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Online Sharing Platform for Course Modules: Understanding Materials Use and Effectiveness

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Dr. Haolin Zhu earned her BEng in Engineering Mechanics from Shanghai Jiao Tong University and her Ph.D. in Theoretical and Applied Mechanics from Cornell University, with a focus on computational solid mechanics. Dr. Zhu is a Senior Lecturer of the freshman engineering education team in the Ira A. Fulton Schools of Engineering at Arizona State University (ASU) and the recipient of the Fulton Outstanding Lecturer Award. In this role, she focuses on designing the curriculum and teaching in the freshman engineering program and the mechanical engineering program. She is also the Assistant Director of the NAE Grand Challenges Scholars Program (GCSP) at ASU and works closely with the Director to ensure the success of the program. Dr. Zhu is also involved in the ASU ProMod project, the Engineering Projects in Community Service program, the Engineering Futures program, the Global Freshman Academy/Earned Admission Program, and the ASU Kern Project. She was a part of the team that designed a largely team and activity based online Introduction to Engineering course. She has also co-developed two unique MOOCs, Introduction to Engineering and Perspectives on Grand Challenges for Engineering for the Global Freshman Academy/ASU Earned Admission Program. Her Ph.D. research focuses on multi-scale multiphase modeling and numerical analysis of coupled large viscoelastic deformation and fluid transport in swelling porous materials, but she is currently interested in various topics in the field of engineering education, such as innovative teaching pedagogies for increased retention and student motivation; innovations in non-traditional delivery methods, incorporation of the Entrepreneurial Mindset in the engineering curriculum and its impact.

Amy Trowbridge, Arizona State University

Amy Trowbridge is a Senior Lecturer in the Ira A. Fulton Schools of Engineering at Arizona State University and is the Director of the National Academy of Engineering (NAE) Grand Challenges Scholars Program (GCSP) at ASU. Through the GCSP, Amy aims to prepare students to become globally and socially aware engineers who will lead future efforts to solve the world's biggest challenges. Amy also helps new schools to develop GCSPs as part of the GCSP Network New Programs committee. She is also actively involved in the Kern Entrepreneurial Engineering Network (KEEN), focused on students' development of entrepreneurial mindset through GCSP and curriculum. Amy received the 2019 KEEN Rising Star award for her efforts in encouraging students to develop an entrepreneurial mindset. Amy has contributed to the development of a new hands-on multidisciplinary introduction to engineering course, a unique introduction to engineering MOOC, and another MOOC focused on exploring global challenges from an interdisciplinary perspective. She is interested in curricular and co-curricular experiences that broaden students' perspectives and enhance student learning, and values students' use of Digital Portfolios to reflect on and showcase their accomplishments. Amy earned her Master's degree in Biomedical Engineering from Arizona State University (ASU), and is currently pursuing her PhD in Engineering Education Systems and Design.

Mr. Keirien Taylor, Arizona State University, UOEEE

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Building on existing research, I use advanced statistical analyses and research methods to answer questions regarding parenting, family relations, disabilities, and other topics. I also use these skills to evaluate the effectiveness of programs. I use R and other statistical software for my analyses and reports. I am continually expanding my skill set in statistics and data science to best answer research questions.

Leaders in science, policy, and business committed to evidenced-based decision-making embrace the refrain, "Data or it didn't happen." I have adopted this refrain as a guiding principle in my life and work.

I use data to make sound decisions and draw conclusions that do not extrapolate beyond the data. When hard data are not available, I wait to make a decision, when possible, or critically evaluate what is known before making a decision.

My extensive training and experience have focused on obtaining and analyzing data. As a firm believer that days of statistical analyses cannot make-up for a missed hour of project design, I value the design process of generating good data. Indeed, some have suggested a revised refrain ”Good data or it didn’t happen.” Good data are data that answer the right question. Part of the design process involves updating measures and methods to answer the question and, in many cases, revising the question to address what we really want to know.

I have invested and continue to invest significant time and effort into developing quantitative and qualitative analytic skills. I do this because it allows me to select the methods that best answer a research question. It also allows me to balance methodological rigor and practical constraints, but still obtain the most correct answer possible. My approach to data analysis is (paraphrasing Einstein) that data analysis should be as simple as possible, but not simpler.

Online Sharing Platform for Course Modules: Understanding Materials Use and Effectiveness

Abstract

This paper describes the use and effectiveness of open access online course modules shared with faculty and administrators from multiple institutions on an online platform. These course materials are centered around the National Academy of Engineering's (NAE) Grand Challenges for Engineering. Collectively, these modules aim to initiate first-year students' development of an interdisciplinary systems perspective of global challenges related to the themes of sustainability, health, security, and joy of living. A platform was developed and launched in Spring 2020 to share these course modules with faculty and administrators at institutions in and outside of the NAE Grand Challenges Scholars Program (GCSP) network. As of February 2021, these materials have been accessed by 91 users (i.e., faculty, administrators, etc.) from institutions and organizations across the world.

Two survey instruments were administered to registered users of the online platform to understand the motivations behind users' interest in and use of the modules, how they are using and/or planning to use the modules, how the materials impacted the users' courses and students, and the effectiveness of these modules and the online sharing platform. Follow up interviews were conducted with 5 users to better understand their challenges and successes in using the course modules, and the usability of the platform. Results from surveys and interviews indicate that a variety of users were interested in using the course materials, primarily to introduce the global challenges or other concepts in their courses. Users described using videos, activities, and discussion materials to engage students in engineering courses, GCSP-related courses, and other courses, impacting a total of 2,470 students through September 2020. Overall users were satisfied with both the course modules and the online sharing platform. They felt that the materials worked well, were helpful, of high quality, well organized, accessible, and applicable to their courses. They also felt that the course modules were successful in meeting their course objectives and had positively impacted their students' learning. Users indicated that they would use the materials again in the future and recommend them to their colleagues.

Introduction

The National Academy of Engineering (NAE) Grand Challenges Scholars Program (GCSP) is an educational supplement that aims to prepare engineering graduates who possess not only technical skills but also social skills and global awareness in order to tackle the challenges facing society in the 21st century [1]. Students in the program achieve the following five competencies through their engagement in individually selected courses and extracurricular experiences: Talent Competency, Multidisciplinary Competency, Viable Business/Entrepreneurship Competency,

Multicultural Competency, and Social Consciousness Competency [1]. Students' pathways through the program are largely individual, as each student is provided the flexibility to choose courses and/or experiences they are interested in to meet the requirements of their institutions' GCSP. In order to support and encourage students' retention and success in the GCSP, some institutions have developed (or have considered developing) an introductory course for their GCSP students and/or other community-focused events and activities.

At Arizona State University (ASU), a 3-credit course, Perspectives on Grand Challenges for Engineering, was developed specifically for GCSP students to take during their first year in the program [2]. The main goal of the course is to introduce students entering ASU GCSP to the global challenges and current efforts in addressing these challenges from an interdisciplinary systems perspective. The course offers opportunities for students to actively explore the relationship between technology and society from multiple perspectives and to explore global challenges related to the themes of sustainability, security, health, and joy of living. Students in the course are also asked to begin a digital portfolio to reflect on their interests, and to start identifying which courses and experiences they will pursue to achieve the competencies of the GCSP. This course fulfills the first of two requirements for the Multidisciplinary Competency at ASU GCSP, and also counts toward a general studies requirement. In 2019, a Massive Open Online Course (MOOC) version of the course was developed and initially offered through ASU Universal Learner Courses (formerly Earned Admission) in Spring 2020, using the open edX platform [3]. Through the development of the MOOC, various new course content was created, including videos, activities, and discussion prompts. Other course materials from the on-ground version of the course were also adapted for the online environment and used in the MOOC.

