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UNIVERSAL DESIGN: AN EXPLORATORY STUDY EXAMINING TEACHERS' EXPERIENCES IN NAVIGATING A DIGITAL CURRICULUM REPOSITORY

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ABSTRACT

Aim/Purpose	The development of web-based platforms and curriculum resources, as well as the assessment of user interactions with these platforms, is critical to ensuring an optimal user experience. This study examines the redesign of a middle school engineering digital curriculum repository within the broader framework of curriculum implementation, with a specific focus on how teachers interact with and utilize its resources.
Background	The redesign was in response to a scale-up implementation of a prior 4-year study, to accommodate a wide range of teacher users. The redesign process prioritized accessibility by embedding universal design principles into both the repository's structure and accompanying teacher resources. These principles were used to create an adaptable and inclusive platform that meets the needs of a diverse user base. This paper outlines the key design considerations that informed the redevelopment, highlights improvements made in response to teacher feedback and examines how the repository supported instructional practices.
Methodology	A qualitative user study was conducted with four middle school engineering teachers who used the redesigned repository for lesson implementation.

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Contribution	The study aims to provide insights into the practical application of universal design principles, addressing gaps in existing research on designing tools that accommodate varied learning needs.
Findings	Findings revealed that integrating universal design principles reduced cognitive load by streamlining navigation and improving access to curriculum materials. Teachers reported that the redesign provided significant support for lesson preparation, thereby enhancing their ability to implement the curriculum in their classrooms effectively.
Recommendations for Practitioners	These findings highlight the benefits of applying universal design principles to design web-based curriculum resources and platforms, thereby ensuring their accessibility and usability for all users.
Recommendations for Researchers	Continuing to explore how web-based curriculum resources and platforms, designed based on the universal design principles, may improve inclusion among diverse populations and ensure the sustainability of their use.
Impact on Society	This study underscores the potential of such designs to promote inclusion among diverse populations and discusses the implications for the long-term sustainability of websites developed with these principles.
Future Research	Future research will continue to explore how universally designed web-based curriculum resources can enhance user experiences and foster equitable access to educational resources.

Keywords: universal design, universal design principles, digital curriculum, K-12 engineering education

INTRODUCTION

Technology is a powerful tool for transforming teaching and learning in K-12 education, as it helps to reinvent pedagogical approaches, diminish equity and accessibility gaps, and is adaptable for teaching and learning to meet the needs of all users (Delgado et al., 2015). Digital technology, including the use of educational websites and web-based curriculum resources, has been a popular and preferred tool for K-12 teachers during lesson implementation (Webel et al., 2015; Wolven, 2013). The effective use of these digital learning resources remains a critical factor in supporting teachers' content knowledge development (Guggemos & Seufert, 2021; Heine et al., 2023). Therefore, the design of these curriculum resources can affect how teachers access and use them for lesson implementation. Conducting user studies with real users can be valuable for assessing how effectively web-based curriculum resources serve their intended purpose and achieve their objectives (Villamañe & Alvarez, 2024). In K-12 education, conducting user studies with teachers can help uncover how they use web-based resources in their teaching, as well as identify areas for improvement during lesson implementation (Wolven, 2013; Young, 2024).

The importance of considering real users to understand their perspective has been discussed in the literature (Nielsen, 2012), as their access to and interaction with a website are central to designing one that effectively meets user goals and objectives (Youngblood, 2013). Gaining insight into how web-based curriculum resources are utilized by teachers, including ensuring access to all available resources and information, may ultimately aid in supporting the implementation of lessons. Only a small number of studies have evaluated how users utilize and access educational websites and web-based curriculum resources with real users (Campoverde-Molina et al., 2020). To understand website usability and accessibility in real contexts, it is essential to incorporate genuine user feedback during reviews and redesign.

For this study, an existing digital curriculum repository ("website") was redesigned to support a middle school STEM-integrated curriculum, STEM Innovation and Design (STEM-ID), as part of a broader research initiative investigating the implementation in middle school engineering classrooms. While the existing website provided teachers with organized access to curriculum materials, past teacher users and project staff provided feedback to improve navigation, consolidate supplementary resources, and expand accessibility across different devices and for diverse users. To build on these limitations, the redesigned website's layout, features, and resources (e.g., teaching materials, videos, and student worksheets) were intentionally developed in alignment with the universal design (UD) principles to enhance accessibility and usability for educators while fostering diversity and inclusiveness among the teacher user base (Burgstahler, 2009).

This paper presents an overview of the redesigned STEM-ID website, emphasizing its alignment with UD principles. We also present findings from a user study and follow-up interviews conducted with teacher participants, analyzing how the redesigned website supported their instructional practices.

The study aims to provide insights into the practical application of UD principles in instructional technology, addressing gaps in existing research on designing digital, web-based curriculum interfaces that accommodate varied learning needs and teaching contexts. Furthermore, this work establishes a foundation for future studies exploring the impact of universally designed interfaces on user engagement and the integration of STEM curricula in middle school classrooms.

LITERATURE REVIEW

This section reviews the challenges and barriers that K-12 teachers encounter when using online resources, as well as the specific accessibility and usability requirements necessary to design websites that effectively support a diverse range of users.

CHALLENGES FACED BY K-12 TEACHERS USING ONLINE RESOURCES

The rise of the Internet has significantly expanded access to education and learning resources, transforming it into a platform for disseminating online content (Youngblood, 2013). As online educational resources become more prevalent in K-12 classrooms, learning platforms should cater to the practical needs of K-12 teachers and be user-friendly, ensuring seamless access to materials. Moreover, teachers' technological skills and competence play a crucial role in determining the successful adoption and continued use of web-based resources in their teaching (Garba et al., 2013). To further support teacher users, they require adequate guidance in utilizing educational tools, which helps them integrate learning materials effectively (Song et al., 2015). Practical applications of teachers using web-based resources are supported through multimodality, which emphasizes the integration of various modes, including text, image, video, and interactivity (Knight et al., 2019). However, despite the benefits of supporting the integration of online resources, research studies have identified several challenges that teachers encounter when incorporating them into their teaching practices. One notable challenge is the navigational overload experienced by teachers as they review the extensive amount of information available on a website. This can lead to cognitive fatigue, affecting teachers' ability to concentrate and effectively utilize the resources (Ertmer & Ottenbreit-Leftwich, 2010; Recker et al., 2004).

Additionally, technical barriers such as slow loading times and broken links can hinder access and reduce the reliability of online platforms and resources (Kim et al., 2013). These challenges underscore the paramount importance of designing online resources to be responsive and accessible. By ensuring that online educational resources provide user-friendly, well-organized, and streamlined information, teachers can more easily integrate web-based resources into their classrooms.

Accessibility and Usability of Websites

The Web Content Accessibility Guidelines (WCAG), developed by the World Wide Web Consortium in 2018, lists standards related to accessibility. As outlined by the World Wide Web Consortium (2018), accessibility encompasses the design and creation of websites, tools, and technologies that are accessible to individuals with varying physical and cognitive abilities. The WCAG comprises four fundamental principles, collectively known as POUR, namely perceivable, operable, understandable, and robust. Perceivable means that users can identify content and interface elements through their senses, whether visually, through sound, and/or touch. Operability ensures that users can effectively control and navigate the website using various methods, including assistive technologies. Understandable refers to the website's consistent format, which provides predictability in its use. Robust indicates that the website's content is designed for easy interpretation by a wide range of agents, including assistive technologies.

