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Using Digital Workbooks to Collect Design Process Data

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Abstract

Obtaining rich data for research data collection can often be quite tedious. An innovative approach to circumvent this task is to modify an already existing interactive learning tool designed for classroom use. The following paper discusses the modification of a digital workbook into a streamlined data collection tool. The customizable curricular tool presents a multimedia option capable of providing rich research data to extend what could previously be collected using a static research protocol. The tool was subsequently developed and used to collect data on student engineering design processes. The research team was able to use this tool to collect data from students around the country including images of built prototypes.

Introduction

RoboBooks™ is a software initiative started in 2007 by an engineering education research and outreach center. The goal of the project was to produce an interactive electronic workbook that brings together many different technologies to one location. The initial target populations were teachers and students in an effort to provide a customizable curricular tool that would make it easier for teachers to engage students in challenging design-based projects.[1,2] Within the environment, students are able to follow along teacher-created curriculum, input responses in the form of text, pictures, and audio, and connect to external robotics hardware and sensors.

The customizable environment of RoboBooks made this new learning tool an intriguing alternative for research data collection. The interactive electronic workbook was subsequently modified and used in a series of studies investigating student engineering design processes. The following paper describes the process by which the RoboBooks learning environment was used to collect research data of students engaged in the problem solving process.

Research Focus

Engineering design is a key practice deeply embedded within most disciplines of engineering. Regularly, engineering programs are now using design as a central theme in first-year engineering experiences as a powerful way to introduce undergraduates to engineering.[3-5] Engineering design has also been a focus for introducing pre-college students to engineering as illustrated by its inclusion in state and national frameworks.[6,7] The epistemology of engineering design stems from an emphasis, within engineering, of there being a systematic approach to analyzing problems, synthesizing knowledge, and evaluating results to make informed decisions in the pursuit of high quality solutions.[8,9] Since engineering problems are often ill-defined or sometimes “wicked”,[10,11] the engineering design process assists engineers in: (1) recognizing that there may be a “multitude of satisfactory solutions”,[9] (2) considering multiple perspectives (by information gathering) through which to frame the problem,[12] (3) producing myriad alternative solutions,[13] and (4) iterating solutions through testing and redesign as they optimize solutions to ensure they have not missed critical details as they optimize solutions to meet identified needs.[14]

The sorts of strategies and skills associated with engineering design have emerged as a popular area of research as engineering educators, psychologist, and learning scientists have tried to understand the process by which people design and what expertise looks like in design.[12,13,15,16] Crismond and Adams's review of research on design proposes a framework for considering the development of expertise in a number of common design strategies and skills highlighting differences between beginning designers and informed designers.[14] This research informed the current modification of an educational tool to investigate how educational experiences impact how people design.

Researchers at the center were conducting studies investigating the engineering design processes of undergraduate engineering students as they solved open-ended design challenges.[17-20] Previous research suggested using verbal protocol analysis, a form of think-aloud, to study the cognitive processes of the research participants.[21] The research design included a hands-on task with the objective of designing an assistive device that opens a jar. Pilot studies were conducted with engineering experts; each was presented with the design challenge and 15 stacks of index cards containing a variety of information (e.g. talk to a possible client, review important math or science concepts, view available materials, plan/draw/sketch, and build a prototype) that they could choose to peruse as they solved the task. After conducting a number of these tedious pilot interviews, the research team decided they could collect a larger corpus of data by streamlining the data collection protocol. The solution was to develop a digital version of the task using RoboBooks.

Upgrading the RoboBook Platform

As the name suggests, the RoboBook platform (Figure 1) was originally designed with two main intentions: (1) to provide an interactive digital environment to support robotic-based projects and (2) deliver curriculum content in a workbook format that was customizable by teachers and allowed students to document their engineering practices. The original RoboBook platform was built on a desktop piece of software (LabVIEW) used in many robotics applications and ran locally in order to directly connect to the hardware platforms used by the students.