The development of the MOOC also presented an opportunity to create course materials about the NAE Grand Challenges for Engineering and other global challenges that could be shared broadly amongst the GCSP network and the broader engineering education community. According to Donaher, et all, as of 2017, only six institutions with approved GCSP had a similar Grand Challenges specific course [4]. With the growing expansion of GCSP both nationally and internationally, the materials developed for the MOOC may benefit other GCSP institutions as well as institutions that are preparing to establish a GCSP. In addition, the Grand Challenges have also become a popular topic in many engineering and non-engineering courses and programs, as well as K-12 education programs, because they provide relevant, meaningful, and rich real world learning experiences for students [5-21]. Making the course materials developed for the MOOC widely available may also benefit these courses and programs. Thus, as part of the authors' work with the Kern Entrepreneurial Engineering Network (KEEN) [22], an online platform was developed for the purpose of sharing these course materials in the form of course modules with GCSP and non-GCSP faculty and administrators from other institutions.

Since the target audience and intended purpose for this work is different from that of the MOOC, a separate online platform was identified for materials sharing purposes. Efforts have been made by others to create platforms for similar purposes. For example, Bhaskaran developed SimCafe, a wiki based open platform as a repository of learning modules that focus on the teaching of simulation technology [23]. Lutz, et al. created a website for organizing and sharing a collection of software engineering curriculum materials [24]. Peters, et al. developed a web-based repository of curriculum materials and best practices [25]. KEEN established Engineering Unleashed as an online community for engineering faculty and staff to share materials that are focused on promoting the entrepreneurial mindset in the form of cards [26]. While these online sharing platforms have their own strengths, some are more focused on collaborative efforts from faculty for sharing materials while others require technological expertise from both the creators and users. Canvas Learning Management System (LMS) was chosen as the online sharing platform for the purposes of this work because it is a well-developed and widely used learning management system, is easily accessible, and it allows faculty members to download and import course materials easily into their own learning management systems [27-29].

The research described in this paper aims to understand the users' interests in and use of these course modules, how these course materials have impacted the users' courses and students, and the effectiveness of these materials and the online sharing platform. The sections that follow will describe the development of the platform, introduce the research questions and methods, and discuss the results and insights gained.

Development and Description of the Online Sharing Platform

The online platform developed to facilitate sharing of the course modules was built using the Canvas LMS. The platform requires each user to have an email address for registration to access the course modules. On the landing page of the platform, a detailed description of the course modules and the learning objectives for the collection of materials (i.e. a full course built from the materials contained within the platform) are included. The learning objectives of the course modules, and the first-year introductory course on which they are based, include the following:

- Develop an interdisciplinary understanding of the global engineering Grand Challenges that human societies face in the 21st century;
- Describe the NAE Grand Challenges themes, and learn about ongoing research in all Grand Challenges theme areas;
- Identify opportunities to create added value in the Grand Challenges areas, and apply customer-focused design and an entrepreneurial mindset to conceptualize a potential future solution;
- Interpret why (and in what ways) a technology or design solution adds value from multiple perspectives (technological, sociocultural, economic, environmental, global,

etc.), and describe a design solution in terms of its societal value (as well as its technical features and function);
- Demonstrate an awareness of societal issues (e.g., sociocultural, political, economic, environmental, etc.) that influence and/or constrain engineering solutions.

On the sharing platform, the course materials are organized into modules, which are interrelated but also stand alone. This organization allows users to choose course modules and/or specific materials within the modules to use in their courses and/or programs as appropriate based on their needs. Efforts were made to organize the course modules and materials in an easily accessible and user-friendly manner. Clear instructions were also provided throughout the course modules so that minimal efforts from the users would be required to adopt, adapt, and implement the course modules and/or specific course materials into their own courses and/or programs.

When organizing the content within the Canvas LMS, efforts were made to keep the interface simple and clear to enable users to easily find and access the materials they are interested in. For example, the menu for the Canvas shell was reduced to include only two items, Modules and Discussions. The discussions section was left intact solely to allow a forum for user's questions to be answered. The Modules section includes a welcome and orientation module as well as all course content organized into the following course modules:

1. Module - Goals for engineering in the 21st century in an interdisciplinary, global context
2. Module - Developing solutions to make our lives more sustainable
3. Module - Developing solutions to make our lives healthier
4. Module - Developing solutions to make our lives more secure
5. Module - Developing solutions to make our lives more joyful
6. Module - Impact of engineering solutions
7. Module - How can you make an impact?
8. Module - Future solutions project
9. Module - Research assignment
10. Module - Professional portfolio
11. Module - Additional resources

The Welcome and Orientation module contains a description of the course modules, information on how to use the specific types of material included in the modules, a tour video, a course modules overview page that contains links to specific course modules materials, an entry survey, and a general questions discussion board.

Each of the subsequent modules is organized into subsections based on the topics discussed within that module. The course materials (i.e., videos, discussions, activities, etc.) within each subsection are included in the order in which they were originally designed to be implemented in a course, however, users can adapt the order of materials to suit the needs of their course or

program. The title of each page included in the subsections clearly indicates the type of material included (e.g., Activity, Discussion, etc.). Figure 1 below shows an example of this organization scheme for one of the course modules, “Developing solutions to make our lives more secure”.

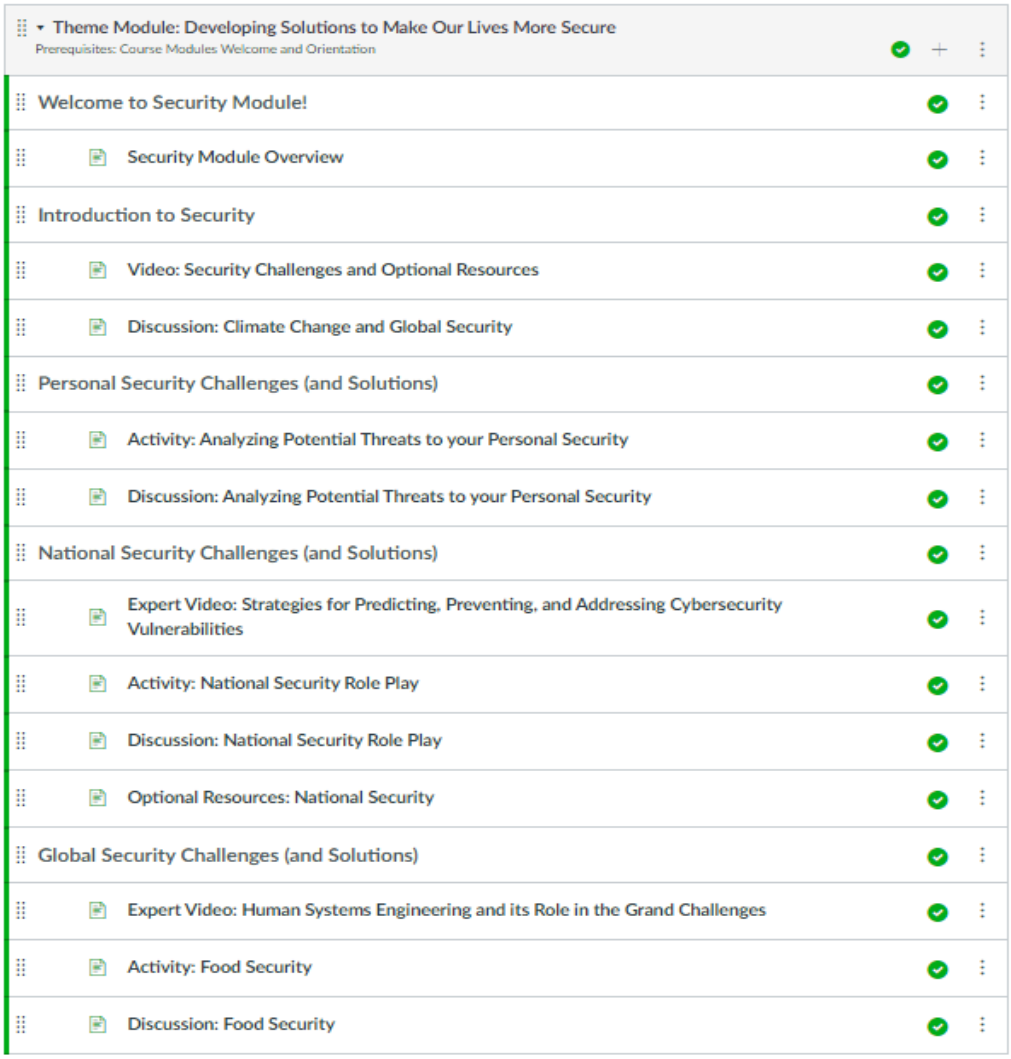

Fig. 1. Organization of the module “Developing solutions to make our lives more secure.”

