Enabling Access to Engineering Education Materials Everywhere By Design

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Abstract – **We are currently engaged in a redesign of the method we use to distribute Engineering Teaching Kits (ETKs) via the Internet. This work in progress reports the results of the user-centered conceptual design phase of the project.**

ETKs are self-contained STEM education standards-based units that promote integrative learning about STEM via engineering design challenges. The current distribution method, a page on the University of Virginia's course management site, Collab, was adopted based on ease of developer access and use after a successful professional development session at ASEE's K-12 workshop in 2009 resulted in high demand for the presented activities. However, the page has proven to be increasingly unfriendly to users despite several redesigns and reorganizations, the results of which have had limited impact on user accessibility due to Collab's features and functionality.

A site that can't be accessed or navigated easily may lead (would-be) users to seek alternatives. This situation is not consistent with our philosophy of sharing materials as open source and with user-centered design values, including the work done by the UI/UX and HCI communities. Our first task in the conceptual design phase was to consult with users via a short survey. We wanted to understand more fully their expectations and needs for a content delivery method and to verify anecdotal feedback we had received over the years to make sure we had identified the problem and project goals correctly. The results will also inform preliminary requirements and be used to develop persona, or user profiles, for use in usability testing. The second task was to investigate current "best practices" in web page design by reviewing popular sites on both traditional and mobile devices. The preliminary requirements based on these results will be used in future design activities.

Index Terms – Engineering design process, Engineering Teaching Kits, HCI, P-12 engineering education, STEM outreach, UI/UX, User-centered design.

I. Introduction to ETKs

Since 2002, teams of students and faculty in the School of Engineering and Applied Science and the Curry School of Education at the University of Virginia (UVA) have developed, tested, and distributed Engineering Teaching Kits (ETKs) for use in K-12 science and mathematics classes, addressing real and present needs to have students understand the profession of engineering in all its varieties and to investigate whether the study and practice of engineering is doable for them. The primary goals of the lesson plans are to provide necessary background on the science and math concepts needed to complete the engineering design challenge. The challenge serves to reinforce the targeted concepts via project-based learning while introducing the students to the engineering design process. Initially, the focus was on middle school with later expansion to the rest of K-12, due to the inherent flexibility in how the units could be scaffolded and delivered.

ETKs are the means by which the Virginia Middle School Engineering Education Initiative (VMSEEI, now joined by *The Engineer's Way* [1]) connects and supports a community of informal and formal educators interested in using engineering design challenges to integrate and enhance learning in science, technology, and math. Additional details on these standards-based lesson plans are found in previous work, including [2] – [4]. This rich library was developed with a goal of wide dissemination.

II. Motivation

Throughout the years, the ETK Development Team has given numerous presentations in classrooms, summer camps, professional development sessions, and conference workshops. Consistently, we receive requests for access to the presented ETK and often, to the other ETKs we have available for use. As a result, we currently have 560 users, comprised of K-12 teachers, administrators, and parents and university-based engineering education researchers, registered on our ETK dissemination site. This site is part of UVA's internet-based course management system, Collab, which is built on open source software from Sakai. At the time of the site's creation, it was thought to be the most efficient means of providing access to the ETKs and supporting materials such as parent/teacher guides. However, the site has proven to be increasingly unfriendly to users despite several redesigns and reorganizations – which have had limited impact in increasing traffic due to Collab's features and functionality.

Also throughout the years, distribution of (digital) sources have changed based on available technology: we've gone from hard copies to various data storage devices ranging from 5.25" floppies to USB drives to internet downloads. Unfortunately, as user friendly the storage devices are, they also capture data at a given point at time. It is up to the user to upgrade his/her inventory as updates become available. Unfortunately, there is no guarantee that that they do so, leading to the use of outdated or unsupported information. As well, the use of mobile devices is increasing, and we need to be responsive to the needs of those users as well. To place this need in context, the number of smartphone users in the US in 2017 is projected to be at least 222.9 million, and the number of users worldwide will exceed 2 billion based on available estimates [see, e.g., 5]. To place this information into context, these numbers of users represent 68.4% of the US and 26.7% of the world's populations [6]. If a web site is not designed using responsive design principles, then it will not be as easy to use on a mobile device. We need to offer a good user experience in accessing the site regardless of the device employed.