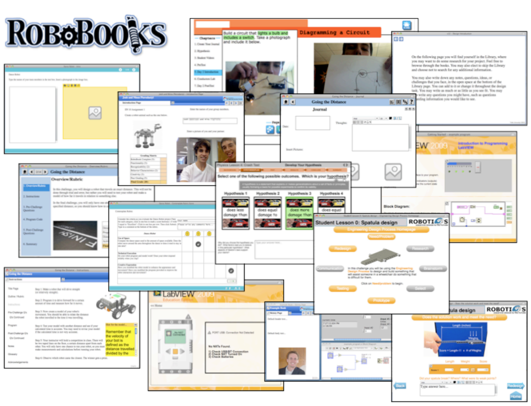

Figure 1: Collection of RoboBook screenshots, showing the variety of interfaces and formats possible

It was necessary to modify the original platform in a couple ways in order to transition to the application of education research on a larger scale. First, since the engineering design challenges being tested didn't require direct connection to hardware, it was no longer necessary to directly tie the platform to a desktop piece of software. Second, a web-based version of the RoboBook platform that could be accessed on any platform from any location at any time was created to account for the large amounts of data that would be collected from participants geographically distant from the researchers. As such, a transition of the original system was required, adding in a multi-user user-management system (on top of a user database) and converting the RoboBook environment to be purely a web-based platform (Figure 2). As such, new design activities could be created and participants could run through the challenges via the online application, thus providing all log-data (and other relevant artifacts, like text, images, etc) for the researchers to analyze.

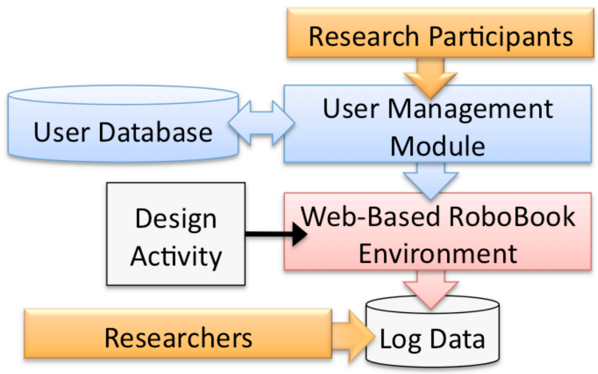

Figure 2: System diagram showing updated RoboBook structure to include user-management module and researcher available log data

Several features inherent in the Robobook environment lend themselves to being leveraged as a data-collection tool even though the system was not originally designed for such a purpose. This provides a distinct advantage over traditional static-survey based techniques. First, the addition of the customized logging tool provides a rich detailed account of all actions the user took throughout the design challenge. By having the design activity presented through the RoboBook platform, there are detailed records of exactly when each piece of information was presented to the user (e.g. when the user encountered new data, read background information, watched supplemental videos, etc.) and how long the user interacted with each. Second, the multimedia nature of RoboBooks meant that artifacts collected from the user, including written text, pictures of constructed items, sketches/drawings, emotional feedback of the user (ratings), and potentially movies/audio recordings from the design session, could be collected. These additional components, collected automatically by the system without need for researcher intervention, help provide a much more complete picture of the participant and design experience. Third, due to the non-linear nature of the RoboBook activities, it was possible to present to the user and simulate within the environment a more realistic design experience. The user could "jump" between parts of the design process with ease, exit partial explorations early to pursue other options, etc. Thus, the environment then provided a more natural design experience for the participant allowing the researchers to track what they did innately, rather than dictating and constraining them throughout the process.

Repurposing a Technological Tool

The basic structure of RoboBooks allows for researchers to quickly build a task. Participants enter the digital environment and are immediately presented with a Welcome page with instructions on how to work within the interactive tool (Figure 3). As a participant navigates the task they are presented with a link to an external survey (Figure 4), a place to input a username (Figure 5), a description of the design challenge (Figure 6), and instructions on how to proceed through the task (Figure 7). The intuitive environment makes it easy for participants to navigate the challenge without any great instructional detail.

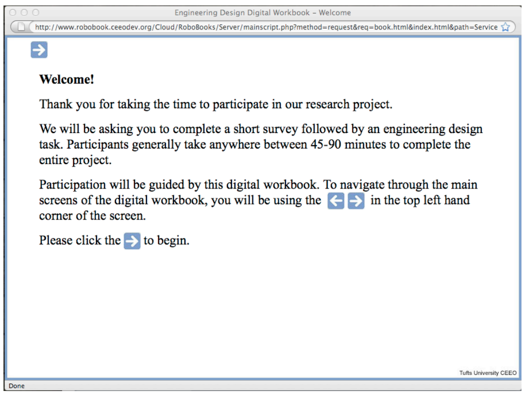

Figure 3: Welcome screen providing participants with general information.