An overview page that includes a description of the module, objectives, and links to specific course materials is also included for each module. Many different types of materials are included in these course modules including expert talks, instructor-led videos, application videos that feature voice-over animations and images, case studies, discussions, role play based simulations and games, design activities, mind mapping activities, a debate, a professional digital portfolio, a research assignment, and a project.

The embed code for each video is available for users to copy and paste into their own learning management system and/or course/program pages. The slides used for each video are also shared in .pptx format such that the users can edit and use them to deliver the presentation on their own

in any learning environment. On the activity/assignment/discussion pages, instructions, prompts, and/or rubrics are shared in MS Word documents so that they can be edited and adapted by the users for use in their own courses and/or programs. Multiple variations of these materials are shared on the platform such that they can be implemented in different learning modalities including synchronous online, asynchronous online, and in person. The activities included in the modules are designed to be interactive and utilize active learning and thus, digital tools are suggested to users to engage students in the activities in an online environment.

When the platform was launched in Spring 2020, the link to it was shared with potential users via multiple means, https://courses.cpe.asu.edu/browse/ira-a-fulton-schools-of-engineering/courses/interdisciplinary-perspectives-grand-challenges. As of February 2021, 91 users have registered to access the course modules including faculty, administrators, and staff from institutions and organizations across the world. Each user has accessed the course modules to a different extent and for various purposes. The team partnered with evaluators from the University Office of Evaluation and Educational Effectiveness (UOEEE) for assessment creation, data analysis, and reports.

Research Questions

The following research questions were addressed by this study:

- Who are the users accessing the course modules?
- How did the users find the course modules?
- Why are users accessing the course modules?
- Before accessing the modules, what were users' expectations of the modules?
- How are users using or planning to use these course modules?
- Are these course modules and the online sharing platform effective?
- How are these course modules impacting users' courses and students?

Methodology

Answers to the research questions were obtained by analyzing data from three sources: the introductory module survey, the follow-up survey, and the follow-up interview. Data was collected from registered users of the platform using data collection protocols approved by the Institutional Review Board at ASU. Only data provided by participants who gave informed written consent for their survey and interview responses to be used for research purposes are included. This study is based on data from 20 participants who completed the introductory module survey, 13 participants who completed the follow-up survey, and 5 participants who completed the follow-up interview and provided written consent.

Introductory Module Survey

Users of the online course modules were required to complete the first, introductory module (the Welcome and Orientation module) before accessing the other modules. At the end of the first module, users were asked to complete a survey that invited them to provide information about the organizations and institutions with which they were affiliated, whether they were affiliated with a GCSP (and their role), how they found the course modules, their purpose in accessing the course modules, and their expectations regarding the course modules. Data collection occurred between the launch of the online platform on March 6, 2020 and July 13, 2020, when data was exported and provided to the UOEEE for analysis. Responses from 20 users who gave consent to use their responses for research purposes were analyzed using thematic analysis [30] to identify patterns/themes. As part of the survey, respondents were asked if they could be contacted to provide additional evaluation of the course modules.

Follow-up Survey

In September 2020, a follow-up survey consisting of open- and close-ended questions was sent by the UOEEE to 29 users who had completed the introductory module survey and agreed to be contacted. Of the 29, 13 (44.8%) completed the survey and gave consent to use their responses for research purposes. Some of the 13 users had utilized the course modules materials in a class while others were planning to use them in the coming semester or near future. The purpose of the follow-up survey was to collect information regarding (1) users' use or planned use of the materials and (2) users' feedback on the usability and effectiveness of the materials and the online sharing platform. Responses were analyzed using thematic analysis [30] to identify patterns/themes and descriptive statistics.

Follow-up Interview

Between November 2020 and February 2021, nine users of the course modules who had completed the follow-up survey were invited to participate in a 15-minute interview. Of the 9 users invited, 5 (55.6%) completed the interview. The topics of the interview included (1) materials used from the modules, (2) how the materials had been used to meet the users' course objectives, (3) how the materials had impacted the users' students, (4) how students reacted to the materials, (5) challenges encountered while using the modules, and (6) whether the respondent intended to use the materials again. In addition, one participant who was using the modules to help in the process of creating a GCSP at their institution was asked to explain how they were using the materials for that purpose. Responses were analyzed using thematic analysis [30] to identify patterns/themes and descriptive statistics.

Results

Results are organized by research questions into four topic areas: users and their motivations, use of the course modules, effectiveness of the course materials and platform, and overall impact of the course modules on users' courses and students. The data source (i.e., introductory module survey, follow-up survey, or follow-up interview) for each result is indicated. Quotes included in this section may have been lightly edited for spelling, grammar, and clarity.

Users and Their Motivations for Accessing the Platform

Information about the users, how they found the modules, why they are accessing the modules, and how they plan to use them was collected in the introductory module survey before the users were given access to subsequent modules. The survey results show that 80.0% of users who responded to the survey (n=20) were affiliated with institutions/organizations inside the United States while 20.0% (n=4) were affiliated with institutions/organizations outside the United States. Out of the users who responded to the survey, 60.0% (n=12) were affiliated with a GCSP while 35.0% (n=7) were not affiliated with a GCSP (5.0% (n=1) did not provide enough information to determine their affiliation). Those who were affiliated with a GCSP include program directors, committee members, faculty members, and staff while those who were not affiliated with a GCSP were either faculty members preparing to start a GCSP at their institution(s) or were unrelated to GCSP. Users were asked to select from a list of options and indicate how they found the online course modules platform. The results show that 40.0% of users (n=8) found the modules via the KEEN card on EngineeringUnleashed.com and 40.0% of users found the modules via email communication from the NAE GCSP. The modules were also found via the KEEN GCSP subnet, forwarded emails/recommendations from colleagues, and an ASEE conference presentation about the modules.

As part of the introductory module survey, users were asked about their reasons for accessing the modules. Users identified eight different reasons as to why they were accessing the modules. Results show that 35.0% (n=7) of users were accessing the modules for course development (e.g., utilizing resources to develop or revise a course), 25.0% (n=5) were accessing them out of curiosity (e.g., interest in new materials), and 15.0% (n=3) accessed these modules for program development (e.g., utilizing resources for the development of a new/proposed GCSP program). Other reasons cited by users include to serve students (e.g., "*To see what it has to offer and how we might use it with our students.*"), online course applications (e.g., using materials for courses now conducted virtually), and to learn about and be prepared to administer a GCSP. A complete summary of the results and illustrative responses can be found in Table A1 in Appendix A.

In addition to asking about users' motivations for accessing the materials, the survey also asked about what materials they hoped to find. Users identified four unique expectations. The top three expectations were as follows: 63.2% (n=12) hoped to find tools to enhance their teaching and course (e.g., users hoped to find materials suited for a diverse group of students), 15.8% (n=3) hoped to find ways to enhance an online course (e.g., users hoped to find materials that enhance

the interactiveness of online courses), 10.5% (n=2) hoped to find a platform to engage with instructors (e.g., users hoped to find a community of instructors to share content and ideas). Other responses to this question about expectations indicated that users hoped to gain knowledge of the GCSP (e.g., "*Material that will help us disseminate the local GCSP-program, explain the different scales of perspective on the 4 large GC areas, and awaken the vocation of students for themes in these GC areas*") or did not have specific expectations (i.e., "*open expectations*"). A complete summary of the results and illustrative responses can be found in Table A2 in Appendix A.

