AC 2009-1749: CULTURALLY-RELEVANT SCIENCE CURRICULUM - EFFORTS IN A SECONDARY SCHOOL - UGANDA

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Culturally-Relevant Science Curriculum: Efforts in a Secondary School, Uganda, Africa

Key Words: Culturally-relevant, simulated, laboratory, learner-centered

Abstract

This paper describes the design of a simulated science laboratory experiment which has been customized to meet the needs of St. Denis Secondary School in Uganda, Africa. The on-line program was developed by two master level graduate students in computer science attending Colorado School of Mines. Both students were enrolled in an independent study which was designed to support the acquisition of advanced computing and design skills while exploring humanitarian applications in another country. The targeted high school students have had limited laboratory and computer experience. This paper describes the resultant online experiment which adheres to the curriculum while appealing to students' cultural experiences. The user interface is designed to support a comfortable learning experience while facilitating the acquisition of scientific knowledge and hands-on experience with computers. The methodology employed to develop this software was a hybrid of learner-centered design.

1. Introduction

Meaningful science instruction, at any level, needs to be culturally relevant. According to Konnen [5], an 'investigation-based' approach to science instruction helps students to recognize science as a method of answering important questions rather than as an inventory of previously discovered facts. The first step in a scientific experiment is often to formulate a relevant scientific hypothesis and then explore this hypotheis empirically. Aikenhead [2] stresses that science instruction has more practical utility and connectedness when personal and societal issues are considered. As part of instruction, students should learn that science is a method of answering the important questions that impact their lives [5]. Linn and Muilenburg [10] explain that elegant theories are attractive to scientists because they explain a wide set of phenomena with a minimal set of principles but these theories are often too abstract to be effective for students. Students need to be able to see the benefit of applying their science instruction to situations in their lives. An example used by Linn and Muilenburg is that people who have a conceptual understanding of heat flow die in the wilderness every year due to lack of practical knowledge of insulation and conduction.

Substantial work has also been completed in devising new approaches for teaching people about science through technology. For example, White and Frederiksen [1] created an intelligent learning environment in the domain of electrical circuits which transitioned students from naïve conceptions to expert understanding. Rivers and Vockell [11] hypothesized that the practice provided by interacting with computerized simulations would help students acquire scientific problem solving skills. Their results generally supported this hypothesis, with the caveat that simulation content must be appropriate for the type of problem solving skills to be acquired. Najjar [9] has reviewed analyses by various researchers comparing traditional and multimedia instruction and concluded that, in general, interactive lessons have a positive impact on both students' learning and attitudes.

Using this prior research as a framework, this article describes an effort to develop culturally relevant software designed to support the scientific learning of students at a secondary school in St. Denis, Uganda, Africa. The secondary education system at St. Denis is based on a traditional, lecture format. Teachers within this system seek to transfer their knowledge to students by writing on the blackboard while their students take scrupulous notes. According to the research previously discussed, this passive method of instruction may place students at a learning disadvantage, especially in mathematics and science [1, 9, 11]. A major obstacle in improving the educational system at St. Denis has been a lack of imperative resources.

Through the efforts of a non-profit organization, Into Your Hands, and a collaborating U.S. university, the educational environment for students attending St. Denis secondary school in Uganda is beginning to change. Into Your Hands has established at St. Denis a computer laboratory with nine computers which include internet access. This electronic environment has the potential of changing the learning experience of attending students. A major challenge to this effort, however, is that not only do the students have limited experience with computers and the internet but so do their teachers. Additionally, their teachers have years of experience teaching through a lecture format, reinforcing lectures as an established habit for instruction. Furthermore, many of the software programs currently available to support secondary instruction contain examples which are culturally irrelevant to Ugandan students. According to Hodson [12], efforts to make science education more learner-centered must build on knowledge and experiences of the learners, which requires an understanding of the impact of different perspectives and experiences of dissimilar cultural groups. The purpose of the project described here is to develop a simulated science laboratory experiment, as a pilot for future software development, which was culturally relevant to the students' of St. Denis and which was consistent with the mandated science curriculum [5]. The research question of interest is:

> Can the traditional method of learner centered software design be altered in a manner that supports the development of educational software that is culturally relevant and supports the scientific learning needs of students in remote, inaccessible locations?

2. System Design and Content Selection

The science laboratory described in this article was designed to meet the following system requirements. These requirements were defined through e-mail correspondence with the Head Master of St. Denis.