The International Organization for Standardization (ISO) (2018) defines usability as focusing on user-centered design to ensure that products and systems are easy to use and meet the needs of the target audience. The ISO presents three components of usability: effectiveness, efficiency, and satisfaction. Effectiveness refers to the accuracy and completeness with which users achieve their goals when using the system. Efficiency is the resources that users use to perform and achieve goals. Satisfaction refers to the extent to which a system meets users' needs and expectations. In terms of user interface design, usability is often addressed and discussed based on Nielsen's (1994) work. Nielsen initially developed and proposed "10 Usability Heuristics" based on a factor analysis of 249 usability problems. These 10 heuristics have been used to evaluate and serve as the basis for design interfaces (Kuhail et al., 2022; Lu et al., 2022) and include the following: visibility of system status, a match between the system and the real world, user control and freedom, consistency, and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognize, diagnose, and recover from errors, and help and documentation. These heuristics are fundamental for designing user-friendly interfaces, focusing on criteria such as visibility, flexibility, and minimizing effort and use to make products clear, consistent, and intuitive for users.

Both accessibility and usability are significant when discussing the concepts of product and system design, as they yield more inclusive outcomes. They aim to enhance the user experience and ensure inclusivity for a broad spectrum of users. Usability encompasses the ease of use and efficiency of the design, including navigation and comprehension. Simultaneously, accessibility guarantees that users have equitable access to the product and system.

While online educational resources hold great potential for enhancing K-12 instruction, teachers continue to face persistent challenges, including limited technological proficiency, cognitive overload, and technical barriers. These challenges underscore the importance of user-centered, accessible, and usable digital platforms that adhere to established accessibility and usability standards.

Theoretical Framework

The website redesign was guided by the seven UD principles proposed by the Center for Universal Design (CUD) at North Carolina State University. In this study, the UD principles function both as recognized guidelines in the literature and as the framework guiding the redesign. The goal was to maximize accessibility, usability, and inclusivity, thereby aligning the design with the project's broader commitment to equitable access to curriculum resources.

Universal Design Framework

The UD framework is commonly employed for design and development. It is based on the belief that designers aim to create products that are accessible and usable by all users without requiring specialized adaptations (Burgstahler, 2009; Preiser, 2008). As noted in the literature, UD "attempts to make products, equipment, as well as information technology, accessible to and usable by all without regard to gender, ethnicity, health or disability, or other factors that may be pertinent" (Preiser, 2008, p. 78). Building on this premise, CUD at North Carolina State University established seven UD principles to steer the design of products and environments. The principles are crucial for guiding website development as they address the perspectives necessary to consider when developing educational tools, including websites (Mayer, 2005). The principles and their description are listed in Table 1.

Table 1. Universal design principles and description

Principles	Description
Equitable use	The design is useful and marketable to people with diverse abilities.
Flexibility in use	The design accommodates a wide range of individual preferences and abilities.
Simple and intuitive use	Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or concentration level.
Perceptible information	The design communicates necessary information effectively to the user, regardless of ambient conditions or of the user's sensory abilities.
Tolerance of error	The design minimizes hazards and adverse consequences of accidental or unintended actions.
Low physical effort	The design can be used efficiently and comfortably, and with minimal fatigue.
Appropriate size and space for approach and use	Appropriate size and space are provided for approach, reach, manipulation, and use, regardless of the user's size, posture, or mobility.

THE STUDY AND RESEARCH QUESTIONS

For this study, the STEM-ID website was redesigned according to the seven UD principles and guidelines. To explore the redesign of the website, the following research questions were asked:

1. To what extent do the website design and supplemental teacher resources address the seven UD principles?
2. In what ways do teachers' perceptions regarding the accessibility and usability of the website and experiences, during curriculum implementation, contribute to the refinement process?
3. How do teachers perceive the accessibility and usability of the website?

METHODS

RESEARCH CONTEXT

Research study

This research study was conducted as part of a broader research initiative aimed at investigating the implementation of the STEM-ID curricula in more than 20+ middle school engineering classrooms in a large metropolitan county in the Southeastern United States. The study is a Discovery Research PreK-12 (DRK-12) project (#2101441) funded by the National Science Foundation (NSF) with the goal of investigating the scale-up implementation of STEM-ID following promising results in a prior 4-year development and implementation study.

One of the aims of this research initiative is to further refine the curriculum and its lesson materials for broader implementation, scaling the project to reach a larger population of middle school teachers and students while ensuring the best ways to accommodate a wide range of teacher users. The implementation research is guided by the Innovation Implementation Framework (Century & Cassata, 2014), in which the authors define implementation as the extent to which innovation components are in use at a particular moment in time. Implementation is examined in accordance with specific critical components of the curricula, including structural and interactional components, and how they unfold within distinct teaching contexts (Gale et al., 2024). Structural components encompass "organizational, design, and support elements that constitute the foundation of innovation," which are subdivided into procedural components (organizing steps, design elements of the innovation) and educative components (support elements communicating what users need to know) (Century & Cassata, 2014, p. 88). Interactional components encompass "behaviors, interactions, and practices of users during the enactment," which are divided by user groups (e.g., teachers and students) (Century & Cassata, 2014, p. 88). One of the structural-educational components, the utilization of STEM-ID materials, including the website, was selected for redesign. This approach is designed to provide adequate support for the large-scale implementation and enhance teachers' ability to effectively implement the curriculum, regardless of their teaching experience or familiarity with digital platforms and/or web-based curriculum resources.

Digital curriculum repository

The website provides the necessary information engineering teachers need for implementation, including lesson descriptions and activities for all units, learning resources, and lesson materials to use as part of the lessons. The engineering curricula include four unique challenges at each grade level, and the website guides teachers through the lesson units within these challenges for 6th, 7th, and 8th-grade classes. Table 2 introduces the four challenges and a unit description for each grade level.

Table 2. Description of challenges for each grade level

<table>
<tr><th>Grade level</th><th>Challenges</th></tr>
<tr><td>6th Grade: Carnival Tycoon</td><td>Data Challenge</td></tr>
<tr><td rowspan="3">The unit explores the engineering design process and entrepreneurial thinking in the context of a carnival.</td><td>Systems Challenge</td></tr>
<tr><td>Visualization Challenge</td></tr>
<tr><td>Design Challenge</td></tr>
<tr><td>7th Grade: Flight of Fancy</td><td>Data Challenge</td></tr>
<tr><td rowspan="3">The unit places students as engineering consultants to design the interior and exterior of an aircraft.</td><td>Systems Challenge</td></tr>
<tr><td>Visualization Challenge</td></tr>
<tr><td>Design Challenge</td></tr>
<tr><td>8th Grade: Robot Rescue</td><td>Cellphone Holder Design Challenge</td></tr>
<tr><td rowspan="3">The unit introduces a design challenge to design a product, followed by an open-ended challenge to design a robot.</td><td>Robot Rescue Systems Challenge</td></tr>
<tr><td>Robot Rescue Investigation Challenge</td></tr>
<tr><td>Robot Rescue Design Challenge</td></tr>
</table>

The initial website was originally developed using Google Sites as its platform and included lesson activities and resources for teachers to use. For the website redesign, the project team continued to use Google Sites as the platform to support classrooms that utilize Google Classroom and have access to Google accounts.

