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The Interface Design and the Usability Testing of a Fossilization Web-Based Learning Environment

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This article describes practical issues related to the design and the development of a Web-Based Learning Environment (Web-LE) for high school students. The purpose of the Fossilization Web-LE was to help students understand the process of fossilization, which is a complex phenomenon and is affected by many factors. The instructional design team faced the challenge of designing an environment that could enable its users to construct knowledge actively by manipulating the various variables of organisms, ecological systems, and physical burials. An effective user interface is essential to the enabling of students who try to explore knowledge presented in the learning environment and who, in monitoring their own learning progress, hope to avoid overwhelmingly complicated content. The analyses of both the interaction of learning activities and the design of system functions are discussed. In addition, a usability test was conducted so that the effectiveness of the interface design could be examined. The findings reveal that target users are satisfied with the usability of the Fossilization Web-LE and consider use of the user interface to be easy. At the end, several practical applications in the design of instructional software's user interface are suggested.

KEY WORDS: interface design; earth science; Web-based learning environment; learning with technology; 3D-representation.

Without a doubt, the design of user interface is one of the most critical components in the development of a software product. In the last few decades, a considerable number of studies have been made on how user interface design affects users' ability to process information on a computer system. For example, a good interface design can help engage users (Metros and Hedberg, 2002) and reduce their cognitive load (Jones *et al.*, 1995; Martin-Michiellot and Mendelsohn, 2000; Sweller and Chandler, 1994). This article centers on the application of user interface design principles to the design and the development of a Web-Based Learning Environment (Web-LE) interface, illustrates the production process, and describes the usability testing results.

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BACKGROUND

The development of the Web-LE was a subset of a laptop evaluation project conducted in a K-12 school in a southeastern state (Hill *et al.*, 2001, 2002). The teachers and the middle and upper school students have been using laptops since 2000 at this school. During the evaluation project, some teachers suggested activities that could be run on the laptop in addition to mere use of the laptop as a writing tool or as an information-gathering tool on the Internet. The teachers were seeking more effective ways of integrating laptops into their teaching. After assessing the needs and the possibilities characterizing the completion of a software product within a limited time period, a team was formed that, working with a science teacher, would design a product to help upper school students understand the process of fossilization.

Referring to decades of teaching experience, this science teacher reported that the students were

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having problems in comprehending the concept of fossilization. In the unit of fossilization, students have to understand how and why ecological systems and physical burials influence the fossilization of certain organism. Students' grasp of the material had to overcome three obstacles: fossilization is dauntingly intricate, being a result of complex combinations of organisms, ecological systems, and physical burials; moreover, students scarcely have the requisite motivation to learn such abstract concepts compared to the concepts in other units; finally, the teacher could not find enough correct or useful materials that would help the students visualize the process of fossilization. Before considering use of the computer as an instructional tool, the teacher had students select, as a topic, one of the possible combinations that produce fossils and illustrate the process. However, each student had the chance to be familiar with only one condition out of more than 10 possible conditions. Furthermore, the production of illustrations is time-consuming. Therefore, the teacher was looking for a tool that would be realistic, reusable, and accurate in its explanation of fossilization and provide learners with opportunities to consider the potential combinations of different decisions.

After the current available computer-based tools were evaluated, a Web-LE was selected to carry the instructional content. The content is best delivered through the web, because the web medium has practical operations that, for example, enable non linear net-like structures, carry multimedia, distribute cross-platform systems, and—most important—allow for immediate updates. Web-based learning materials are located on the server side instead of the client side. Once the data on the server side is updated, learners can immediately access the latest information. There is no need for the learners to update their own personal copies of learning materials.

The Fossilization Web-LE can be accessed at the following URL: http://iris.nyit.edu/∼skwang/fossil. A more detailed description of the design, the development, and the analysis of the motivational influence of the Web-LE is reported in Wang (2003).

INTERFACE DESIGN OF THE FOSSILIZATION Web-LE

Interaction

The interactive learning activities of the fossilization Web-LE had to be determined before its development because the nature of the interactivity of the learning activities would affect the design of the user interface. The objective of this unit is to help students who are studying the unit on fossilization in the teacher's classroom be able to explain why one scenario is more conducive than others to fossil development. The teacher indicated that accurate animated illustrations would be the best tool to help students learn the concepts underlying fossilization. He believed that graphics and movies, along with pictures of actual fossils, could help students visualize different types of fossilization, develop more robust mental models of the processes involved, and cultivate a greater appreciation for why fossilization is such a rare geological event.

