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Cognitive and affective implications of persuasive technology use on mathematics instruction

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ABSTRACT

This study investigated the effects of different computer based interventions on mathematics achievement, attitudes towards search engines and Internet self-efficacy. Participants were 105 pre-service teachers enrolled in a calculus course at a Turkish state university. A 3 (interventions) × 2 (pre- and post-test) factorial design was implemented. The first group resorted to activities provided by a web-based semantic search engine (i.e. Wolfram Alpha). The same content was provided to the second group through a computer algebra system (i.e. Mathematica). The third group followed the same content through linear web pages. The intervention lasted eight weeks. Data were collected through focus-group interviews, an achievement test, an attitude scale on the instructional use of search engines and an Internet self-efficacy scale. The quantitative data were analyzed through descriptive statistics followed by univariate and multivariate analyses of variance whereas the qualitative data were examined through descriptive analysis. MANOVA results revealed that the main effect of testing time, the main effect of intervention, which favored the semantic search engine group, and the interaction effect of intervention by time led to significant differences between students' achievement scores. However, the intervention and interaction effects were not significant for attitude and self-efficacy. Qualitative data revealed strengths and limitations of each intervention.

1. Introduction

Advances in emerging technologies have a profound impact on contemporary communication and learning experiences. ICTs contribute to the production and consumption rate of information, which increases the importance of equipping 21st century individuals with relevant information processing skills. Accordingly, many learning technologies have been adopted in the last century most of which perform perceivably well at the inception. However, failures or shortcomings also occur while implementing relevant instructional technology principles with the novel instruments. Then, new applications and alternatives emerge and scholars begin to question the persuasive power of the previous one in comparison to the most recent one.

Persuasion is an influential construct, which shelters both argumentation and information sharing to change individuals' beliefs, attitudes and behaviors. Traditionally, it means *'human communication designed to influence the autonomous judgments and actions of others'* (Simons, Morreale, & Gronbeck, 2001, p. 9). The current study questions the potential persuasive power of different web-based tools in mathematics instruction since an increasing amount of human communication and instruction is facilitated through web-supported tools. Even a troubleshooting problem pertaining to the web lead individuals to resort to the web for potential solutions. In this regard, the persuasive role of these technologies is highly prominent in individuals' daily experiences whereas the educational persuasiveness is still under scrutiny.

The evolution in the field of persuasive technology has accelerated in the last decade particularly in terms of applications in human–computer interaction. These applications had fiscal outcomes such as user-based customization of advertisements or usability hints in commercial web pages. On the other hand, the reflections of persuasive technologies in instructional design and educational settings have

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been observed rarely (Mintz & Aagard, 2012). Thus, the current study aimed to implement relatively novel and potentially persuasive tools to enhance mathematics instruction. That is, the research design is expected to scrutinize on the persuasive potential of the selected tools for instructional settings. The following session revisits the theoretical foundations of the study.

2. Theoretical framework

Internet has a prominent role both on daily endeavors of individuals and instructional practices. Through the advances in web-based technologies, scholars revisit several cognitive and affective variables related to instructional effectiveness such as achievement, attitude and self-efficacy. This study addressed these variables and resorted to different web-based tools to facilitate effectiveness in mathematics instruction. The theoretical rationale of the study is summarized under the following headings.

2.1. Persuasive technology use and mathematics instruction

Persuasive technology or ‘captology’ refers to the overlap of technology and persuasion. That is, captology focuses on ‘the design, research and analysis of interactive computing products created for the purpose of changing people’s attitudes or behaviors’ (Fogg, 2003, p. 5). The theoretical framework of persuasion can be adopted for different instructional applications including virtual reality, educational games, mobile devices and web-based environments. These tools can be used to address the change in critical learning variables including attitude, behavior, motivation, perspective and adaptation. Thus, persuasive technologies which are quite common in individuals’ daily lives are also expected to facilitate instructional endeavors (Ijsselsteijn, de Kort, Midden, Eggen, & van den Hoven, 2006).