PARTICIPANTS

Four middle school engineering teachers were recruited for this study from the larger cohort of teachers participating in the STEM-ID research initiative within the same school district. These teachers were selected to provide detailed insights into the usability and effectiveness of the redesigned website, ensuring the study's findings were grounded in authentic classroom experiences and reflective of diverse instructional contexts.

All four teachers planned to implement the curricula during the upcoming semester by utilizing the website. The teachers came from diverse backgrounds, varying in both years of teaching experience and the subject they taught before becoming engineering teachers. Their teaching experiences ranged from eight to 29 years, and they taught science, mathematics, English language arts, or engineering. Of the four teachers, two had previously implemented the curricula and were familiar with the initial version of the website, while the other two had only been introduced to the redesigned website less than a month prior to the study. All four participants voluntarily participated in the study and received compensation for their time and effort.

DATA COLLECTION

At the beginning of the study, researchers reviewed the initial website by collecting feedback from previous teachers and determining its feasibility based on the UD principles. Project staff who conducted professional development with teachers implementing the curricula shared their feedback. Next, researchers reviewed the initial website's current feasibility and categorized the findings based on the UD principles and their descriptions given in Table 1. Based on this initial review, researchers identified areas that needed refinement on the website, which underwent a comprehensive redesign grounded in the principles of Universal Design (UD).

After the website was redesigned, qualitative data were collected through an individual user study with each of the four teachers. The user study was conducted via Zoom in the summer, prior to participants using the website for implementation of the curricula in the upcoming fall semester.

The user study process followed Moran's (2019) recommendations and consisted of three elements: the facilitator (the researcher), tasks, and the participant (the teacher). The researcher began by asking the teacher to perform specific tasks on the website and observed and gathered feedback as they proceeded. The researcher created real-world, authentic scenarios to guide the teacher through different sections of the website, each designed with at least one component of the UD Principle (e.g., low physical effort). In each scenario, participants were asked to complete a task (e.g., navigate to a specific page on the website) while the researcher observed and collected feedback. All participants were asked to use a think-aloud approach (Virzi et al., 1993) to verbalize their thoughts during this process. Each participant shared their screens with the researcher as they navigated through the website and completed these tasks.

The guiding questions to ask the participants during the user study were developed based on Nielsen's (2012) quality components of web usability. Nielsen proposes five categories, including learnability, efficiency, memorability, errors, and satisfaction. For this study, the memorability category was omitted, as teachers would primarily use the website for curriculum implementation during the upcoming semester. Consequently, the guiding questions were designed to address questions in the following four categories. Learnability assesses how easily users can accomplish basic tasks on the first encounter with the design. Efficiency evaluates how quickly users can perform tasks once they have become familiar with the design. Errors are considered in terms of frequency, severity, and ease of recovery from errors made by users. Satisfaction assesses the overall user experience and pleasantness of the design.

After conducting user studies with four participants, the website was refined based on the findings, incorporating suggestions and addressing any challenges that the participants encountered. The refined website was then ready for the participants to use for implementation at the start of the fall semester. To further gather feedback from the participants at the end of the semester, open-ended semi-structured follow-up interviews (Creswell, 2014) were conducted in the spring. These interviews aimed to understand participants' perceptions of the website's accessibility and usability. The questions were designed to align with at least one component of the UD Principle and to understand better the enhanced user experience (e.g., To what extent do you think the information on the website was organized and supported your instruction?), as well as to gather general feedback (e.g., What are some areas for improvement to make the website more easily accessible?). The interviews were conducted via Zoom and audio-recorded and then transcribed for analysis.

Data Analysis

The qualitative data consisted of four user study sessions and four follow-up semi-structured interviews. Thematic analysis (Braun & Clarke, 2006) was employed across all eight datasets to identify themes reflecting the overall accessibility and usability of the website. This process involved recognizing commonalities and differences in participants' perspectives from both the user studies and interviews. A peer debriefing process was used to gather feedback on the analysis and interpretation of the generated themes. The lead researcher initially proposed the themes, while the second researcher provided feedback to reach a consensus on the analysis. Throughout the analysis, the researchers ensured the validity of the emerging themes (Merriam, 1995).

Website Design Cycle

A user-centered design (UCD) cycle (Gladden, 2018; Lowdermilk, 2013) was adapted as the groundwork to form the basis for this study and to address the research questions. The UCD cycle includes the following phases: (1) Understand the Context; (2) Specify Requirements; (3) Design; and (4) Evaluate. In the Understand the Context phase, the process began with a review of the initial website to establish a baseline for areas in need of improvement and set the foundation to apply the seven UD principles in the redesign. Next, in the Specify Requirements phase, the seven UD principles were used to outline the specific requirements necessary to address accessibility and user needs on the website more effectively. In the Design phase, the website was redesigned to support more intuitive and equitable use to address the diverse needs of users. The Evaluate phase involved an individual user study with the teachers who explored the redesigned website by performing a series of tasks. To tailor the UCD cycle unique to this study, findings gathered from the Evaluate phase informed iterations leading to website refinement, and follow-up interviews were conducted with the teachers as part of the follow-up iterative cycle, serving as Phase 5, Redesign and Follow-up. Figure 1 is a visual representation of the UCD cycle, presenting each phase of this study.