- St. Denis secondary school has inconsistent power delivery with periodic down time and brown-outs. The software needs to be designed such that it is easily restorable from the point of last usage.
- Many of the participating teachers have limited computing experience and hence, the software could not require any supplemental knowledge on the part of the teachers in deployment and use.
- Participating students have no computer experience. The interface needs to be accessible to first-time computer users.

In addition, the Head Master provided the participating university with the established science curriculum at St. Denis.

The methodology that was originally proposed for the development of this software was a blend of techniques from goal-directed design, as described by Cooper et.al [4], and inspiration from learner-centered design as described in [6][7]. While the focus of system design for most applications is ease of use and enabling users to complete desired tasks efficiently, the goals for learner-centered design include enhanced understanding of a topic and increased motivation of learners.[6] Developers applying a learner-centered design methodology draw upon a number of ideas from educational research, including active construction of knowledge, inclusion of authentic problems, anchored tasks, communities of learners, and extension of learner activities via cognitive tools and scaffolding. [7]

User design techniques generally require close interactions between the end user and the developer. Given the location of St. Denis and the participating university, this type of interaction was not possible. In fact, even electronic correspondence was limited. Therefore, an alternative development strategy that captured the needs of the end-users, but did not include the end-users, was necessary. This constraint was addressed through the identification of provisional users for the system, as suggested in [4].

Five provisional users were selected. User 1 had worked in an elementary school in the Dominican Republic, Bolivia and Mexico, User 2 provided instruction to middle and high school students in Jamaica, and User 3 was a student raised in Bolivia. Much like Uganda, these countries have limited resources and challenging instructional environments. User 4 was a middle school science teacher in the United States, providing an appropriate pedagogical and content background, and User 5 was a subject matter expert who had spent a week at St. Denis during the prior year, providing personal knowledge of the students and the region.

Interviews were conducted with each provisional user. Based on these interviews, the following software requirements were identified:

- The application should be easy to operate and the layout should guide users through the laboratory.

- The content should be presented in an understandable and logical manner, proceeding from simple concept definitions to more challenging material.
- The images of components in the application should be appropriate (i.e., easily recognizable by students in Uganda and relevant to topic).
- Keyboard input should be minimized.
- The laboratory should be interesting, easy to comprehend and culturally relevant.

The next task was to identify the topic in science that the laboratory would address. One idea was to create a laboratory that addressed electricity and electrical circuits. This concept is consistent with the Ugandan curriculum for physics. However, St. Denis students have very little exposure to these concepts in their daily lives, creating an immediate challenge to the goal of cultural relevance. It was decided that for the first laboratory the content should be closely related and applicable to the students' daily experiences. More complex and abstract concepts, such as electricity, could be introduced in later units, once an appropriate background had been established.

Through interactions with User 5 who had spent two weeks at St. Denis in the previous year, heat transfer was identified as a viable content area. Heat transfer is consistent with the Ugandan science curriculum for physics. Heat transfer, however, could not be addressed in the same manner that it is taught in the United States. Students in the United States use electric and gas ovens; students in Uganda use open fire pits and clay or brick ovens. Adjustments would need to be made to the typical presentation of these concepts in order to make them culturally relevant to the target audience.

3. Design Implementation

Based on feedback from the provisional users, the decision was made to begin the unit with the introduction of the basic definitions that are required to understand the heat transfer unit. Figure 1 displays a screen shot of the initial screen in the unit. The purpose of this screen is to introduce basic vocabulary. According to Najjar [9], the inclusion of illustrations with text is especially important for learners with little prior knowledge. Furthermore, such graphics should illustrate what is described in the text and not be included simply for visual appeal.