Reasons why it is critical to incorporate engineering into the P-12 curriculum have been discussed in previous work [see, e.g., 7]. These reasons remain valid, as the number of challenges which engineers are uniquely qualified to address, often in conjunction with other professions, continues to proliferate in our technology-based society. Numerous sources have documented the projected shortfall in qualified STEM professionals for several decades. While ETKs cannot solve all of the roadblocks to preparation for and performance in the "STEM pipeline," it is a start in raising awareness about the engineering profession in the pre-college community. However, one must have access to the ETKs to use them.

Finally, we appreciate that time for learning outside the normal curriculum is scarce in many schools. There are a number of reasons for this situation, including meeting state and national standards and preparing for testing. Combined, the continued need for professional development for both pre- and in-service teachers on STEM topics and the challenges of finding time, materials, and appropriate curricula provide a powerful argument for using a truly integrated approach to STEM in pre-college classrooms: it is a more efficient use of time and resources. ETKs are one method of realizing this outcome.

III. User-Centered Conceptual Design

The engineering design process is at the heart of the discipline. There are a number of models of the design process in use. There are commonalities among them, including recognition that engineering design is problem-based and starts with the identification of a problem and research on related issues; end-state goals to achieve are set; a multidimensional design space is defined within which solutions are developed, bound by constraints, needs and desires regarding features and functionality, and other limiting factors such as regulations coming from identified "design for X" attributes; developed solutions are evaluated based on metrics derived from the design space; the solution with the best evaluation score is selected for prototyping; and an internally iterative cycle of design-build-test occurs. When a stopping rule is encountered, the design artifact is reviewed to determine if it meets, within tolerances, expectations or whether the design team needs to re-enter the process at a phase appropriate to the amount of redesign that needs to occur. Throughout, there is communication among team members and with clients, customers and users, recognizing that people involved in the design process may assume one or multiple roles at any time during design, delivery, and implementation [8] – [14].

It is important to note that there must be forward and backward traceability throughout the process: for example, goals must be derived from the problem/needs statement; requirements and evaluation metrics must flow from the goals; and stopping rules are based, in part, on constraints, market analysis, and client schedules.

The conceptual design phase, in which functions and features are identified from research directed by the problem statement and project goals, results in a design space within which possible solutions are developed and evaluated. It is extremely important that the design team has a clear understanding of the needs and desires of users in order to develop as complete a space as possible, since all possible solutions are derived from this space.

To bring a user-centered design orientation to the design process, user needs, wants, and abilities must have priority focus throughout, since clients, customers, and the design team may not have the required knowledge or background to develop requirements regarding usability and functionality that will result in a design that supports user needs rather than making users adapt beyond basic training (if needed). Interviews and observations provide information important to the design effort, especially in the problem/need definition, and perhaps reframing, phase as user emotional, physical, mental, and spiritual needs are identified and factored into the process. The environment in which the end product will be used also needs to be considered from both physical and cognitive viewpoints, to ensure that user requirements and situational demands are fully met.

The user-centered design process for computer-based systems is embodied in the user interface (UI)/user experience (UX) process, which is part of the human-computer interaction (HCI) field of study. Both physical (e.g., repetitive stress injuries, eye strain, and overuse) and cognitive (e.g., ability to understand, process, and respond appropriately to directions or instructions issued by a computer application) factors are considered when developing a computer-based system. The factors also provide a structure for developing persona, or user profiles that will be used during the design process to guide, analyze, and evaluate the development of requirements and possible solutions; the results of the design-build-test phase, especially via user and functionality testing; and determining whether a system is "good enough" to release [14] – [17].