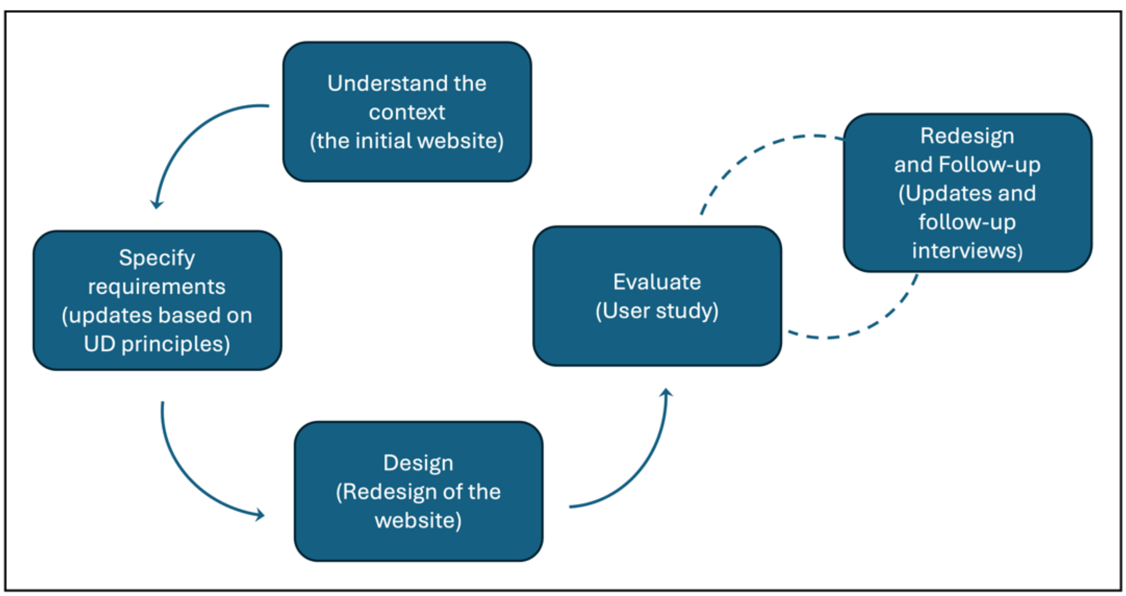

Figure 1. User-centered design cycle for the study

FINDINGS

The first part presents the refinements and iterations made during the phases of the UCD cycle, illustrating how the website design and accompanying teacher resources align with the UD principles. Subsequent parts identify key themes and design recommendations that emerged from the user study, highlighting the modifications made as a result of the study.

PHASE 1: UNDERSTAND THE CONTEXT

A comprehensive review of the initial website identified several areas that require enhancements. The review revealed that the main page lacked an organized structure and was predominantly text-based, which hindered user navigation. While the lesson pages generally presented clear instructions and content descriptions, related documents listed in the lesson materials section, including teacher materials (e.g., PDF documents, videos) and student worksheets, failed to address the diverse needs of users and lacked support for audio and visual learners (Figure 2). Furthermore, the website lacked alternate text, which also limited accessibility for users with diverse abilities. The text-heavy content throughout the lesson page required excessive scrolling, further impacting usability (Figure 3).

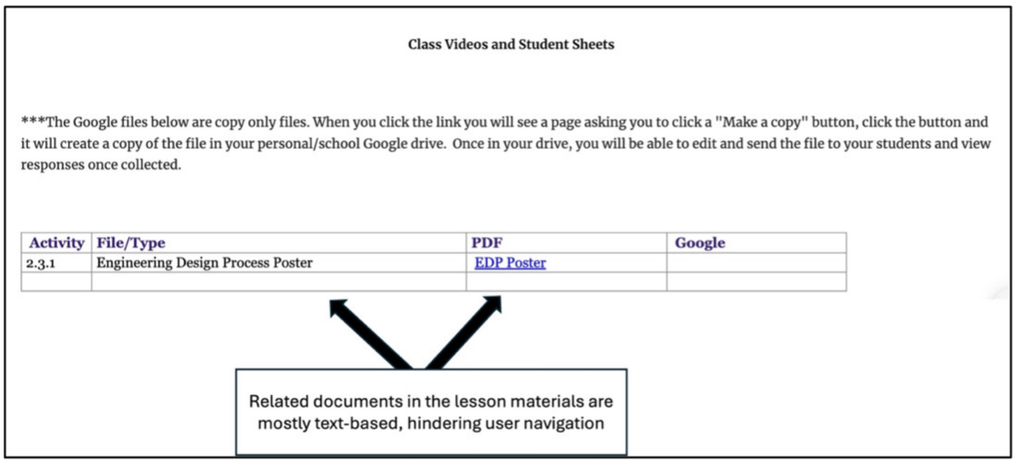

Figure 2. Example of lesson materials section

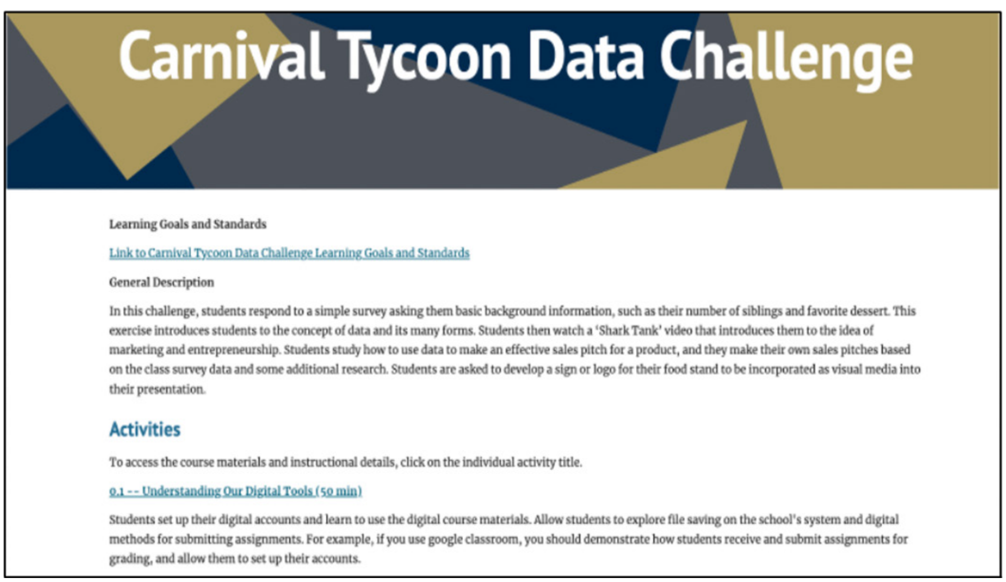

Figure 3. Example of the lesson page

Phase 2: Specify Requirements

During this phase, the UD principles and their descriptions were reviewed based on the areas identified for refinement from the initial website. Table 3 lists the UD principles and the major design features of the website that were updated.

Table 3. Principles of universal design mapped to website design features

Principles	Website design features
Equitable use	• Interface design: Navigation, resource categorization
Flexibility in use	• Video captions available, user-controlled playback speed
Simple and intuitive use	• Organization of resources and support materials • Clarification of instruction
Perceptible information	• Accessible documents, including alternate text for images and figures • Use of descriptive text link
Tolerance of error	• Consistent layouts, clear labels, logically organized content
Low physical effort	• Promote minimal scrolling • Multiple ways to access the pages • Update to horizontal menu bar
Appropriate size and space for approach and use	• Provide easily accessible content • Responsive design to adapt to different screen sizes, including desktops, tablets, smartphones

Phase 3: Design

The redesign considered the design and structure of the platform, as well as accessibility to supplemental curricula resources, to ensure the technical and cognitive aspects of teachers utilizing the platform for implementing lessons. Specifically, the design and structure were refined, adhering to the following UD principles, including equitable use, simple and intuitive use, low physical effort, and size and space for approach for use. Supplemental teacher resources were enhanced by adhering to the descriptions of the UD principles, including flexibility in use and perceptible information.

Equitable use

For users to access the curriculum for any grade level, the initial website had a menu bar with links to the different curriculum pages (i.e., 6th grade, 7th grade, 8th grade), along with a paragraph-long description of the overview of the curriculum, and a list of course materials that were also accessible on the main page. To better streamline information and enable more convenient navigation, the website's landing page was redesigned to include a direct link to the curricula, which then leads to the specific curriculum pages (i.e., 6th, 7th, or 8th grade). Moreover, the initial overview description was paraphrased to include text and video, updating the description with a brief introduction and an overview video, and enabling users to use either text or audio options.