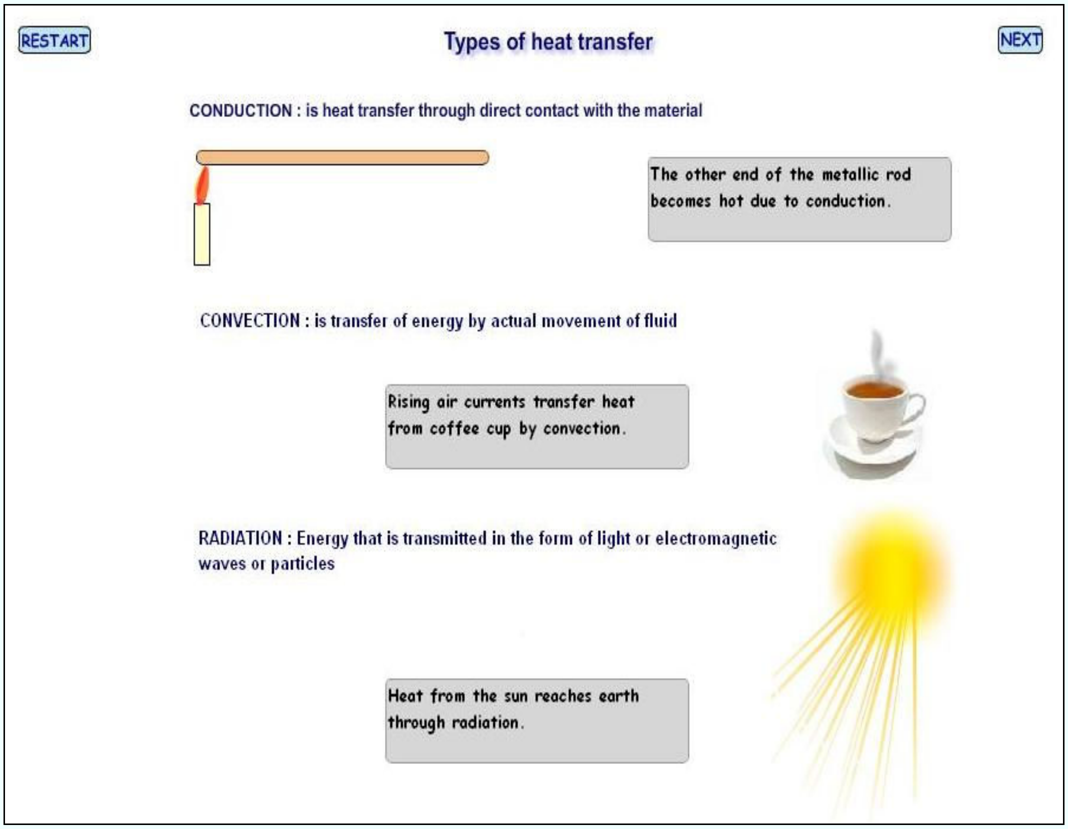

Figure 1: A screenshot of simple heat transfer concepts demonstrated with common everyday examples.

The remainder of the unit is designed to introduce the fundamentals of heat transfer by illustrating these concepts through cooking, a daily experience of the children in the region. Figures depicting the typical cooking practices of the region are presented to the student. In Uganda, food often cools and is reheated to prevent disease-causing bacteria from spoiling the food. This results in wasted fuel (wood).

In the developed on-line unit, principles such as Newton's law of cooling are illustrated through practical, culturally relevant examples, such as the amount of time that it would take for food to cool to a desirable temperature. In early phases of the unit concepts such as rate of heat flow, insulation, and rate of cooling are illustrated through examples that are common to the students' kitchens. Later in the unit, the concept of refrigeration which is foreign to most of the targeted students is presented as the extreme opposite of heating. Questions are posed throughout the unit, reinforcing the concepts addressed. Animated graphics are used to illustrate and explain the applications of heat transfer in students' daily lives. Computer jargon is kept to a minimum.

This unit is also designed to encourage the students to complete online experimentation. Rivers and Vockell [11] compare active engagement in biology laboratories to the acquisition of problem-solving skills by programming students as they develop, revise and test strategies during the debugging process. It is therefore essential to the proper learning of a scientific principle for the student to have a laboratory experience. As was discussed earlier, due to limited resources the students of St. Denis have few opportunities to complete hands-on experiments. Figure 2 displays a screen shot of the unit that supports students as they investigate cause and effect relationships between various insulating materials and the impact on heat loss. The insulation materials include straw, felt, and sawdust, all which are readily available in the students' environment. To facilitate student comprehension, modifications to the parameters result in changes in the corresponding graphics that reflect the impact in real applications. For example, if students input changes in the thickness of a material, that material increases in thickness on the screen.