The instructional designers in this team carefully reviewed the materials that the teacher had previously used for this unit. After further discussion with the teacher, the team determined their overall instructional goal: after using the Fossilization Web-LE, students would be able to identify the necessary conditions for fossilization and construct possible scenarios for fossil formation by manipulating variables within a simulation. In the meanwhile, the team identified 18 possible scenarios concerning the development of dinosaur fossils. Whether or not a living thing becomes a fossil depends on three general conditions: the organism, the ecological system, and the physical burial. A combination of the three conditions generated 18 possible paths of fossilization: 1 organism, 3 ecological systems, and 6 physical burials; that is, $1 \times 3 \times 6 = 18$ paths. Therefore, the interface should enable students to combine multiple conditions and observe how the selection might affect the result of fossil formation. Students will not passively receive knowledge as they watch the animation of fossilization; instead, they will be empowered to construct these very conditions. In doing so, students should be able to analyze the characteristics of every variable (3 ecological systems and 6 physical burials) and compare the similarity and dissimilarity among them effectively.

As the teacher requested, the tool was designed to support individual-paced learning. Although it was intended that the Fossilization Web-LE would be implemented in class, the teacher asked students to finish the assigned task individually with the tool. Thus, to make the learning progress visible becomes the challenge of interface design. The interface should enable students to actively access the information and monitor their self learning progress. Therefore, a navigation tool (Fig. 1) was designed to help students

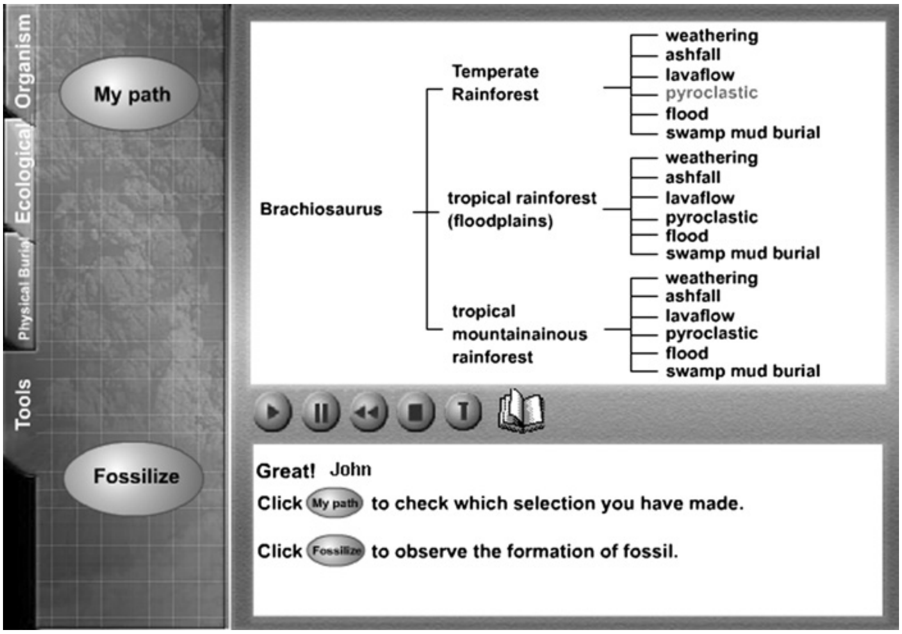

Fig. 1. Path tool records a learner's selection.

not only monitor all possible conditions of fossilization but also be aware of their own learning paths.

Students explored the tool with the purpose of solving a task requiring higher-order thinking skills. A task consisting of questions (about, for example, the defining of those conditions that provide the best opportunities for development and justifications underlying choices) was assigned to students before they launched the tool. Figure 2 is a flow chart of learners' interaction with the Fossilization Web-LE. When entering the Web-LE, learners must input their names. A learner's name is visible on the screen at all times to increase his or her involvement, therein. Researchers suggest that a display of the user's name on the screen can personalize the learning context and increase his or her motivation (Cordova and Lepper, 1996).

Next, learners who follow the fossilization process select an organism to observe. The description of the selected organism is placed in the text screen (Fig. 3). By clicking blue keywords, learners can access the online encyclopedia to look up information if they have any questions. Keywords are presented in a nonlinear arrangement, and learners can access these concepts based on their interests and needs. They then select the ecological system and physical burial conditions. The combination of their three decisions determines how the fossil will be developed. The fossilization simulation begins when decisions are finalized. The system records paths that learners have taken and helps learners identify the learning process. After experiencing all 18 possible paths, learners are able to identify the situations that can create fossils and solve the tasks the teacher has given them.