Figure 4 is an example of the updated landing page and the STEM-ID Overview video with accompanying text. These updates were made to offer an easier way to directly access the curriculum as well as create a balance between accessing the resources using text and audio.

Figure 4. Example of a landing page with curriculum overview

Simple and intuitive use

The content on the website, including video resources and lesson descriptions, was restructured to condense the information for convenience and clearer instruction. To streamline the different resources across the website, just-in-time instructional lesson videos to support teachers' understanding of the curriculum were developed. These videos were placed on the video resources page and categorized into either "Tech Talks," videos related to technology manufacturing, or "Teaching Tips," videos related to teaching and implementation. Moreover, each lesson video was linked to the related lesson activity to help scaffold teachers in making connections. The purpose of consolidating and structuring the video resources was to reduce clutter and support teachers in easily using the website based on their needs. Figure 5 presents an example of the video resources page.

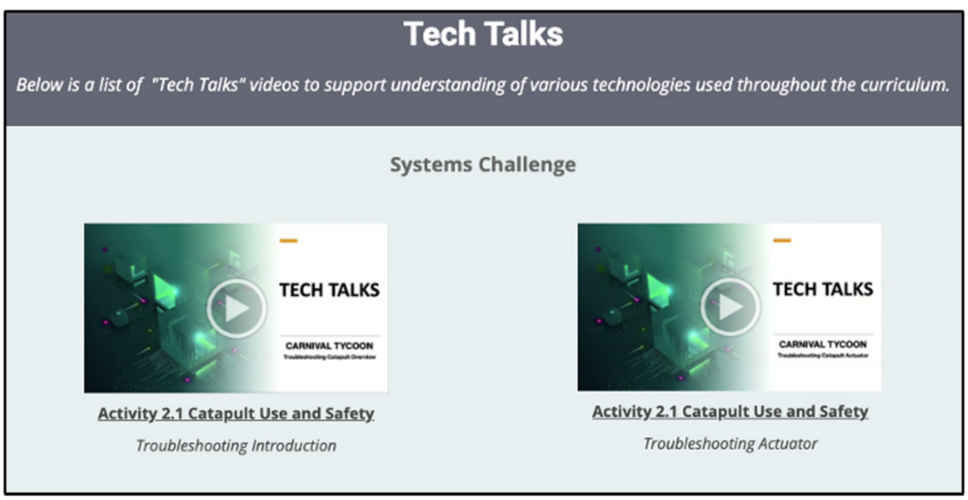

Figure 5. Example of a video resources page

Additionally, the lesson activity pages, which included extensive text and descriptions of the curriculum, were primarily updated for simple use and to help teachers understand and prepare for activity implementation. The text descriptions were recategorized into the following sections, including Activity Description and Getting Started. The Activity Description section was added to provide an overview of the activities students will take part in, followed by a Getting Started section that describes an engaging question the teachers can use, along with a list of necessary preparations. Figure 6 shows an example of the lesson activity page.

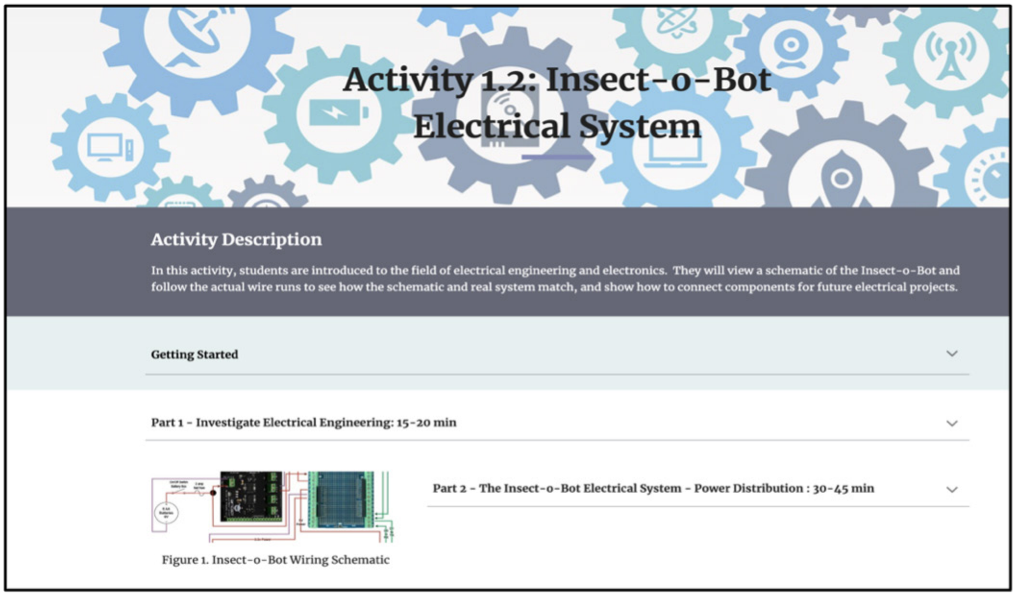

Figure 6. Example of a lesson page

Tolerance of error

A logical design employing consistent layouts throughout the website was adopted. The curriculum introduction and lesson activity pages were consistent in terms of video type, text description, layout, and color scheme. Consistency enabled users to become familiar with the interface, reducing confusion and facilitating seamless navigation. Additionally, the revision focused on the organization of content within the various lessons by incorporating a collapsible tab.

Low physical effort

The menu bar was redesigned to a horizontal layout to minimize physical effort. All lesson activity pages were also reorganized with a collapsed text function, with the different sections divided into distinct subsections (e.g., Part 1, Part 2, Part 3). The website's design was optimized to provide multiple access points to lesson pages, with a clickable tab with direct links to the lesson activity pages, complementing the existing menu bar access. This enhancement offers users an alternative navigation option. Figure 7 is an example of the challenge introduction page.

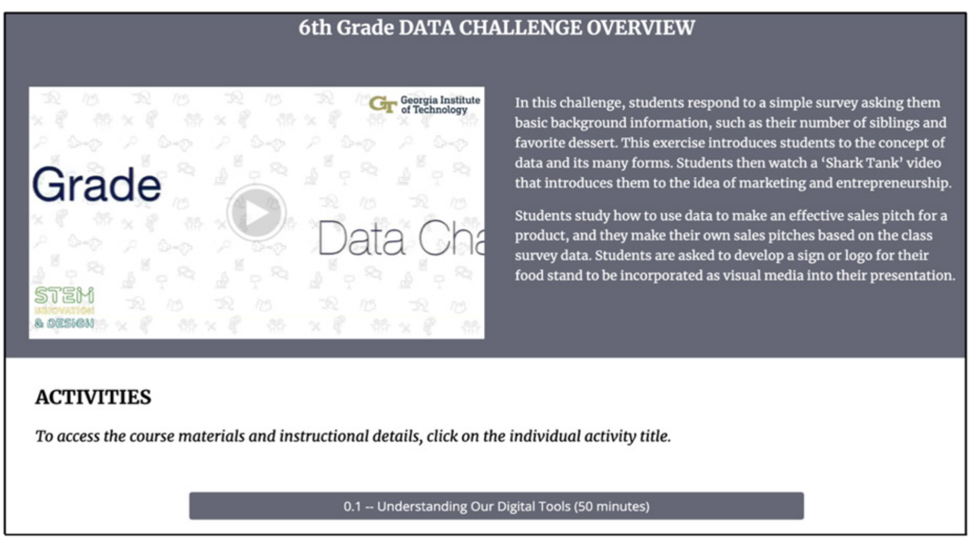

Figure 7. Example of the challenge introduction page

Appropriate size and space for approach and use

The website underwent a review to ensure consistent layout throughout the pages, with ample space between the elements. To support multiple ways of navigating the website, navigation via operating the different menus using a keyboard was also included. The redesign also emphasized responsive design, ensuring seamless adaptation of the website to various screen sizes and orientations, whether accessed from desktops, tablets, or smartphones.