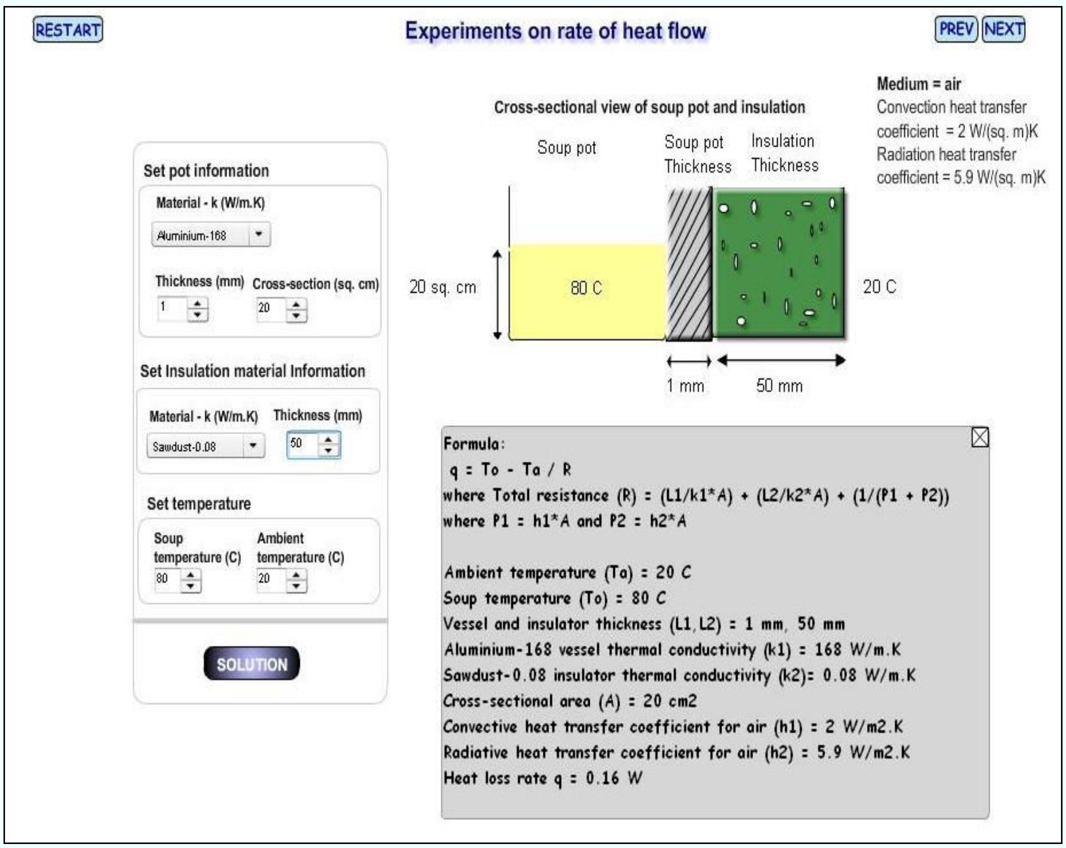

Figure 2: A screenshot of the control panel and animated demonstration of parameters controlling heat loss rate.

A final goal for the software is to encourage students to derive solutions to numerical problems. Figure 3 displays a screen shot which requires users to manually input the result of a calculation in a textbox. The user has the option, at any time, of reviewing the formula by selecting the solution button. Since the calculation is based on temperature values selected by the user, this page allows the student to practice computational skills and knowledge repeatedly, at his or her discretion.