The introductory module survey also asked users how they planned to use the materials before they accessed the modules. The top two ways users planned to use the materials identified were as follows: 63.2% (n=12) planned to integrate the materials into a course/program (e.g., "*To improve my research, my classes, and to be a better interdisciplinary professional.*") and 10.5% (n=2) planned to use the materials as inspiration (e.g., users sought to use the materials to foster inspiration to develop their own materials). Other intended uses of the materials included sharing the materials with others (e.g., a user would like to "*share similar resources to invigorate what we typically do face to face.*"), engaging with faculty and students (e.g., *"Engage faculty and students in the program to work on potential projects.*"), online implementation of courses (e.g., to aid in the process of establishing online courses), student recruitment (e.g., to create compelling student recruitment materials), and personal growth (e.g., to learn of new resources and concepts). A complete summary of the results along with the users written responses can be seen in Table A3 in Appendix A.

Use of the Course Materials

As part of the follow-up survey, information was collected regarding the types of courses and number of students in the courses where users had used or planned to use the materials. As shown in Table 1, as of September 29, 2020, 2,470 students had been taught using the materials and users planned to teach an additional 596 students.

Table 1. Information About the Courses in Which the Materials Were Implemented or in Which Users Planned to Implement Them

Number of courses	**Type of Course**	**How the Course was Taught**	**Range of Number of Students in the Courses**	**Total Number of Students**	**Total by Use**
Courses and students taught by six users who implemented the course materials during or prior to the Fall 2020 semester					2,470
2	A Grand Challenges Scholars Program-related course	Remote or Online	65 - 100	165	
5	Another Engineering Course	Remote or Online	25 – 1500	2305	
Courses and students taught by three users who planned to implement the course materials during the Fall 2020 semester					358
4	A Grand Challenges Scholars Program-related course	A hybrid course of in-person and remote/online	30 - 80	210	
1	A Grand Challenges Scholars Program-related course	Remote or Online	N/A	8	
1	Another Engineering Course	Remote or Online	N/A	140	
Courses and students taught by three users who planned to implement the course materials at some point <u>after</u> the Fall 2020 semester					238
1	A Grand Challenges Scholars Program-related course	A hybrid course of in-person and remote/online	N/A	30	
1	A Grand Challenges Scholars Program-related course	Remote or Online	N/A	8	
1	Another Engineering Course	Remote or Online	N/A	140	
Total number of students taught or who users planned to teach					**3,251**

More specific course information was collected from four users who had used the materials in a course during the follow-up interviews. Courses included primarily introductory engineering courses and one junior-level GCSP seminar course.

The four interviewees who had implemented course materials explained that they used the videos available on the platform in a variety of ways, such as (1) introducing/re-introducing students to the NAE Grand Challenges, the 17 United Nations Sustainable Development Goals (UN SDGs), and the NAE GCSP competencies, (2) introducing new information to students, and (3) using videos as part of activities, discussions, projects, and/or to teach students specific skills and ideas, such as how to define a problem, the values embedded in technology, and sustainability as well as the connections between those concepts. Further, a user reported utilizing the video that provides an overview of the global challenges facing society to show chemical engineering students examples of problems they can contribute to solve after graduation. Another user reported using multiple components (e.g., one user reported using about 70% of the materials) throughout their course. Finally, one user reported using the materials to recruit students to the GCSP. Additional information about materials used by the four follow-up interviewees in their courses can be found in Table A4 in Appendix A.

The fifth interviewee was selected because they had previously reported in the follow-up survey that they were using the modules to help develop a GCSP at their institution. They were asked to explain, "How are you using the materials to help you in the process of creating a GCSP at your institution?" They responded that they were using the materials to learn about the GCSP, the challenges and "*principles*." Further, they reported using the rubrics as a guide to developing assessments and other materials. In addition, they reported using the videos and assignments. In summary, they explained, "*I think [the materials] will help a lot because, […] it's very […] new information [to us] and now we are starting the program, and we are learning [... about] the structure*" of the GCSP.

Effectiveness of the Course Modules and Online Platform

Information was collected as part of the follow-up survey regarding the effectiveness of both the course modules and the online platform. Specifically, users were asked about how well the course materials worked, their quality, and the applicability of the materials to their courses, as well as the usability of the platform.

Effectiveness of the Course Modules

Follow-up survey respondents who had already implemented the materials were asked to rate (1) how well the materials worked for their courses, (2) how helpful the materials were in delivering course content, and (3) the applicability of the materials to their courses on a five-point scale ranging from 1 (*Not at all*) to 5 (*Extremely*). Users were also asked to explain their ratings. As

shown in Figure 2, nearly all users reported that the materials worked “very” or “extremely” well. The one user who gave the lowest rating of “moderately” well explained that they had “*just implemented*” the materials at the beginning of the quarter, and thus they may not be able to adequately rate the materials yet. The users who indicated that the materials worked “very” or “extremely” well highlighted that “*the videos [were] very useful in an online setting*,” the “*materials [were] excellent*” and “*outstanding*,” and that their students “*seem[ed] to enjoy the variety*.” Finally, one respondent praised the materials as they shared how they intended to use the materials: “*I had planned to include a critique of the Grand Challenges at the end of the course, and this material offered a way to bookend the experience thinking about engineering as a profession and the values inherent in it*.”

Nearly all users reported that the materials were “very” or “extremely” helpful. Only two users gave lower ratings of “slightly” or “moderately.”, one of whom (the former) indicated that they had not used many of the materials, but modified some of the activities while the latter was the same respondent who had mentioned they had just started implementation in response to the previous question. The users who indicated that the materials worked “very” or “extremely” well highlighted that “*everything [was] so well presented [...] [and] a super flexible set-up*,” the materials helped them “*make a leap with [their] students that they had bever fully been able to make before*,” and that “*explanations of the materials, how [they were] used, and modifications [were] very useful*.”

Most users reported that the materials were “very” or “extremely” applicable to the course(s) they teach. Four gave lower ratings of “moderately,” “slightly,” or “not at all.” Concerns included that the materials were focused on the United States and on first-year students. Related to the second concern, it is important to note that these materials were originally developed for use in first-year courses. Of the users who indicated that the materials worked “very” or “extremely” well, users highlighted that “*practically all the materials could be applied with small adaptations*,” that the materials are “*incredibly applicable*” to the course they are “*building [...] focused on the Grand Challenges*” and that “*all materials can be used in our classes, not only materials but ideas, structures, [and] resources*.”