Flexibility in use

The revised website's supplemental teacher resources included just-in-time video learning resources to aid teachers with implementation. All videos were updated to incorporate video captions, allowing users who need assistance to follow along with the audio through readable text. The videos also allow users to control media playback. This offers flexibility and accommodates diverse user preferences, allowing users to engage with the videos at their own pace.

Perceptible information

The website includes images throughout the lesson pages that can be presented during implementation to guide student learning. Alternate text on images and figures was included to convey the visual content for those in need of assistance through descriptive text. A descriptive text link (e.g., "Who Are You? Worksheet) was also added in the placement of phrases such as "click here" to clearly indicate the purpose of each hyperlink. This was done to help users understand the relevance of the links. Moreover, at the bottom of the lesson activity page, classroom materials, including PDF documents and related links for implementation and student worksheets pertaining to each lesson, were also made available. Although both PDF and Google files were available as text links on the initial website, updates were made so users could see a visual preview of the files. This update was made to provide users with both text and visual options in accessing the materials. Figure 8 presents an example of the updated classroom materials section.

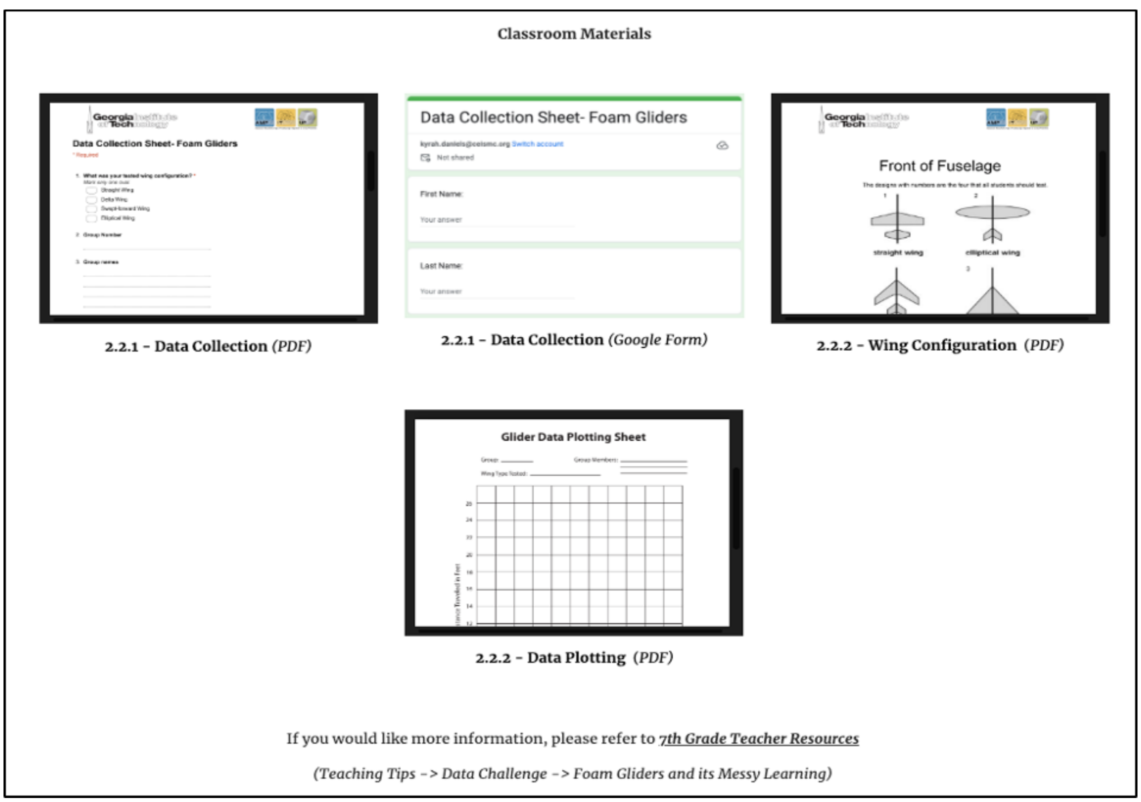

Figure 8. Example of classroom materials section

Phase 4: Evaluate

To evaluate the updated website, the teachers explored the redesigned website. They shared their preferences as users of the website, as well as issues in the design during the user study, thus uncovering areas for improved user experience. In this section, we discuss related findings of the user study that address teachers' experiences of the website features, such as the interface, overall design, structure of the website, and access to course materials, including lesson descriptions, learning materials, and resources, to ensure they are user-friendly and accessible (Swann, 2023). Teacher quotes are labeled using pseudonym identifiers (T1-T4) to ensure anonymity.

Teachers shared positive feedback centered on the improved layout and organization, which facilitated easier navigation and lesson planning. Teachers found the lesson's introductory page intuitive and user-friendly. T1 commented that the "lesson introductory page is straightforward, and the lesson unit, videos, and lesson activities are obvious." The study also revealed that teachers preferred simplicity in the website's layout, interactivity, and reduced text. For instance:

> The navigation, how it is easier to find things. If I want to go to sixth grade, I know how to get to sixth grade, and then once I am there, it splits it up into the challenges. It gives you a preview of how many days it is supposed to take, just how organized it is so much easier to use that the organization, I guess, is the short answer. (T2)

Teachers also appreciated the organization and structure of the lesson pages, which follow a consistent format that helps avoid confusion when navigating and finding pages on the website. Consistency supports effective lesson planning by providing a predictable format that reduces the cognitive load on teachers (Ertmer & Ottenbreit-Leftwich, 2010):

> I like that it is like a quick snapshot. It has the introductory video and the opening page for each challenge. That is what I like the most about the website. They all look the same. So when I go to seventh grade, I have the same thing. If I click on my seventh-grade page, I have my introductory video and my four challenges, so I know where I am supposed to take my students. I can see in a quick snapshot how long that is supposed to take. That is important for lesson planning for teachers. (T3)

In addition, the lesson activity page, which details the lesson introduction, the time needed for each activity, and preparation steps, was valued as it helped teachers with planning. In particular, teachers shared that the Getting Started section on the lesson page is very helpful, as it lists the introduction and preparation that is needed for the lesson activity. T2 noted, "I am that teacher that needs to see it as a step; what am I doing first? What am I doing second? What am I doing next? And so forth for the students, for me to prepare for my students." This teacher had seen the previous website and taught the curriculum the year before and went on to share the differences between the previous and the updated website to explain, "I was skipping over things because of the way that things were laid out. So, I really do like the layout. When I open each one of these, everything is clear. I can just read through it and prepare for my kids."