IV. ETK User Survey Results

An eight question survey was developed and sent to registered users of the ETK Collab site in February and March, 2017. The goal of this survey was to validate anecdotal feedback we had received over the years regarding site accessibility, usability, and functionality. The information will be used to confirm design problem statement and goals and to develop preliminary requirements and persona. The questions and results are presented in Appendix A. We discuss key results here.

The very small number of respondents could be interpreted in several ways. First, it could be that school or other firewalls could be blocking that id since the invitation was sent as an email from the Collab site, meaning that a good number of users are not able to access the site. Second, enough time may have passed since the professional development or conference workshop at which a user signed up for the site that s/he is not able to recognize the id. Finally, it could be that accessing the site was so problematic that the user has essentially written off using Collab and hence the ETKs. The distribution of answers to questions 1 – 3 provides some support for these inferences. We thus know that preliminary requirements with respect to the web domain include that it is easy to remember, easy to access, and will not be tagged as spam.

The answers to questions 4 and 5 will be used to develop requirements as to site content and functionality, respectively. Respondents show a clear preference for ETKs as originally designed, with lessons and activities on applicable science and math concepts as well as the related engineering design challenge. In addition, we see that we need to reorganize certain information to a format and location more familiar to users as well as add commonly expected functionality and features. For example, we do have contact information on the Collab site, but it is buried on the home page. A list of available ETKs is under the ETK guides tab and implied through the available tabs, but a user needs to be familiar with the product to find a desired ETK.

The answers to question 6 are a confirmation that we need to use responsive design principles in developing the site, so that users can access the ETKs on the device of their choosing.

Finally, the answers to question 8 provide information useful in developing persona. We know, for example, that a significant percentage of users are interested in ETKs for grades 3 – 5 and therefore we definitely need to develop persona for teachers and parents working with children aged 8 – 11 to use in developing and testing a distribution site for this critical user population. Our preliminary list of persona categories includes pre-service K-12 teachers, in-service K-12 teachers, K-12 administrators, K-12 homeschoolers, and university faculty and researchers.

Administering this survey, which occurred in the middle of the design process, provided critical information. We knew that the majority of users didn't use Collab to retrieve ETKs based on the number of complaints we received regarding access, and thus we needed an alternative distribution method. However, we started the design process with the assumption that we could operate totally from a mobile platform. Feedback from the survey and summer professional development courses showed this assumption to be only partially correct. For example, there are a number of areas in Southwest Virginia and Albemarle County, VA [18] with minimal wireless coverage and internet access. The lack of access is experienced in other rural areas in the United States, with only 55% of rural residents having access speeds that qualify as broadband [19]. Therefore, we cannot ask users to access ETKs solely via mobile devices.

V. Web Page Design Survey

A number of web sites were surveyed with respect to their design using an iPhone 6 (Safari) and a Mac (Chrome). Representative sites are listed in Appendix B. The following preliminary requirements are drawn from the survey results:

We must use responsive design principles in designing the site. Having dedicated mobile and "regular" sites is not practical with the resources available to us. It is also important for the display to size itself automatically to the active browser window without user intervention; see the next requirement for additional sizing/placement considerations.

We should also factor in "fat finger syndrome" when designing links and tabs. Otherwise, the user is constantly swiping in and out (and concomitantly causing repetitive stress to hands) to be able to click on the desired link or tab. Reader view available (four horizontal lines to the left of the URL box) can mitigate this situation somewhat by removing extraneous material from the browser window, but it is not a complete solution.

It is important to keep navigation icons and paths similar to those on other sites to lessen the learning curve. For example, we need to use commonly used icons, such as the "hamburger" menu (three bars, representing the bun and patty) magnifying glass for search, and a house to return the user to the home page. We also need to place these icons on the page where users most expect to find them (e.g., menu on the upper left and search towards the top).