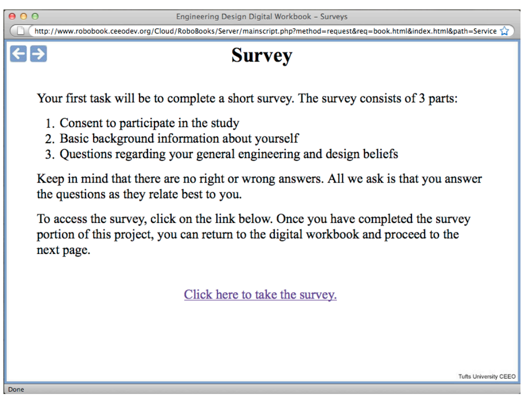

Figure 4: Survey screen with hyperlink taking participants to an external survey.

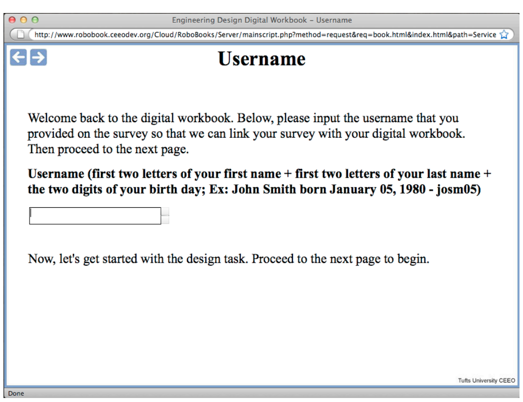

Figure 5: Username screen allowing participants to input an identifying username.

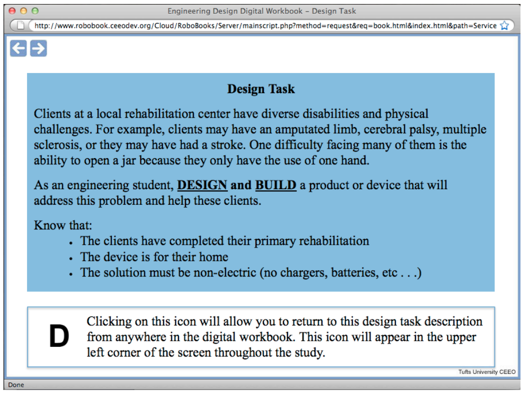

Figure 6: Design task description clearly outlining the goal of the task and how they can refer to this information later.

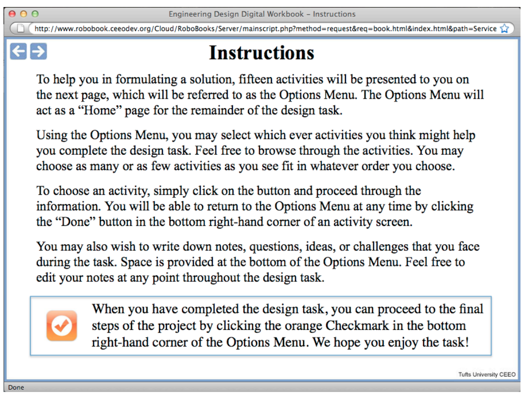

Figure 7: Instructions for completing the task.

The stacks of index cards were easily converted to a series of radio buttons (Figure 8). Below the various options was a space for students to write notes or ideas that they wished to record.

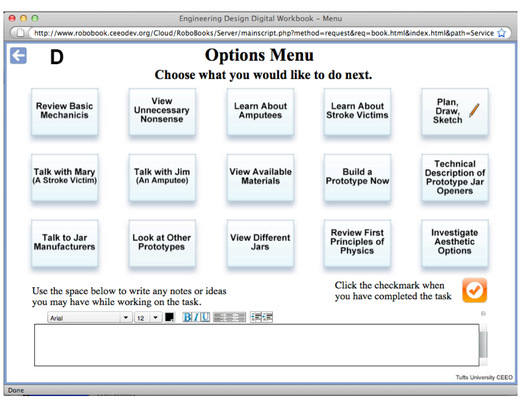

Figure 8: Design task interface.