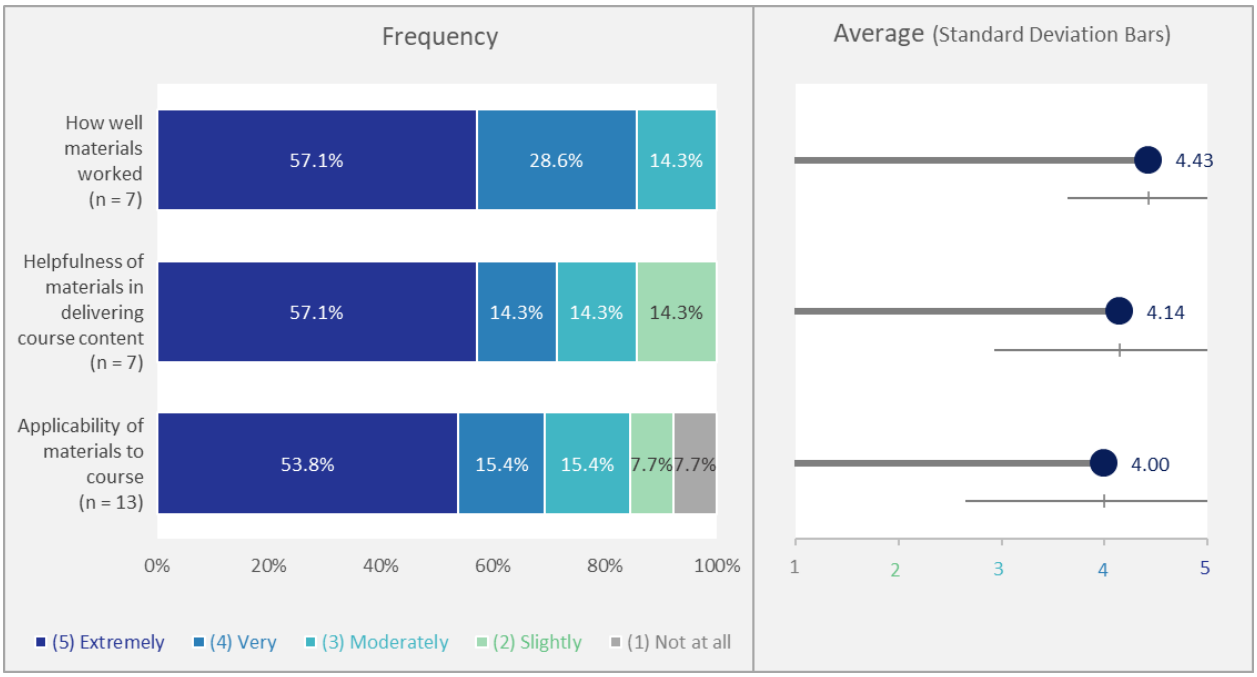

Fig. 2. User ratings of materials. *Note.* One user rated two classes on how well the material worked and the helpfulness of the material.

To understand users' perceptions of the quality of the materials, follow-up survey respondents (whether they had implemented the materials in a course or not) were asked to rate the quality of the materials on a seven-point scale ranging from 1 (*Extremely poor*) to 7 (*Exceptional*). As shown in Figure 3, all users reported that the materials are of "good," "very good," or "exceptional" quality. Users were also asked to explain their ratings. Users highlighted how the materials were "*presented concisely with several options for delivery*," were "*well-produced, well-organized, and on-point*," and "*translate[d] well to other courses*." Two users raised minor concerns with following the "*overall flow of the course*" and a desire for the PowerPoint presentations to "*have more details, like what is given in the videos*."

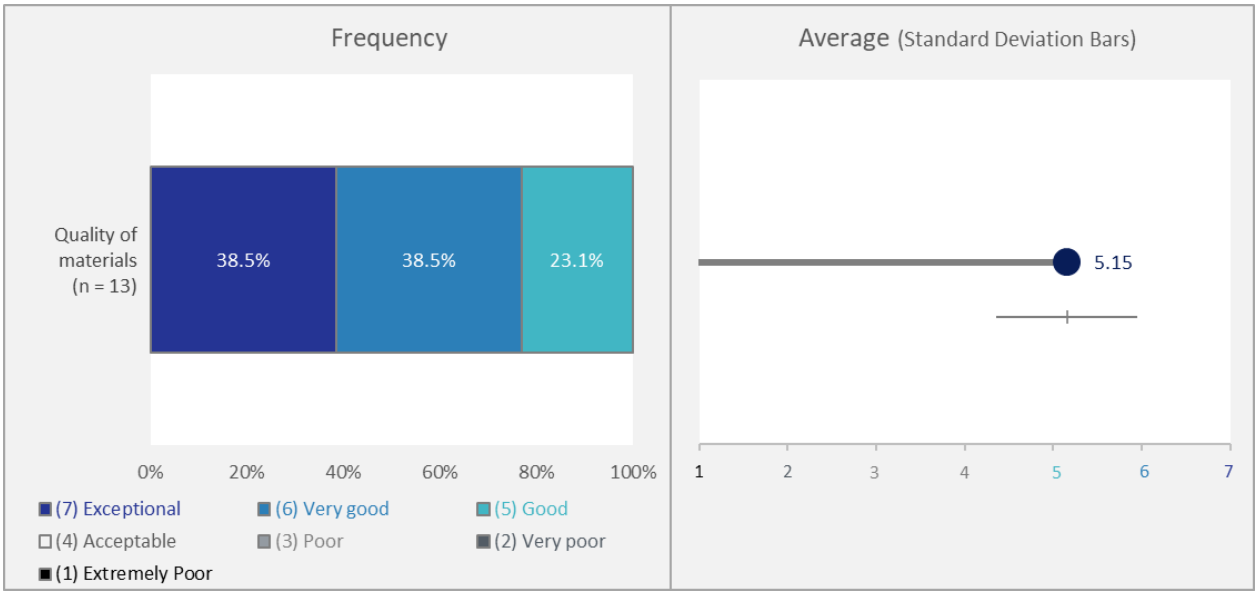

Fig. 3. User ratings of quality of the materials

The four interviewees who had used the materials in a course reported on how students reacted to the materials. Three users reported that the materials were enjoyable and helpful, particularly for reviewing videos to reexamine content they had previously missed, as needed, when working on projects. One user was unsure how students reacted but thought their reaction was possibly "*favorably*."

These interviewees identified four unique challenges that they faced while using the materials. The following challenges were identified: (1) Too much great content to choose from, (2) it was difficult and time consuming to identify which materials to use without adding excessively to the students' workload, and (3) the module materials were designed for a three-credit course, which make it challenging to use in a course with fewer credits. In addition, a user wanted to incorporate the course modules into a first-year course, but students already had a heavy workload.

These interviewees also identified multiple reasons as to why they intended to use the materials again. The reasons identified are (1) the modules are already incorporated into their course, (2) the materials are easy to incorporate, (3) "*super responsive*" support was provided to address questions, (4) they intended to use the materials in the future for additional recruitment efforts, (5) they were considering incorporating materials into a one-credit course, and (6) they want to look for additional materials to use in the future. One user reported that they were "*not sure*" if they will use the materials again as more course planning is needed for when students return for in-person courses.

Follow-up survey respondents were asked if they would recommend the course modules to colleagues and to explain why or why not. All users indicated that they would recommend these

course modules to colleagues. The reasons that these survey respondents provided include, the materials are applicable to their courses (e.g., "*I would highly recommend these modules because they are pretty easily plugged into a current course.*"), the modules are well-organized and labeled (e.g., "*I think it is well organized and divided up into topics.*"), and the materials are insightful and thought-provoking (e.g., "*I like that these modules promote a way of thinking rather than memorizing factoids regarding the Grand Challenges.*"). A complete list of their explanations is provided in Table A5 in Appendix A, organized by theme.

The follow-up interviewees were asked if they had any additional comments regarding the course modules. Respondents used the opportunity to express gratitude for the "*high-quality*" and "*very good*" materials, the creation of "*fun and engaging*" activities, and materials that facilitated and sped up the grading process. Further, one user expressed gratitude that the materials were shared and available on a platform for "*other [GCSP] directors*" to use when "*trying to create courses*." Finally, one user expressed gratitude that the materials are provided as an education resource for all students as "*more of a national project to educate the students of the future*."

Usability of the Online Sharing Platform

Follow-up survey respondents were also asked to indicate their level of agreement with four statements regarding the usability of the Canvas LMS-based sharing platform. Users responded to the statements using a five-point scale ranging from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*), and were asked to explain their responses. The first, second, and fourth statements, shown in Figure 4 below, are from a website usability evaluation measure [30].

Means and individual scores are shown in Figure 4 indicating that users highly rated the usability of the platform. Two users provided explanations; both agreed or strongly agreed with the four statements. One user stated, "*The website is well-done for the purpose*." The other user reported that "*everything went very well*" in regards to using the platform. One individual strongly disagreed with all four statements. None of their written comments provided any context for their ratings.