Design Principles

When the decisions had been made about the essential interactions of the learning activities, the team started to investigate the general design principles to follow in order to develop a user interface that would enable learners to interact with the content effectively. Several principles suggested by researchers and promoted by experts from related fields were adopted (IBM, 2004; Lohr, 2000; Suess, 1997). These principles are centered on the concept of user-centered design.

(1) *Make the most important information distinct:* To communicate the most important information, the team used clear graphic designs and contrasting colors to highlight keywords and important messages. Gray is employed to identify the dysfunctional buttons. The interface balances visual weight

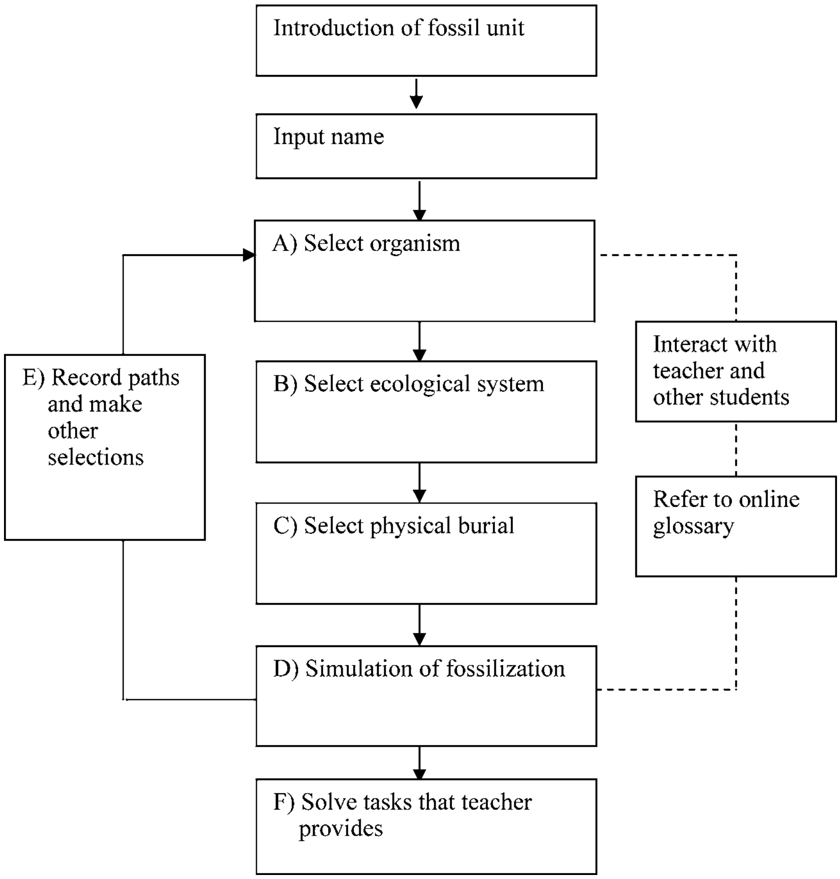

Fig. 2. Flow chart of the learning process.

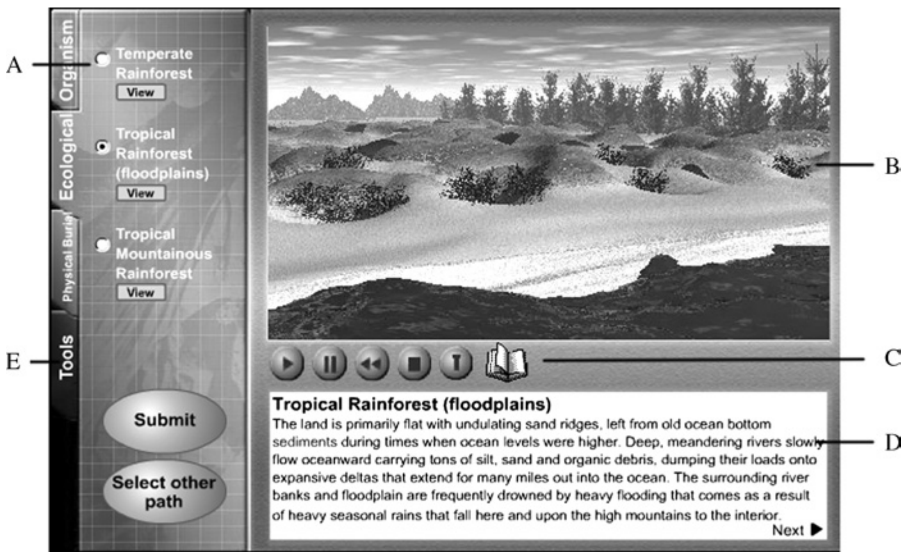

Fig. 3. Current version of interface design.