Three means of persuasion are proposed in the literature, which are human–human interaction, human–computer interaction, and computer supported human–human interaction (Oinas-Kukkonen, 2008). The prominent type of persuasiveness in instructional settings is generally human–computer interaction (Mintz & Aagard, 2012). Accordingly, instructional web-based tools employed in the current design are instances of human–computer interaction.

Integration of human–computer interaction with the concept of persuasion can be realized through semantic web applications. Studies which address semantic web and hypertext simultaneously (Cristea, 2004; Papasalouros, Retalis, & Papaspyrou, 2004) maintain that semantic web is generated in a really smart way by Berners-Lee (2003). This is because it requires XML use rather than HTML, which helps it diagnose meaningful statements of users. Similar applications are used in mathematics instruction through additional markup languages such as Mathematics Education Markup Language (i.e. MeML, Zou, 2005). If such languages are used in a way to integrate the math language and content with web contemporary facilities, effectiveness of online mathematics instruction can be improved.

To name an instructional technology as persuasive is not possible within the scope of small-scale empirical works. On the other hand, interactive and instructional affordances of semantic web tools are promising to claim that they can be persuasive as long as attitude and behavior changes in the desired direction are observed. For instance, several studies suggested that these applications are effective facilitators in mathematics instruction (David, Ginev, Kohlhase, & Corneli, 2010; Jones, Geraniou, & Tiropanis, 2013; Ullrich & Melis, 2010). In this regard, the current work focuses on a web-based semantic search engine (i.e. Wolfram Alpha), and discusses its instructional affordances on the basis of the diffusion and acceptance models so that its persuasive potential can be justified theoretically.

2.2. Innovation–Decision process

Almost all adoption and diffusion theories propose that adoption of an innovation is not a single act but a process occurring in a social system over time (Straub, 2009). Potential users go through stages when interacting with an innovation. These stages are discovery of an innovation (knowledge), formation of a positive impression (persuasion), adopting or rejecting (decision), actual usage (implementation) and evaluation of the impact of the innovation to continue or discontinue usage (confirmation) (Rogers, 2003). Accordingly, adopters are categorized through a five-stage continuum ranging from those who readily adopt (i.e. innovators) through those who resist an innovation (i.e. laggards). Another contribution of the Innovation–Decision Process model is the concept of perceived key attributes, or the perceptions of potential users regarding the advantages of an innovation. That is, ‘individuals are more likely to adopt an innovation if it offers them a better way to do something (relative advantage), is compatible with their values, beliefs and needs (compatibility), is not too complex (complexity); can be tried out before adoption (trialability); and has observable benefits (observability)’ (Surry & Ely, 2007, p. 106). Based on this theoretical framework, in order to consider a web-based semantic search engine as an innovation, its perceived key attributes should be unique or comparatively stronger than a preceding application. For instance, the comparison of a contemporary computer algebra system (CAS; Mathematica) with a web-based semantic search engine (Wolfram Alpha) is summarized in Table 1.

CAS can be considered as an innovation in comparison to previous instructional applications. However, Wolfram Alpha is relatively new and looks somewhat advantageous. For instance, it does not require any additional license cost or installation effort. All a user need is the Internet access. In addition, command use is not as strict as Mathematica. In addition to ready commands, conceptual search queries can

Table 1
Comparison of a sample computer algebra system with a web-based semantic search engine.

System	Example	Relative advantage	Compatibility	Complexity	Trialability	Observability
Computer algebra system	Mathematica	It is necessary to know how to ask a question	Manipulation of formulas through commands	Prerequisite steps and commands are needed	Specialized software is needed	Observation of individuals who already use it
Web-based semantic search	Wolfram Alpha	Similar to contemporary search engines	Basic understanding of concepts is sufficient	Even simple questions may lead to holistic knowledge	Internet connection is sufficient	Can be shared through blogs, social networks or e-mails

Adapted from Andersen, 2009.