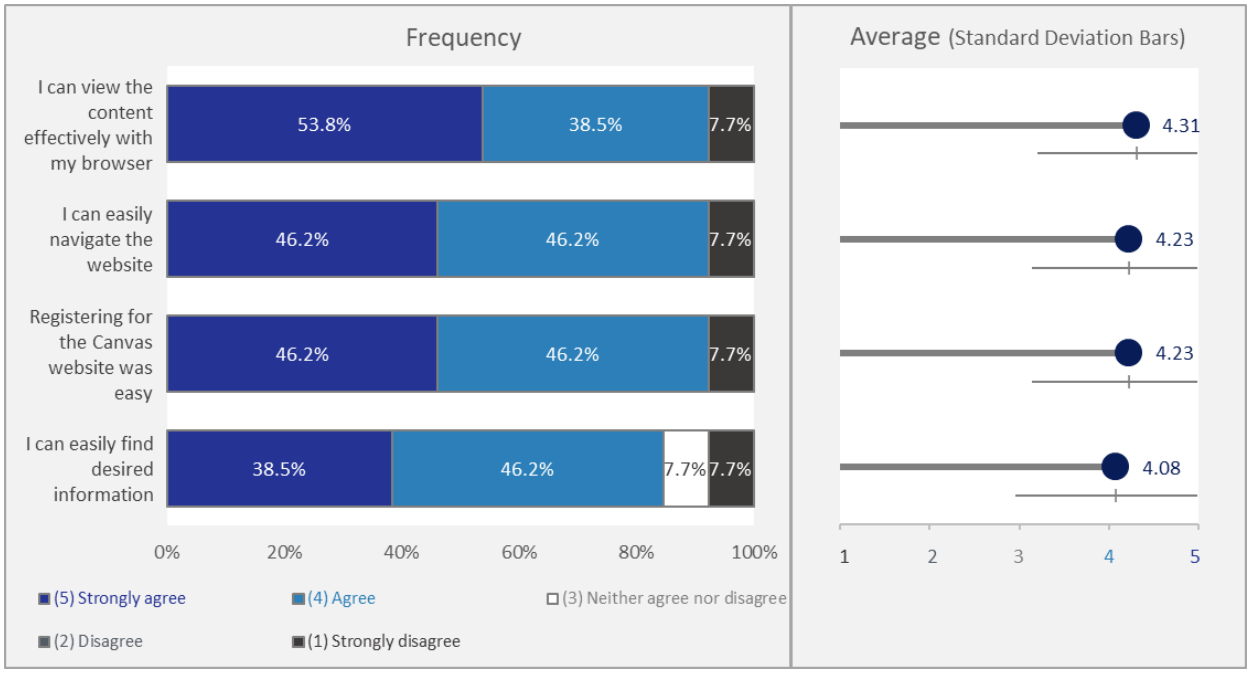

Fig. 4. User ratings of the usability of the online sharing platform (n = 13)

Impact of Online Course Modules on Users' Courses and Students

The four interview respondents who had implemented materials from the course modules in their courses were asked to explain how they used the materials to meet course learning objectives and impact student learning. Their responses were coded and are shown in Tables A6 and A7 in Appendix A. Users explained that they used the materials to introduce key concepts in effective ways (e.g., "*it helped bring about the introduction of key concepts in a way that I thought was a lot better than just me having to talk to my screen*"), introduce students to the Grand Challenges, make connections between the Grand Challenges and social sciences and humanity (e.g., "*Identifying the various social science and humanity connections to the grand challenges.*"), and develop skills such as teamwork and critical thinking skills (e.g., "*So things like that where we're thinking about and how the decisions we make as engineers can affect society, environment, life, things like that. So, I guess it helped me achieve that initial start to critical thinking.*"). Two respondents explained the impact of the materials on their students beyond the classroom. One user reported using the materials to help prepare students to receive the Grand Challenges Scholar designation by encouraging them to start early preparing their electronic portfolio. Another user reported using the materials to provide students with tools to prepare them for employment (e.g., "*I think it gave them a tool set that would help them further if they go work for a company that isn't necessarily addressing a specific grand challenge, but it's still addressing something within a theme.*"). Those who reported that the materials were effective in meeting their course learning objectives explained that this was determined based on course evaluations and feedback surveys, anecdotal evidence from students'

comments, and the fact that students were performing satisfactorily and successfully meeting key deliverable deadlines.

Discussion and Conclusion

This work aimed to assess the effectiveness of open access Online Course Modules shared via an online platform for use by faculty and others interested in curriculum related to global challenges. The platform, built in the Canvas LMS, was developed to share the course materials, focused on exploring the NAE Grand Challenges for Engineering and other global challenges from an interdisciplinary systems perspective. The course materials on the sharing platform were originally developed and used in a MOOC and/or in-person introductory GCSP course at Arizona State University. Surveys were administered to registered users of the platform to assess who is using the modules, why they are accessing the modules, how they are using (or plan to use) the modules, how the modules are impacting their courses and students, and the effectiveness of the modules and online sharing platform. Interviews were conducted with a few survey respondents to gain further insight into the use of the modules and their effectiveness.

Survey results indicate that a variety of different users are accessing the modules, primarily to consider them for use in their courses, and several have already implemented the materials or plan to implement them soon. The majority of users (80%) were from within the United States, which is not surprising as the members of the KEEN and NAE GCSP Networks through which these modules were initially advertised contain primarily United States based institutions. Notably, 35% of users were not affiliated with the GCSP, and the modules were used more often in engineering courses than in GCSP-specific courses. This provides an indication that course materials focused on discussing global challenges from an interdisciplinary viewpoint and encouraging development of an entrepreneurial mindset have broad applicability within engineering courses. The relatively large number of students who have been taught using these modules over a short period of time provides further evidence of the applicability of these materials and indicates the great potential impact these materials could have on the development of future engineers. When asked which materials they used in their courses, users mentioned using the videos most frequently to introduce the Grand Challenges, sociotechnical topics, or other concepts. Several users also mentioned the use of various activities, discussions, and project materials. Interestingly, several users described using the materials in a different order or in different ways than the ways in which they had originally been used by the authors. This finding aligns with what the authors had intended in that they had tried to organize the material in a cohesive order while showing that materials could also be used individually or as part of larger standalone modules.

Based on results from surveys and interviews, the authors were successful at reaching their goals of effectively sharing open access course modules with faculty and others via an online platform. Users stated that they liked how the materials were presented and organized, and rated the

platform highly in terms of its usability. They also appreciated that several options were provided for course material delivery (i.e. in-person, online, etc.), and felt that materials were applicable to a wide variety of courses. Perhaps most importantly, the users felt that these materials had a positive impact on students, contributing toward making learning more fun and engaging while also contributing to the development of students' skills and interdisciplinary perspectives on the topics.

Although users indicated that these course modules and the sharing platform were successful, there are opportunities for improvement and future research related to this work. One area of future work is to address the challenges users identified in using the materials. For example, one main challenge the users mentioned was identifying which materials to use without adding to students' existing workload. This challenge may be addressed by adding simplified versions of the materials that could be used in courses with a lower number of credit hours. Exploring the ways in which people adapt and use open access course modules, such as these, in their own courses could also be an area of future research. Since users also indicated their hope to engage with others via the platform, identifying ways to effectively facilitate discussions and collaboration among the users regarding their teaching and use of the modules is another area of future work. Lastly, as another next step, the success in sharing course materials developed for one course discussed in this work could be used to inspire the expansion of effective materials sharing across multiple courses by multiple faculty members within the GCSP network and the broader engineering education community.

Acknowledgement

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Appendix A. Complete Summaries of Results and User Responses

As a part of the introductory module survey, users identified eight reasons as to why they were accessing the online course modules and the results are shown in Table A1 below.