Categorization of different instructional videos throughout the website was easy for teachers to look through, and T2 added to the feedback that the videos are also helpful for implementation, sharing that it is a "great addition and also a mini-lesson to help understand the content."

Themes for Design Recommendations and Modifications

During the user study, teachers encountered challenges in utilizing the website, which contributed to the refinement process. The challenges the teachers encountered on the website are discussed below and categorized based on the themes, including navigating within the website and utilization of learning resources.

Navigating within the website

Menu bar. All teachers encountered difficulties and expressed confusion with the horizontal menu bar, which, due to the design scheme, cut the page titles short. The menu bar was placed at the top right of the page, making it challenging for teachers to identify. When asked to navigate to specific pages from the main page, they faced issues locating the dropdown menu. Teachers found it difficult to navigate and use the dropdown menu at the top.

Lesson page layout. With the collapsible text features on the lesson activity page, T1 and T4 were unaware that they could expand each section for additional description. In contrast, T4 did not notice the section until later in the exploration. T4 also perceived the Getting Started section as a header to the sections below (i.e., Part 1, Part 2, etc.) rather than as a separate section.

Utilization of learning resources

Accessing hyperlinks. Although the hyperlinks were updated as descriptive text links (e.g., "Who Are You?" Worksheet), these links were bolded but not underlined throughout the website. As a result, the teachers did not click on the hyperlinks because they were not aware they were clickable and required them to hover over them to learn that they led to a separate link. Teachers expressed frustration, as T2 stated, "I do not know that these are active links." T4 also noted that hovering over to detect links could be challenging, depending on the user's technical comfort level.

Easy access to curriculum materials. Teachers appreciated the extensive number of worksheets organized according to each lesson activity. However, they expressed difficulty in locating the necessary worksheets due to the large number of lesson activity pages and associated materials. Three out of four teachers (T2, T3, and T4) expressed a desire for a central location on the website where all the curriculum materials could be accessed and easily made available in lesson planning. T3 indicated that it would be helpful if everything were "just one giant file" and there was a place where "all the activities are culminated, all of the resources."

Streamline the video resources page. While reviewing the Video Resources page, three teachers revealed that the videos looked similar and required much scrolling.:

> Because sixth, seventh, and eighth grade [videos] are all on the same page, sometimes scrolling and navigating can be challenging. You might miss a topic because it is not immediately clear. There is nothing wrong with it. It is easy to use. You can see them, but you really have to pay attention to make sure you are accessing the right video, if that makes sense. (T3)

T4 also expressed the importance of providing a "big-ticket item" with a page listing the preparation for each grade level when navigating this page.

Phase 5: Redesign and Follow-Up

Based on the feedback, several modifications were made to address any difficulties or confusion that may hinder the teacher's use of the website. The design scheme was updated to address the concerns, and additional pages were created to increase access to different resources available on the website. Table 4 is an overview of the design decisions made in response to the teachers' recommendations.

Table 4. Teachers' design recommendations and decisions

Themes	Navigation functions	Design recommendations	Design decisions
Navigating within the website	Menu bar	Update the dropdown menu bar to make the titles for all the pages fully visible	Selected a different design scheme that is vertical to display the full title
	Lesson page layout	Distinguish the collapsible sections	Added sectional color schemes to distinguish the sections

Themes	Navigation functions	Design recommendations	Design decisions
Utilization of learning resources	Accessing hyperlinks	Make hyperlinks visible	Enhanced visibility of the hyperlinks to appear as bold, underlined text
	Access to curriculum materials	Make all files accessible at once	Created a .zip file containing all classroom materials for each grade level and added a search bar
	Streamline the video resources page	Minimize the number of videos on a single page	Created a *Course Preparation* page to collectively gather videos and support materials to help teachers prepare for implementation

After the website was updated for the second time, according to the design decisions outlined in Table 4, follow-up interviews were conducted with the teachers after they had utilized the website during the fall semester. During this interview, teachers shared their perceptions of accessibility. Findings revealed that teachers generally found the website's design, organization, and navigation to be user-friendly and well-structured, although some expressed mixed feelings about the level of organization. All teachers appreciated that the website was "easier to navigate." T2 found it straightforward to "navigate through different grade levels and lessons," and T1 and T3 liked the Course Preparation Files page for making it "easy to just navigate right there instead of digging through the lessons" to prepare for the lessons. The overall sentiment was positive, with T2 specifically mentioning that the website's design was especially useful for new teachers, as "everything is just right there" under clear headers, making it simple to find essential materials and resources.

In terms of the organization of the various pages, while all the teachers perceived that the website was well-organized, T3 further shared that the thorough breakdown of the different pages and the high degree of organization may be "kind of counterproductive" and cause confusion, as some users might struggle to follow the navigation path, due to the detailed structure. Consequently, the teacher suggested finding a way to "compartmentalize" the pages in some way. Nonetheless, the other three teachers appreciated the flow of the pages. Teachers shared that once users become familiar with the website, they can simply "figure out which buttons to select to get to where I needed, where this one is located." The navigation may become "very easy," allowing them to move step-by-step through the units smoothly.

In addition to the design and navigation of the website, T2 and T3 particularly shared their experiences with the website's accessibility. These teachers shared an appreciation for the multiple ways to navigate directly to the curriculum from the main landing page, as well as the flexibility of accessing different pages. This is particularly evident when using the prominent button to access the curriculum, the dropdown menu on the left, or further dropdowns that separate the curriculum by grade level. They also valued the additional, multifaceted approach that was complemented by features like the search bar, which would come in handy when they didn't have the "time to figure out where the information was." They also noted that the presentation of information had improved, making it more accessible. Specifically, learning resources were now more visible, such as the visual previews of the resources found under Classroom Materials. They noted an improvement in the new design that supports visibility and organization of the lesson activities, as one teacher mentioned that it "made it easier to find things on the website."

DISCUSSION

The evaluation and follow-up phases of the redesigned website have yielded a diverse range of outcomes, both positive and areas for improvement. These insights reveal that applying established UD principles to websites can tangibly resolve challenges highlighted by K-12 teachers in using online resources and respond to usability, as it underlines the value of evidence-based, user-centered website improvements.

Drawing on teachers' perceptions and experiences with the redesigned website, this discussion explores how it provided guidance for design refinements. It highlights how thoughtful attention to usability and accessibility not only addresses the barriers discussed in the literature but also enhances the overall teacher experience and instructional effectiveness. Lessons learned and recommendations for future improvements are also discussed.