We should not optimize design for a given/dedicated browser (e.g., edas.info is optimized for Firefox, which makes using it on Safari quite a challenge); otherwise, we risk making access difficult if not impossible for users who do not have those browsers.

We should pin the main navigation bar with the web site name to the top of the site.

VI. Conclusions and Future Work

Having determined preliminary requirements, functionality, features, and persona characteristics via survey, we now need to develop and validate them further through user interviews. This process may also include usability testing using likely wireframes to judge ease of navigation.

We also believe that the current model of document delivery, clicking on a link or icon to display or download a file (preferably, a pdf), is still useful; however, we need to design a site that is easily updateable if a better alternative is found.

Above all, we know that we know that we need to develop an alternative to our Collab site to facilitate distribution of our ETKs.

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Appendix A: Survey Questions and Results

The survey was anonymous and data reported only on the aggregate level. Twenty-three users responded, representing a very small sample of users (.0004%). The number of respondents for a given response is listed first, followed by the percentage of response. Both may not sum to 23 or 100%, since respondents skipped questions or some questions accepted more than one answer, respectively.

1. How many times have you accessed the ETK Collab site?

0 times	6 (26.09%)
1 – 5 times	15 (65.22%)
More than 5 times	2 (8.7%)

2. Please rate the ETK Collab site as to accessibility. (4 skipped)

I cannot access it at all	4 (21.05%)
It was easy to bring the site up	9 (47.37%)
It was moderately difficult to bring the site up	5 (26.32%)
It was hard to bring the site up	1 (5.26%)

3. Please rate the ETK Collab site as to ease of signing in. (4 skipped)

I never could sign in successfully	5 (26.32%)
I was able to sign in successfully once, but not after that	3 (15.79%)
I am able to sign in successfully	11 (57.89%)

4. I would like access to the following ETK products (check all that apply): (2 skipped)

List of available ETKs	17 (80.95%)
Full lesson plans	16 (76.19%)
Engineering design challenges only	5 (23.81%)
STEM background and initial exercises	15 (71.43 %)
Publications and presentations	8 (38.1%)

5. I would like to have the following functions available (check all that apply): (6 skipped)

Contact information	12 (70.59%)
Frequently asked questions	17 (100%)
Help	8 (47.06%)
Home (one touch navigation)	7 (41.18%)
Open Access (no sign-in)	8 (47.06%)
Search	13 (76.47%)
Sign-in/out (secure site)	4 (23.53%)

6. I would like access to ETK products through: (2 skipped)

My phone or tablet	0 (0%)
My desktop or laptop	14 (66.67%)
Both mobile devices and traditional computers	7 (33.33%)

7. Would you use ETK products more if there were an alternative access/distribution method to the Collab site? (2 skipped)

Yes	8 (38.1%)
No	2 (9.52%)
Not Sure	11 (52.38%)

8. I am interested in using ETKs primarily for the following audience: (2 skipped)

Early childhood (P-2)	1 (4.76%)
Elementary (3-5)	9 (42.86%)
Middle School	5 (23.81%)
High School	5 (23.81%)
Undergraduate	1 (4.76%)
Other (please specify)	(0%)

Appendix B: Web Sites Surveyed

A number of web sites were reviewed based on the frequency of use by the authors and colleagues. The sites are widely visited, and are felt to be representative of sites either using responsive design principles or creating a mobile site separate from the site accessed from a browser on a laptop or desktop computer. Other sites in the survey use the same design whether accessed through a mobile device or a lap/desktop.

Sites in the first set include dailyprogress.com (local news), espn.com (sports), gmail.com (email), google.com (search engine), richmond.com (regional news), slate.com (news), youtube.com (videos), and washingtonpost.com (national and world news). Sites in the second set include its.collab.virginia.edu (UVA course management site), edas.info (conference management system), Lou's List (UVA course schedule), and seas.virginia.edu (School of Engineering and Applied Science).

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