Information previously included on the physical cards was digitized within the task so that participants could cycle through content with forward and backward buttons that noted which page of how many possible pages they were on (Figure 9). Replacing written descriptions with videos advanced some content.

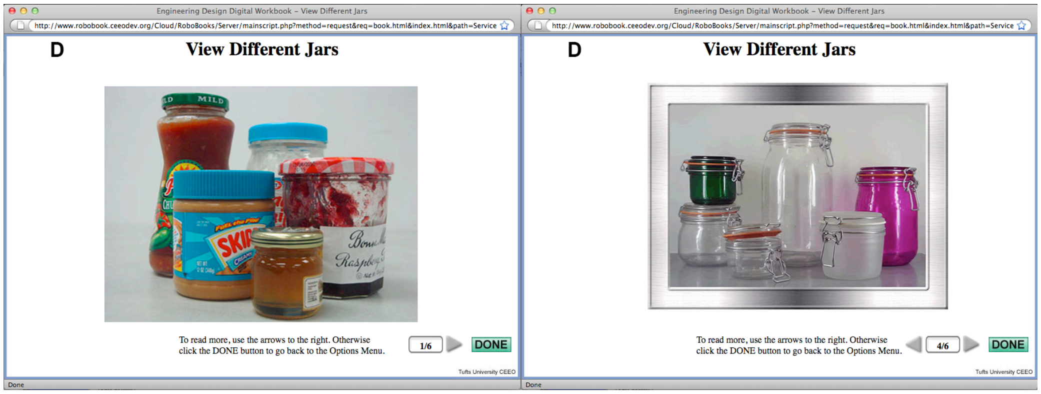

Figure 9: Example content from the ‘View Different Jars’ option.

The picture/video capability of RoboBooks was also utilized to allow the participant to record and document their drawings and their prototype (Figure 10) without the assistance of a researcher.

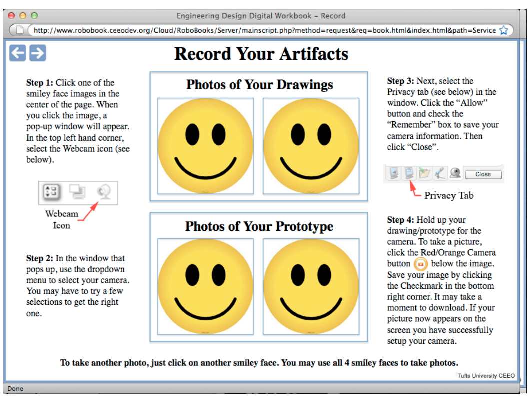

Figure 10: Picture capability of RoboBooks to record images of built prototypes.

Additional features were added to RoboBooks that enabled the researchers to collect data regarding when and for how long the participants accessed information. Participants were prompted to rate “how useful” a particular set of information was to the task (Figure 11).

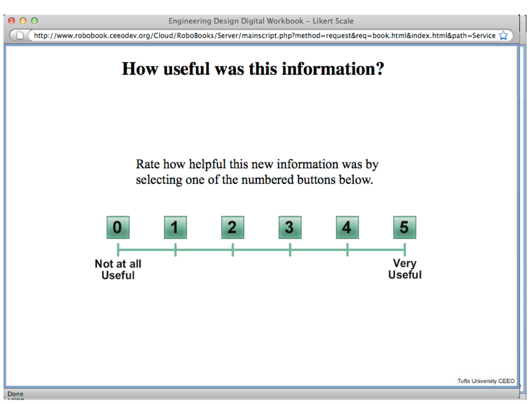

Figure 11: Rating scale presented after viewing a set of information.

The final product was a stand-alone research tool that allowed the researchers to conduct multiple experiments simultaneously for the purpose of widespread use.

Conclusions & Implications

The digital environment of RoboBooks allowed for an easily streamlined data collection process. The tool provided a method to easily assess participants and saved the researchers countless amounts of time. Additional information that would have been extremely tedious to collect (e.g. time stamping, ratings, images) was collected easily through the RoboBooks platform. Usability testing also showed the new digital version of the design task to be well received by research participants. This approach to data collection appears to present a valuable avenue for further data collection once the tool has been further developed.

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