User feedback from the user study was predominantly positive, with recurring themes indicating the success of the redesigned website in addressing the key challenges identified during the initial review. Teachers particularly valued and acknowledged the benefits of the new design, including its clarity and organization, which facilitated enhanced navigation and lesson preparation. These design themes served as guiding principles throughout the refinement process. Notably, the findings emphasize that redesign in line with the UD principles fostered greater satisfaction and engagement among teacher users, as they specifically highlighted the following aspects as particularly advantageous.

First, the revamped layout and structure provided simplified access to materials. The redesign made it easier for teachers to access classroom materials, including student worksheets and PDF documents. Teachers found the new visual previews of resources particularly helpful, as they enabled them to see what materials they would be using without having to download multiple files. Additionally, the creation of a .zip file containing all the materials for each grade level addressed teachers' requests for a centralized location to access everything they needed for lesson planning. This modification aligns with the UD principles of equitable use, simple and intuitive use, and low physical effort, thereby corroborating the value of UD principles and the ISO usability standards (ISO) in practical education settings. These principles are complementary and reinforce each other to create an experience that prioritizes accessibility, usability, and comfort, benefiting all users in diverse ways.

Moreover, teachers discovered the redesigned layout to be more intuitive, with a clearer and streamlined design that facilitated the rapid retrieval of the curriculum materials they required. A significant achievement of the redesign was the enhanced structure of the lesson pages, which now adhered to a consistent and predictable format across grade levels. Teachers acknowledged that this consistency facilitated their navigation between grade levels and lesson plans, thereby reducing the cognitive load associated with navigating the website. As one teacher remarked, the structure enabled them to "gain a concise overview" of the lesson, which is paramount for efficient lesson planning (Burgstahler, 2009).

Second, the redesigned website helped reduce cognitive load. A notable improvement in the redesigned website was its diminished reliance on dense text. Teachers commended the simplicity of the new design, which minimized clutter and facilitated their access to crucial information without the need to scroll through lengthy paragraphs of text. The distinct division of lesson pages into sections such as "Activity Description" and "Getting Started" effectively fragments the information into manageable units. This enhanced teachers' comprehension of the prerequisites for each lesson, highlighting the importance of presenting information in a manner that reduces cognitive overload to enhance the user experience (Kirschner, 2002; Sweller, 2020), and validating Nielsen's usability heuristics (1994), which emphasize clarity, minimalism, and visibility. Furthermore, this also aligns with the UD Principle of appropriate size and space for approach and use, ensuring that the website is usable.

Last, the support for flexibility and customization through the integration of multimodal learning resources (Knight et al., 2019) was deemed helpful. Teachers valued the inclusion of video resources in conjunction with textual materials. The incorporation of video captions, user-controlled playback speeds, and the categorization of videos into "Tech Talks" and "Teaching Tips" accommodated diverse learning preferences, thereby enhancing curriculum flexibility. The videos, characterized as "mini-lessons," provided valuable contextual information for lesson planning and facilitated teachers' deep comprehension of the material. Additionally, teachers appreciated the autonomy afforded by controlling the pace of video viewing, enabling them to tailor their engagement with the content according to their preferences. As a result of these changes, the website was not only simple and intuitive but also aligned with the principle of flexibility in use (Jewitt, 2012; Khlaisang, 2017).

Lessons Learned and Recommendations for a Digital Curriculum Repository

To provide adequate user experiences and make the digital, web-based curriculum resources and repositories adaptable to a wide range of users, prioritizing accessibility and usability, followed by using a framework to create an inclusive and accessible digital experience, has been found to be an effective measure. This approach allowed teachers to navigate and engage with the platform seamlessly, reduced barriers to access, and supported flexible engagement with the content.

Based on the user study's findings, it is essential that websites are developed in alignment with UD principles, which serve as the foundation for ensuring accessibility, usability, and clarity for all users. Building on this foundation, the following recommendations can guide curriculum designers in creating inclusive and effective web-based resources. These include clarifying collapsible sections, enhancing hyperlink visibility, centralizing resource access, and streamlining the organization of video resources.

1. *Clarify collapsible sections:* To address the ambiguity surrounding collapsible sections, one suggestion is to implement additional, prominent visual cues or interactive tutorials that elucidate their functionality. Implementing visual distinctions, such as color coding or icons, can also facilitate user comprehension of their purpose more effectively.
2. *Enhance hyperlink visibility:* To enhance hyperlink recognition, it is essential to ensure that all clickable links are bolded, underlined, or displayed as buttons. This change would offer clear visual signals to users, indicating the interactivity of these link elements.
3. *Centralize resource access:* A single location where all curriculum materials can be easily accessed is preferred by users. One possible solution is to create a dedicated "Resource Hub" where teachers can find all necessary files in one repository. This would reduce the need to navigate through multiple lesson pages. Furthermore, adding a search bar that allows users to filter by resource type or lesson activity would enhance the overall user experience.
4. *Optimize video resources organization:* The video resources page could be improved by categorizing videos by each grade level or according to content type. This reorganization would minimize clutter and help teachers find the specific resources needed for each lesson.

Limitations

As two of the four teachers had used the initial website in the past, they may have been aware of certain lesson details and website components, such as the curriculum structure and descriptions, which could have affected their performance during the user study. Additionally, there is a limitation in the representativeness of users due to the limited number of participants. Future reports documenting website experiences should strive to include more participants to capture broader perspectives of users regarding design, as well as their perceptions and experiences. Furthermore, the website was developed using a Google Sites template for its design, which accommodates classrooms that have access to and utilize Google. While this approach facilitated the conversion of PDF documents into

Google Docs and Forms and supported varying forms of materials to address different user preferences, some UD principles and guidelines may have been inadvertently overlooked due to the constraints of using a Google Sites template.

CONCLUSION

An existing website used by middle school engineering teachers was redesigned to better accommodate diverse learning needs and teaching contexts, with the goal of supporting effective curriculum implementation. This study examined the extent to which the redesigned website and learning resources aligned with the seven UD principles, how teachers perceived the site's accessibility and usability, and how their feedback informed the iterative refinement process.

The study provided valuable insights into the user experience of teachers navigating the website's features. The feedback from the user study highlighted several strengths of the redesigned website, including an improved layout and organization that made navigation easier and facilitated lesson planning, as well as the intuitive and consistent structure of lesson pages. Several areas for refinement were also identified, including challenges associated with navigating the website, a lack of visibility for curriculum materials, and a need to streamline video resources, which led to the redesign. Follow-up interviews after the redesign revealed that teachers found the website to be user-friendly and appreciated the clear structure and improvements in accessibility. Despite some mixed feelings about the level of organization, the overall sentiment was positive and suggested that the updates were particularly beneficial for new users.

The study emphasized the importance of considering various factors to make products adaptable to a wide range of users. The design process, guided by UD principles and strengthened by teacher feedback, improved the overall functionality and user experience. These findings addressed usability guidelines to ensure an easy-to-navigate interface. The revisions demonstrated a responsive approach to user needs, resulting in a more accessible and effective platform for curriculum delivery. The revised website aids middle school engineering teachers in lesson planning and implementation by simplifying access to instructional materials and enhancing user interaction. While the website's redesign has made significant strides in improving the user experience, ongoing refinements based on teacher feedback will be essential to optimize its functionality and accessibility further.

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