a science-oriented website called the Why Files. One story was web-based and hyperlinked and the other was static print. One measure included a five-item postexposure questionnaire that asked the participants to elaborate the story as it related to their own lives and thereby make connections between the content and their own knowledge. Another looked at self-reported selective scanning of the document. Using a path analysis the authors found that users of the web-based document exhibited significantly less learning than those who read the paper version. The web document users employed selective scanning significantly more than the paper readers, which may signal that there was less engagement with the content. Certainly, in the path model derived from their study the authors found that the increased use of selective scanning by the participants in their sample reduced their content knowledge when compared to the group that read paper texts.

Although Eveland and Dunwoody (2002) looked at the effect of the interactivity of a hyperlinked document, this was minor in comparison to that found on a full website. Tremayne and Dunwoody (2001) set out to compare levels of learning that participants achieved from using two science oriented websites, the Why Files and the Exploratorium Museum of Science, Art and Human Perception that differed in their levels of interactivity offered to the user. One web site was a straight text file with few hyperlinks and the other was a fully functional website. Using a think aloud protocol the interactions of average adults recruited from the community were recorded and then coded for information processing style exhibited; that is, elaboration, orientation, or rehearsal of the information that was being presented. The participants were then asked to recall a particular site that they had visited during their session. The accuracy of this description was used as an indicator of learning. The results were complex but in the main showed that interactivity increased content-specific recall for the participants in the study. The more interactive site was more deeply engaging and more participants used elaboration as an information processing strategy. This is important information for those who are working with adults who are separated from the school setting. Although persuasiveness was not measured here, deeper cognitive engagement and elaboration might indicate that an effective website would also affect attitude and belief structures.

Some of the difficulties with orientation on a website might be answered by increased socialization to the nonlinear nature of the texts on the Web, better designs, and an increase in web expertise by the users. However, a recent study found that amount of Internet experience was negatively correlated with the number of idea units found in a website about the rainforest (Schwartz, Andersen, Hong, Howard, & McGee, 2004). Working with young participants at a Space Camp with similar levels of experience with the Web, the researchers had predicted that Internet experience would increase the number of idea units found by the participants. The negative finding was consistent across two different experimental treatments, one in which the entry into the system was through a puzzle interface and the other through a more conventional outline format. Schwartz et al., concluded with this statement, "It remains to be seen whether the Internet-savvy subjects did not have adequate knowledge of hypermedia conventions, or whether conventions consistent enough to be recognizable by learners even exist" (p. 90). Certainly, it also remains to be seen, if such a convention has been learned by an older adult population that has not grown up with such hyper-mediated systems (Kim & Kamil, 2003).

Interactivity, then, does increase somewhat the content elaboration but also increases selective scanning. Selective scanning might limit the perception of cognitive content of the message and limit elaboration and attitude formation. Which effect would be strongest on the formation of knowledge density? Eveland, Cortese, Park, and Dunwoody (2004) sought the answer to this question with a mixed sample of college students and nonstudent adults using two versions of a health related website. They used free recall (open-ended questions) and cued recall (multiple choice questions) of factual knowledge as measures to test two kinds of websites, one with many embedded hyperlinks (nonlinear) and the other which required the user to page through the content to the end (a linear orientation). In addition, they used the results of free recall statements and had the participants show relationships between the concepts rating them on a 1 (weakly related) to 7 (strongly related) scale. Results show that recall was a bit better with the linear website. Most interesting, however, is that knowledge density, as measured in this study, was more pronounced with the use of the nonlinear site.

How mediated and web presented texts interact with users is still understudied, but the evidence presented here shows that there is something different about receiving the information about a science topic over the Web. It may affect belief structures, but it definitely changes learning as measured in these studies. Again, it is important to point out that, as in the refutational texts studies there is artificiality to the measurements of learning from the Web. The sites were not chosen by the participants but merely read by them. What greater effects might be seen when the texts are selected from the thousands available on almost any topic from the

Web? Further study is necessary to truly understand the influence of web sites and documents on adult attitude change and hence on their understanding of science.

SUMMARY AND CONCLUSIONS

The Web plays a variety of roles in commerce, entertainment, and education. Though touted as a source of lifelong learning opportunities, especially for adults, the evidence reviewed in this article presents a mixed picture of positive learning effects from using web-based texts. The texts were less believable and more likely to be selectively scanned rather than read (Murphy et al., 2003; Eveland & Dunwoody, 2002); however, interactivity did lead to more elaboration (Tremayne & Dunwoody, 2001) and the building of denser knowledge structures (Eveland et al., 2004). The recall for specific facts is lessened by the use of these resources and this is true even in the face of a great amount of experience with these texts (Schwartz, et al., 2004). On the other hand, the interactivity did help users to recall general content of a site (Tremayne & Dunwoody).

What is not well-considered in this group of research studies is the dimension of choice. All of the studies used predetermined and in many cases designed web sites. Although this controls many variables it does not answer the question of how opinions, attitudes, beliefs, and motivation, may play roles in learning from web resources. The learning models reviewed here point to the importance of considering these attributes when learning effects are being studied. This becomes an important issue in web research, because its mixed roles are inseparable from the informative texts that can be found there. It is only through studying what learners may choose from the billions of texts on the Web that we can build an understanding of what they will learn.

When considering the learning of science concepts, this is especially critical. As the studies on refutational texts indicate, accepted science knowledge can be learned if a person's prior alternative conceptions are challenged with appropriate evidence. If web users are more likely to choose only texts that reinforce their existing ideas then no learning can occur. Misinformation about personal topics, such as health, and policy topics, such as stem cell research will be strengthened by a user's interaction with web texts rather than refuted. Again, the sheer number of documents and the many possible purposes that they might serve confuses potential learners. There are millions of texts on the Web about almost any topic, including science. Some are well-designed, others are not. Some are factual, others are not. Some are interactive, others are not. As Mayer (2001) indicated learning is not bound to a particular medium, but to the instructional appropriateness of a resource. Matching a learner with a good source is what is required. Knowing what motivates choice is one step in the right direction, so that systems, like portals and digital libraries, can be designed to aid web users in the process of connecting to the information sources they need. If the Web is to serve as an information source for lifelong learning, especially for critical topics, such as science, then better systems must be devised for aiding the potential learner to connect to appropriate resources.

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