so that no particular parts stand out on the screen.

(2) *Establish a visual order of importance for users:* Information in the system is presented in three layers so learners can access the contents according to a hierarchical organization. Learners have to understand one concept before entering the next level. The organism level is the highest in the hierarchy, followed by the ecological systems level and then the physical burial level. The hierarchical arrangement presents the information in a non-threatening manner. Thus, users are not overwhelmed by the amount of information contained in the program (Jones *et al.*, 1995).

(3) *Organize information so learners see the "big" picture:* In addition to the hierarchical organization of information that helps learners explore the content one level at a time, a map of paths is provided to give learners an overview of all sections and how these sections are inter-related.

(4) *Consistent button design:* An interface must provide an effective navigational tool for users' interacting with the content. To help learners focus on the instructional content and avoid distractions stemming from the interface itself, labels are placed on the buttons so learners can choose functions easily. The consistent design of these labels throughout the program prevents frustration and confusion in the learners.

(5) *Visual feedback:* Each behavior that learners perform results in some visual feedback that prompts and directs them to interact with the system. For example, when a student loads a video, a visual index appears as an indicator that lets learners track the progress. The interface design should anticipate all possible interactions that may occur in the learning process and make feedback visible.

The members of the design constantly searched for interface design examples that would effectively convey this topic to teenagers. In view of this goal, the design team received consultation from experts while programmers tested the system. In addition, the teacher described features of the target learners and provided the team members with directions concerning the embellishment of the design.

The version of interface design that was employed in the formal testing research is shown in Fig. 3.

A. Condition selection: Radio buttons designed to facilitate learners' selections.
B. Media representation: Animation and encyclopedia appear in this window.
C. Video control buttons: Opportunities for students to control the learning path or repeat presentations to master the information. Learners can pause, play, and rewind the animation if necessary.
D. Text explanation: Explanations of different organisms, ecological systems, and physical burials appear in the text screen.
E. Identification: A path recorder was designed to help learners track their own progress.

Visual and Audio Issues

Video and animation can represent the complexity, ambiguity, and continuity of concepts. Research supports the usage of interactive video to improve student achievement when it is integrated into the learning environment effectively, and also supports the conclusion that interactive video is more efficient in the conveying of concepts than traditional approaches (Doulton, 1984; Stevens and Zech, 1987). Yair *et al.* (2001) conclude that scientific visual representations provide students with opportunities to observe phenomena that are difficult or impossible to observe directly.

The primary target audience of this Web-LE is high school students, to whom realistic graphics and vivid animation appeal. The science teacher also stressed that the representation of the fossilization process should be realistic and credible. Several endeavors have been made to achieve this requirement. The dinosaur has been developed with correct proportion, color, and movement. The 3D software (Corel Bryce©) was used to develop the realistic landscapes and objects, including ancient plants, volcanoes, lakes, and fossils. Macromedia Flash© was adopted as the primary authoring tool because of its ability to integrate multimedia and its capacity to optimize high quality media to enhance the speed of transmission. Sound files were incorporated to increase students' interests while the students use the tool.

Online Encyclopedia

One major function of this tool is to provide extensive and detailed explanations of selected keywords. These hyper-linked keywords are designed for learners who have difficulty understanding the explanation of the fossilization process. Learners can choose to learn about any keywords without suspending the whole learning process. Streaming animation and hyperlink functions are used to present the encyclopedia information via a hyperlink function. Students can link to the open environment to access other web sites and extend their knowledge about the topic. Furthermore, students can use the online encyclopedia as a separate tool without launching the main tool.

FORMATIVE EVALUATION AND USABILITY TESTING

To ensure that the team made accurate or appropriate decisions in each stage of the Web-LE development, the team members conducted formative evaluations starting at the storyboard design phase. To do the formative evaluation, the team members made continuous use of peer reviews and consulted with experts during the development process.