Table A1. Why Introductory Module Survey Respondents Were Accessing the Online Course Modules (n = 20)

Why Accessing Resource	***n***	**%**	**Illustrative Responses**
Course development	7	35.0%	• *"I'm in the process of developing a class that is very similar to serve as a general education course for [college] students. I am also working on familiarizing myself with how the Grand Challenges are approached at other institutions so this is something I would be looking into even if it weren't for the course I was working to create."* • *"We are developing a one-credit course over that will be offered to incoming freshman over the summer, and I am supporting that course development."* • *"We use similar modules in [courses]. I am looking for new resources and methods of delivery of this type of content."* • *"Looking to refresh a course."* • *"I am teaching a course on the Grand Challenges in Fall 2020."* • *"I've been developing global engineering competency modules at [a University] in Canvas for the last year as a portion of my role."* • *"I am accessing this resource to continue my education about GCSP to: assist my teaching of a seminar course this fall […]."*
Curiosity	5	25.0%	• *"We are curious to see what content others are using."* • *"I am interested to see if the videos can be incorporated into my online summer course."* • *"A couple of the modules (around evaluation and impact) [are] of interest."* • *"I teach an introduction to the Grand Challenges course and am interested in new ideas and materials for the course."* • *"I am curious about the platform used – we also would like to share curricular content with other educators and have been experimenting with various platforms."*

Program development	3	15.0%	• *"I run a USDE supported program to support underrepresented minorities in engineering and computer science […] where we work with students in cohorts to improve retention and graduation. Undergraduate research, peer mentoring, and tutoring are among the many HIPs that we […]. I am looking for ways to involve students in our cohorts in projects that reflect the Grand Challenges."* • *"Because I believe we will be part of the [GCSP] Program soon and we are planning the introduction steps."* • *"Met [Author] at ASEE last June where she presented how at [Institution] they seamlessly integrate GCSP and 3C's of KEEN into Freshman design and thought it was fantastic. She then said some of the material will be made available to the public for use in the spring, and here I am to check it out and see how it could be incorporated into our curriculum."*
To serve students	1	5.0%	• *"To see what it has to offer and how we might use it with our students."*
Online application	2	10.0%	• *"COVID 19."* • *"Currently developing a similar course (online) for incoming first-year students."*
To learn	1	5.0%	• *"To better understand GCSP."*
Experience	1	5.0%	• *"To be prepared to participate [in] the GCSP / NAE programs."*
Other	1	5.0%	• *"I am accessing this resource to continue my education about GCSP to […] augment a proposal to have GCSP appear on the official transcript of students, and to organize and archive this information to pass on to the next coordinator of the GCSP at [my university]."*

Note. Percentages do not add to 100.0% because some users reported multiple reasons for accessing the resource.

The introductory module survey respondents identified four unique expectations as to what materials they hope to find and the results are shown in Table A2 below.

Table A2. What Materials Introductory Module Survey Respondents Hoped to Find (n = 19)

Materials Respondents Hoped to Find	***n***	**%**	**Responses**
Tools to enhance teaching and courses	12	63.2%	• *"I hope to peer-review my plans for developing a similar course, find ideas about how others are formatting learning about and engaging with the grand challenges across an entire semester, understanding what it means to think of the grand challenges in an interdisciplinary context […] I hope to also see if and how service-learning is incorporated at a class level, and in what ways the challenges and their broader themes are discussed and divided up. Additionally, I'm interested in how the course is structured given that it will be no one individual [who] is a subject-matter expert in all of the grand challenges […] These are things I'm thinking about with my own class plans and with teaching engineering outside of their disciplinary context."* • *"New ideas that I can use in my own teaching."* • *"Some ways of thinking about evaluating and measuring student impact, not just on students but beyond the university."* • *"We are just very interested in learning from what other KEEN schools have done for similar course development."* • *"Material suited for a diverse group of first-year engineering students that incorporates EM and GCSP."* • *"Ideas, activities. I have some of my own ideas but am interested in how others are approaching this at other schools."* • *"Methods for interdisciplinary courses that engage all disciplines."* • *"The videos."* • *"Good and new content to increase my knowledge."* • *"A good organizational model and engaging activities and assignments."* • *"Classroom activities related to GCSP, resources for students in the GCSP program, and information to help take GCSP to the next level at [my university]."* • *"I am expecting to find complete resources to deeply understand the GCSP values and how to implement them at my institution."*

Ways to enhance an online course	3	15.8%	• *"Resources that will provide more interaction in an online teaching environment - we are taking our program online this summer and may do so in the fall as well."* • *"Potential project ideas for implementation (now in a virtual online environment)."* • *"I'm interested in both the structure and content of your course. I'm putting three classes on-line, all having to do with science and technology ethics."*
Platform to engage with instructors	2	10.5%	• *"We are hoping to find ideas for projects with an interdisciplinary course. We really would like to engage with the community of fellow instructors that are creating projects focused on the GC."* • *"Seeking info about online platforms for curriculum distribution to other educators (not students)."*
Knowledge of GCSP	1	5.3%	•*"Material that will help us disseminate the local GCSP-Program, explain the different scales of perspective on the 4 large GC areas, and awaken the vocation of students for themes in these GC areas."*
Nothing specific	1	5.3%	• *"Open expectations."*

In the introductory module survey, the users were asked about their intended use of the materials, before they had accessed modules beyond the introductory module. The results of the planned use of the materials are shown in Table A3.

Table A3. How Introductory Module Survey Respondents Planned to Use the Materials (*n* = 19)

How Planned to Use the Materials	***n***	**%**	**Responses**
Integrate into course/program	12	63.2%	• *"We may try to integrate some of the content or resources if it works with our current material and approach. We are not really sure what this is all about, yet, so we do not know if any of it will be applicable. We very much appreciate your work, though, and we are very thankful that you have created a forum where we can explore ideas."*

			• *"We intend to embed the GCSP program contents in all our existing activities, however, in the beginning, whether while promoting the GCSP program or during student screening, we understand this material will be a valuable aid."* • *"I hope to perhaps incorporate some of it into my introduction to the Grand Challenges course."* • *"Revise current course."* • *"Hope to incorporate them into my online course as HW assignments."* • *"To improve my research, my classes, and to be a better interdisciplinary professional."* • *"Primarily to help inform my own class creation, possibly to network with others doing similar work, definitely to inform my approach to directing the GCSP at [my university]. I also do an 'introduction to the GCSP' for our first-year engineering course, so this material will likely inform that as well. I may use it to provide examples of what others are doing related to the GCSP while discussing with administration and faculty who are less familiar with the program."* • *"I plan on reviewing the material for suitability and then adapting appropriate material for […] [a] first-year engineering course, to which I have just recently been assigned."* • *"To create the structure for my class."* • *"Initially these materials will be part of a new seminar course being taught this fall to rising juniors in the GCSP program. Secondarily, the materials will be used to prepare a proposal for the GCSP program to officially appear on student transcripts upon graduation."* • *"I am expecting to apply this knowledge in the GCSP implementation at my institution."*
Inspiration	2	10.5%	• *"Inspiration! May use some specific materials."* • *"We really just hope to gain inspiration and hopefully return the favor based on the course we develop. We plan to engage as many faculty at [our university] as we can to contribute to the course since a secondary objective is to use the course as a platform for introducing faculty (virtually) to students."*
Share	1	5.4%	• *"If possible, I would like to find ideas based on resources incorporated - possibly share similar resources to invigorate what we typically do face to face."*

Uncertain	1	5.3%	• *"Not sure yet."*
Personal growth	1	5.3%	• *"For my learning."*
Engage with faculty and students	1	5.3%	• *"Engage faculty and students in the program to work on potential projects."*
Online implementation	1	5.3%	• *"For putting three courses online."*
Recruitment	1	5.4%	• *"Not sure, but hoping for compelling student recruiting info, videos for workshops, etc."*

In the follow up interviews, four interviewees provided information about the specific materials used in their courses and the results are shown in Table A4 below.