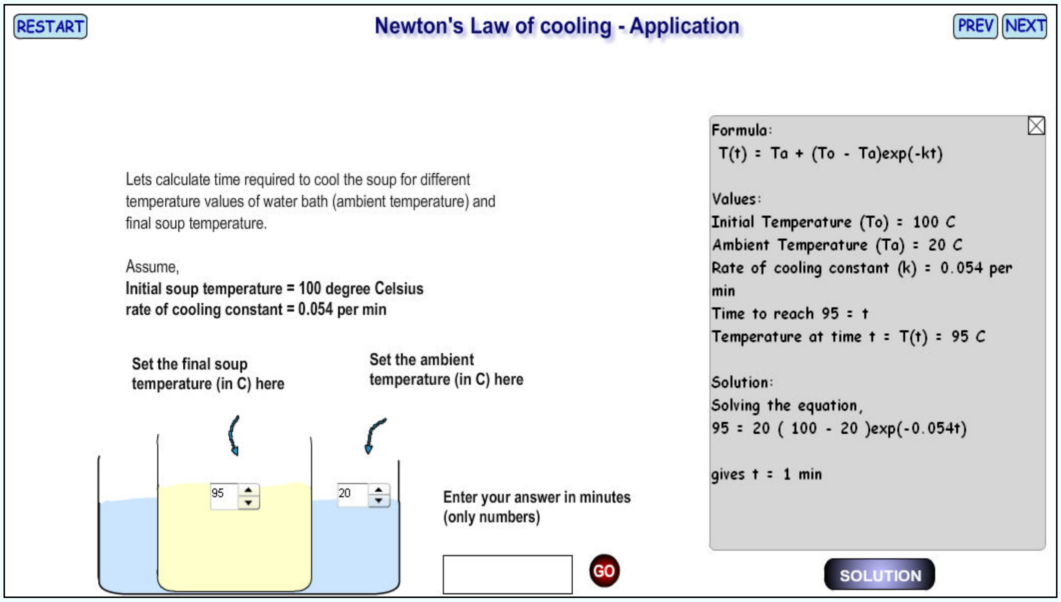

Figure 3: A screen shot of lab where user is provided with detailed solution to the numerical problem.

As illustrated through Figures 1, 2 and 3, the application is designed to capture most user inputs via mouse so as to minimize typing. This is important to support the learning of students whose second language is English. The navigation controls are designed to be simple and user friendly, supporting a seamless transition from one screen to the next. Users can easily navigate screens, and move back and forth between screens. The application follows a methodical, step by step approach, designed to build the students' knowledge from simple to complex.

4. Usability Testing

In order to examine the potential usability and effectiveness of the heat transfer science laboratory, the five provisional users previously discussed completed a peer review of the software unit. This review began with a brief introduction to the unit, the software, the intended purpose and the intended audience. No instructions were provided regarding how to use or to navigate the software. The users were asked to think aloud as they evaluated the on-line unit. Notes were maintained by the investigators throughout this process. After reviewing the software, the provisional users were asked the following questions:

1. Does the software suit the needs of novice computer users?
2. Does the software teach the heat transfer concepts in a culturally-relevant fashion?
3. Will teachers with little computer experience enjoy using the tool?

All provisional users indicated that the heat transfer unit was well designed and easy to navigate. User 5 who had first-hand knowledge and experience at St.

Denis, expressed that the software was user friendly and required a minimal learning curve for use. User 4 indicated that the laboratory had a logical flow and would support student learning. The provisional users also made recommendations for improving the software. Originally, the computational sections of the unit required specific numerical responses. Given that the students were likely to round many of their answers, the software was redesigned to include a tolerant feedback system with a margin of error of 5-10% in numerical answers. Also, the provisional users found the transition from one screen to the next to be too fast for English as second language learners. Based on this, user controlled transitions were built into the system.

5. Results and Future Work

Both service learning and global learning are gradually becoming a common component of the higher education system in the United States. However, due to financial constraints, university students within the United States often have only limited opportunities for interaction with individuals from the country for whom their project is designed to serve. In the development of educational software, this greatly limits the use of traditional methods of software design, such as learner centered design. The target audience in the current investigation was simply unavailable, due to distance and cost of travel. Additionally, at the time of development, St. Denis did not have an internet connection. In order to overcome this limitation, provisional users who had knowledge of the content, the developmental age of the students, environments similar to St. Denis, and of the region surrounding St. Denis were identified and interviewed to support the software development process. These individuals also provided feedback in the refinement of the proposed software. From an assessment perspective, a large component of the formative phases of the software development process was supported through the use of these provisional users.

The next phase in this research will be to transfer this software to St. Denis for on-site use and evaluation. This component of the project will be facilitated through the newly established computer laboratory at St. Denis which includes an internet connection. A preliminary response to the research question posed at the start of this article, "Can the traditional method of learner centered software design be altered in a manner that supports the development of educational software that is culturally relevant and supports the scientific learning needs of students in remote, inaccessible locations?", is yes. Through the use of provisional users, a pilot version of the software has been developed is available for use. The next phase of this research will be to confirm the effectiveness of the instructional unit on the target audience, the secondary students attending St. Denis, Uganda.

The reader may question the need for altering the learner center design approach for software development that serves a distant community. However, in the current global society, all communities, even those in remote locations, require an appropriate, basic, scientific education. Atwater and Riley [8] describe several settings where a lack of cultural knowledge can hinder efforts to engage students and strongly encourage science education researchers to incorporate multicultural issues into their research agendas. The knowledge and understanding that is necessary to modify educational software to address cultural issues may not be available on-site. The research completed here begins to examine how the software design process can be modified to support delivery of science content in a culturally relevant manner, even when the developers have limited communication with and are located many miles away from the users. Additionally, it is becoming a common practice for one culture to develop software that appeals to and is useful in another culture. This investigation begins to develop a framework to support such efforts.

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