Usability problems can impair student performance (Tselios *et al.*, 2001), and it is important to conduct usability testing during the development and implementation process. The twin goals of usability testing are to ensure that target users find the tool easy to use (Rubin, 1994, p. 26) and to facilitate examination of potential usability problems with the interface design.

Usability testing was conducted so that, after completion of the prototype, useful feedback for improvement of the interface design could be collected. Students filled out surveys about this tool, and, as they used the tool in the classroom, the team observed their behaviors and interactions. These methods were employed so that information pertaining to modification and refinement of the tool could be obtained. Two questions were posed in relation to the usability testing: (1) are the media elements effective enough for the target audience? and (2) do the usability testing results support the effectiveness of the interface design?

The prototype for the usability testing included four scenarios of fossilization. Seven 10th grade students (four males and three females) were selected to test the prototype after school. The students were not given specific instructions for using the interface; they were asked to explore the functions of the program by themselves and to undertake an assigned task (to find out which scenario is most likely to preserve the complete skeleton of a dinosaur) by going through the tool. The students spent approximately 30 min with this tool and spent another 5 min filling out the usability questionnaire. The classroom observation, the usability testing questionnaire, and interviews with students were the primary methods by which data were gathered in the usability testing.

USABILITY TESTING RESULTS

The usability testing questionnaire focused on students' opinions of the program. Sample questions included "Using this software was easy" or "Figuring out the path I already completed was easy." To make a selection that best represented their opinions, Students referred to a scale ranging from one to five. The means of the students' usability testing results are graphed in Fig. 4. Generally, students thought the interface design was effective and enabled them to explore all scenarios and the online encyclopedia. They could find certain buttons on the interface and use the path record function to track their learning history.

One item that required attention was "Knowing what I was supposed to do." The overall mean for this item only reached "neutral." A possible explanation of this result is that to activate any one scenario, students had to go through three different layers and might have been distracted by the keyword explanations. When students make the final decision, the simulation does not automatically occur until they press the "submit" button. Several buttons were available on the same screen, and the students may not have understood which button they were to press to enter the next level.

The questionnaire featured two other questions that tested whether students could use the program to complete the assigned task and how helpful the Web-LE might be in improving their learning achievement. The teacher asked students to figure out which scenario has the best chance to produce the complete skeleton of a dinosaur. All the students selected the correct condition, and all the students pointed out that the fossilization tool indeed helped them to learn the concepts of fossilization underlying

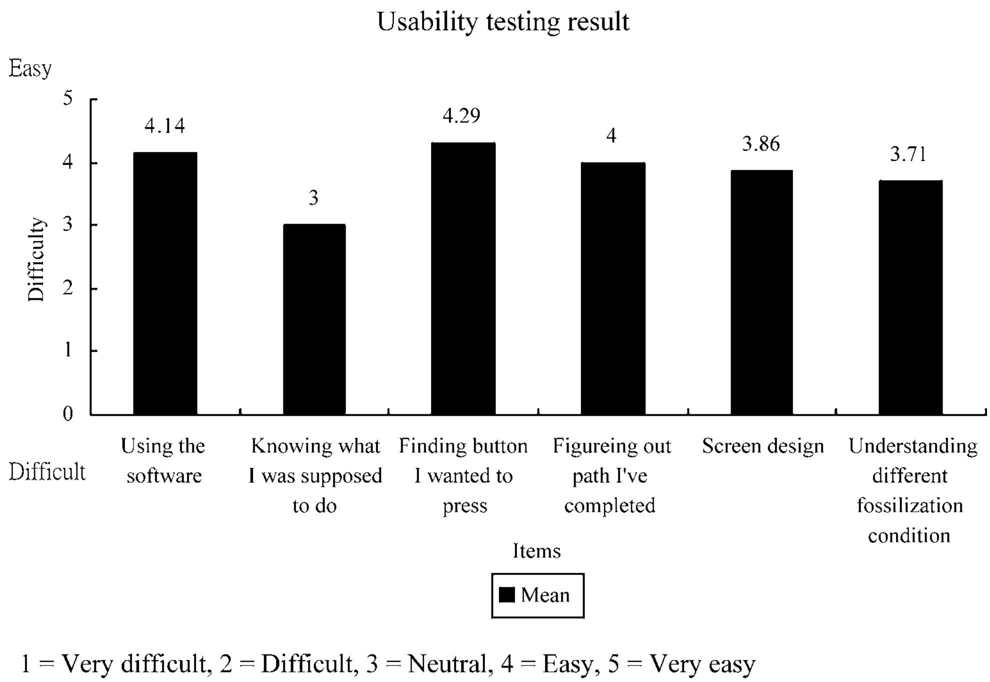

Fig. 4. Usability testing results.

this solution. This is the evidence that the user interface design effectively helped learners concentrate on the primary cognitive task.