Table A4. Information about the Materials Used by Four Follow-up Interviewees in Their Courses (n = 11)

Theme	***n***	**Illustrative Responses**
Videos were used to introduce/ reintroduce students to the Grand Challenges, the SDGs, and the competencies	4	• *"I used a couple of videos. [...] One that went over the 14 grand challenges and the 17 SDG, Sustainable Development Goals. […] Found that useful just to reintroduce to the students even though they were familiar with the 14 goals, they were not familiar with the 17 UN sustainable development goals."* • *"I think that they also had this in the [...] course was to watch the Global Challenges Facing Society in the 21st Century from the National Academy, which is like a short video."* *"The videos […] I did watch them and kind of looked through it for ideas of what to talk about."* • *"I used a couple of videos. […] And then there was another lecture[...] on the five coherencies or competencies that make up the Grand Challenge Program. And that was useful just again to clarify with the students in the class, they need to be working on these five competencies and […] how they tied into the overall Grand Challenge Program. I showed them and then we had a class discussion afterwards."*
Videos to introduce information	1	• *"Especially the videos. We like it very much the videos and we will recommend to them to start watching the videos, to know the information, to watch the explanations."*

Videos as part of activities, discussions, and projects	3	• *"The videos... except I did not use the long speaker series, if you're familiar with the various options. I didn't use really any of those, but I did use a lot of the short, anywhere from five- to 15-minute videos as well."* • *"I had them watch the NISE Network video about the speed bump and kind of the embedded values that were associated with the speed bump. And then I had them do their own activity to think about like a technology or an artifact in the world and think about the values embedded in it. And they had to write a blog from that. So that was kind of the main part of the [...] thing they used."*
Used Grand Challenges video to provide an overview of different applications of chemical engineering students could pursue after graduation	1	• *"So, my course is around the students learning what chemical engineering is and how they can utilize it after graduation. […] the grand challenges video help overlay a lot of different areas that chemical engineering students can actually go into."*
Used multiple components throughout most of the course	1	• *"I would say 70%... So, the activities, the discussions, the final project."*
Used to recruiting students to the GCSP	1	• *"I produced this short video where I introduced myself as director of the program. And I said, "I want to show you a short clip of what this program is all about." [It] was very succinct and nice. It's well done, kind of inspirational, done very well. […] Then I had my own slides on the competencies, which I added to that just to briefly explain to them because [the host institution] probably goes into a little more detail than what would be needed at that level. [Students] haven't even gotten into the program yet. They're just considering it. So, I just had a short PowerPoint slide on the five competencies, and then finished with that. […] I haven't heard from that many students. I think that's just due to the nature of the beast right now on virtual. They were just struggling to do everything virtually, let alone think of it. […] But I plan to follow up this spring with some of our first years coming on campus and so I hope to... Later in the semester, if I can get administration agreement on small socially distance groups to get them together to tell them more about the program. And then I may go back if I still have access to that course, show […] a couple of other videos."*

The follow-up survey respondents were asked if they would recommend the course modules to colleagues and to explain why or why not. Their explanations are provided in Table A5 below.

Table A5. Users' Explanations of Why They Would Recommend the Online Course Modules to Colleagues (n = 10)

Theme	Illustrative Responses
The materials in the Online Course Modules are applicable to their courses	• *"Yes, I would highly recommend these modules because they are pretty easily plugged into a current course."* • *"I definitely think the modules are good for a first-year student course."* • *"Yes, it is easily understood and applicable to many situations."*
The Online Course Modules are well-organized and labeled	• *"Yes, I think it is well organized and divided up into topics."* • *"Yes, I already have. It is a great way to pull different resources together."*
The Online Course Modules are insightful and thought-provoking	• *"I would and I have. These are a huge improvement over what I think has been the typical content in our version of the course. I like that these modules promote a way of thinking rather than memorizing factoids regarding the Grand Challenges."*
No explanation given	• *"Yes, for sure! We will recommend it to the teachers of our institution in general, the mentors of the program, and the students themselves."*

In the follow up interviews, the four interview respondents who had implemented materials from the course modules in their courses explained how they used the materials to meet course learning objectives and impact student learning. The results are shown in Tables A6 and A7 below.

Table A6. Users' Explanations of How they used the materials to meet course objectives and impact student learning (n = 4)

Theme	***n***	Illustrative Responses
Materials introduced key concepts in an effective way	2	• *"So, the material I thought was a good […] because I taught mostly online. So, it helped bring about the introduction of key concepts in a way that I thought was a lot better than just me having to talk to my screen."* • *"I think the videos helped a lot in getting the point across of an introduction to a new idea or a new concept that... Not all [students] were familiar,"*

Helped introduce students to the Grand Challenges	1	• *"It helped to expose the students to the grand challenges."*
Helped introduce students to learning about how to deconstruct complex technological challenges into smaller multidisciplinary issues, a course objective	1	• *"Deconstruct complex technological challenges into smaller multidisciplinary issues, so all the activities that were presented did that."*
Materials helped make various connections between the Grand Challenges and social sciences and humanity	1	• *"Identifying the various social science and humanity connections to the grand challenges. And obviously the resources provided through this module was more on the grand challenge themes as opposed to on the individual grand challenges, but I personally felt that was more beneficial because lots of challenges exist that may not fit into the 14 grand challenges, but many challenges exist that fit into those themes and could be discussed kind of broadly."*
Impacted students by teaching how engineering decisions affect life society, environment, life, etc. and led to a discussion among students about values embedded in technology	1	• *"Some of them specifically mentioned that activity in their final paper [i.e., how engineering decisions affect life society, environment, life, etc.], [when] I asked them basically to talk about what they had learned in the course. […] They had a discussion section where they would post their ideas about the technology that they chose. […] So, they actually started up a conversation about the values embedded in a skateboard."*
Impacted students by making learning fun and engaging	2	• *"I think they enjoyed it. I think they had fun."* • *"I thought that the exercises helped to highlight that in a fun and engaging way. […] I think that they appreciated [the materials], […] I would say [the materials opened] their eyes to caveats, to the nuances, […] that exist with Grand Challenges, the themes as well as the specific Grand Challenges. […] I thought that the exercises helped to highlight that in a fun and engaging way."*
Videos made the online course format more engaging	2	• *"So, I thought the videos due to the fact that my course went from in-person to remote the videos were a lot more [engaging]. It was a very different tool and I thought it was more engaging than me just having to sit there and discuss it myself."* • *"So, I think it has impacted [students] quite a bit because for us, we try to do a hybrid learning style where they had part of the course*

		online and part of the course in-person. So, even though the students really liked the in-person aspect of the course, I think having the online version and having it a little bit more engaging than just looking at one speaker just talking, I think the videos helped a lot"
Impacted learning objectives: The Online Course Modules provided material in multiple learning styles	1	• *"The learning through multimedia presentation modes, I felt like the modules did a great job of providing options. Right? You can do this in an online setting this way. You can use a whiteboard this way, or you can have a discussion board, that type of thing. So, I used those,"*
Impacted learning objectives: Helped teach teamworking skills	1	• *"And then, of course, teams, so I did appreciate that as well. So, a lot of the activities were designed in such a way where you could incorporate teamwork or not. So, all of those, I think, helped address the learning outcomes that we had for our class."*
Impacted learning objectives: Materials helped promote critical thinking skills	1	• *"I had a pretty strong trend of critical thinking throughout the course. So, we would be presented with some materials, maybe about a challenge or about a way to meet a competency, but then focused on critically analyzing it. So, I guess this was a good start to thinking about values embedded in technology and how that relates to what engineers do. I figured as just coming in as freshmen, they may not have a clear idea of what an engineer does after they graduate. So things like that where we're thinking about and how the decisions we make as engineers can affect society, environment, life, things like that. So, I guess it helped me achieve that initial start to critical thinking."*
Provided exemplar presentations for students to follow	1	• *"It helped those who were [un]familiar to get an example of what I was looking for in the project presentation."*

Table A7. Users' Explanations of How the Materials Impacted Students in Other Ways (n = 4)

Theme	***n***	**Illustrative Responses**
Impacted students by helping them prepare to receive the Grand Challenges Scholar designation by encouraging students to	1	• *"It probably put a little fire under them to get busy producing their electronic portfolio products, which are essays and a presentation. And so being that this is... They are going on three semesters away from graduation, they need to really start thinking about that. And one of the requirements of the course is they have to produce at least one first draft of one of their competency essays for me to pass the course. So, it was more of...Because these are juniors, they were introduced to*

start early preparing their electronic portfolio		*the program at least a year to a year and a half earlier, this is sort of reconnecting with them and getting them prepared for their final three semesters to get everything done, to be awarded of the Grand Challenge Scholar designation."*
Impacted students by providing them with tools to prepare them for employment	1	• *"So, I think it gave them a tool set that would help them further if they go work for a company that isn't necessarily addressing a specific grand challenge, but it's still addressing something within a theme."*