Classroom observation focused on how individual students interacted with the program, their expressions of interest and motivation, which part of the program attracted their attention most, what kind of navigation problems they encountered, and conversations about the Fossilization Web-LE among students. The classroom observation provided clear information about some flaws in the interface design, especially about students' difficulties figuring out how to continue the instruction when a scenario was being selected. It appears that some students had problems finding where the "submit" button is and knowing when to press the "view" button.

In student interviews, common words and phrases used to describe the students' initial impressions of the tool included "interesting," "helpful," "easy to use," "cool," "fun," and "provided lots of information." They pointed out that the visualization of the tool was unique and that they had never had this kind of learning experience before. Students identified that the animation, the captions, and the online encyclopedia were the most useful parts of the tool.

The students' overall impression was that the Fossilization Web-LE was useful for developing better knowledge about the concept of fossilization. They identified two problems with the interface design: a "go back" button is needed, and access to the encyclopedia should be easier. As for the learning process, they hoped that, next time, the teacher would give students some instruction about the topic and more time to do the assignment. The team revised the interface based on the usability testing results.

DISCUSSIONS

Interface design flaws can cause severe problems when students use computer tools. The findings of this study suggest the following practical applications in the design of instructional software's user interface.

1. In the preliminary phase of interface design, designers should adhere to the standards for usability and accessibility. When the prototype is finished, the conducting of usability testing with representatives of the end users is essential to the elimination of potential future operational problems. The cognitive load

demanded by an interface should be minimized so that users can focus their cognitive processing on the learning tasks inherent in the Web-LE itself. It is suggested that designers use common metaphors for the design of buttons (for example, apply the metaphors characteristic of VCR buttons to the buttons used in the animation control) or that a button's function be displayed when it is rolled, or moused, over. The maintenance of consistency in interface design is another strategy that can help users intuitively control the tool.

2. The interface should enable students to access information according to their needs. To maximize their control over their progress, designers furnished this tool with several functions: movie control buttons; buttons for accessing the online encyclopedia, keywords, and in-depth explanations; functions for monitoring the learning progress; and interactive functions enabling students to combine various conditions for fossilization. It is necessary to discuss the interface design with the teachers and the target users in the design and development phase and make sure the interface design enables users to interact with the learning activities effectively.
3. In this study, data gathered from student interviews suggested that high school students are visually oriented and are attracted to realistic objects. When designing a tool for different learners, team should consider how to appeal to their needs (e.g., screen design, color usage, degree of realism). Some visual elements, such as the cartoon-style, that attract the attention of elementary students may fail to make upper school students engage with the learning process. On the other hand, realistic simulations may be both appealing and effective.
4. It is important to conduct usability testing to minimize the possible design flaws of the interface. Having a group of target users use the interface when the prototype is completed could help the team probe potential issues while interacting with the Fossilization Web-LE. To avoid later usability problems, designers responsible for the user interface should, early on, address the issue of users and the difficulty level of the interface with which they complete related tasks.

CONCLUSION

User-centered design is a key principle for the design of user interface (McKnight *et al.*, 1996; Torres, 2002, p. 15). An effective instructional software user interface may reduce not only the cognitive load of learners who are performing tasks, but also the possibility of disengagement. However, in order to develop an effective user interface, designers must investigate and understand the target learners' characteristics, including computer skills, prior knowledge of the subject, and visual habits. More important, the creation of an educational innovation and the interaction of learners with learning activities (which is the heart of learning itself) underlie the design of any computer interface and should be analyzed from the beginning.

This study is an example of collaboration among a front line teacher and instructional designers who aimed to develop a web-based learning tool by adopting the user-centered design approach. The results of this study yield some suggestions that can inform future efforts to develop or implement similar instructional innovations. From a practical standpoint, a good user interface will not guarantee a better learning outcome if the underlying learning activities are not meaningful and designed deliberately. However, a non-intuitive user interface can cause frustration and turn learners off.

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