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Communicating Findings about Online Forum Use among Undergraduates in Distance-delivered Calculus: Developing a Help Seeking Usage Model

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Abstract

This paper reports on the synthesis of multiple user-centered design (UCD) tools to develop a model for student help seeking in STEM courses. Data used to construct the model was gathered among science, technology, engineering, and mathematics (STEM) undergraduates enrolled in distance-delivered calculus. The resultant help seeking "usage model" serves as a final project outcome of an NSF sponsored TUES Type I project entitled "Online Learning Forums for Improved Engineering Student Outcomes in Calculus."

The goal of the study was to explore the use of a web-based, asynchronous learning forum, implemented as a class-based treatment intervention, to improve student outcomes in distance-delivered (i.e., synchronous broadcast) engineering calculus courses. Using a quasi-experimental, mixed methods approach, we gathered quantitative (i.e., exam scores, affective survey responses, forum posting statistics) and qualitative (i.e., forum textual posts, student and instructor interview transcripts, and classroom observational field notes) data from science, engineering, and mathematics undergraduates enrolled in control and treatment sections of Calculus I and II. Students enrolled within treatment sections were provided access to the online forum intervention and required to post weekly for the purposes of help seeking and discussion on problem-solving assignments. Taken as a whole, the mixed dataset presented a rich picture of the help seeking processes that students used in the course.

Our approach toward analyzing data and presenting project findings in the form of a usage model related to undergraduate help seeking in distance courses was motivated by the (a) need to integrate mixed data (i.e., quantitative and qualitative data) describing student help seeking behaviors, needs, attitudes, and goals within a holistic set of easy-to-use findings and (b) desire to expand the base of knowledge related to the application of UCD tools for student-focused curricular design in STEM education. In this paper, we describe our approach for developing the project usage model. Using examples from our analysis, we show and describe the steps taken to construct the model by jointly developing and combining three specific user-centered design tools (i.e., personas, scenarios, and landing zones) using an iterative, qualitative approach.

Background and Purpose

There is a well-documented lag between the dissemination of educational research findings and the application of evidence-based instructional strategies within STEM classrooms [NRC, 1, PCAST, 2, 3-5]. Moreover, STEM education scholars attest to a growing discontent within the field related to the slow transfer of research-based innovations into education practice [6-9]. In the spirit of presenting research findings in ways that promote adoption of evidence based instructional practices by STEM education practitioners, this project employs UCD tools to analyze and present project results in an easily accessible and memorable usage model format.

The purpose of this paper is to present an approach for using student data to construct contextual student "usage models" [10] using common UCD tools. This paper expands on related work in

STEM education [9, 11] that explored the use and/or implementation of singular UCD tools (i.e., personas) for curricular design and student-focused communication among curricular stakeholders. By implementing a multi-faceted usage model that uniquely combines multiple UCD tools (i.e., personas, scenarios, and user experience landing zones), this paper presents a novel approach for communicating research findings related to STEM undergraduates' experience within a specific educational context (i.e., undergraduate in distance-delivered STEM education).

Literature Review

Usage models combine multiple sources of user data, through application of various UCD tools and techniques, to create a contextually rich model of system usage [10]. By combining UCD tools, usage models are considered more effective at communicating the connections that exist between users, products features, and product tasks within a stated context [10]. While the concept of combining UCD tools to form usage models of contextualized student experience has not, thus far, appeared in the education literature, a well-known UCD tool called *personas* has seen expanding use throughout the field of education.

Personas have been implemented within the fields of technology product design and human-computer interaction for almost twenty years [12]. Personas, or "hypothetical archetypes" [12] of product users, are most often developed from in-depth, mixed-methods research. Personas not only help to communicate the goals, values, needs, and behaviors of potential users, but also assist product designers in developing user empathy, interest, and focus during early phase/conceptual design. As evidence of their growing appeal within the field of education, personas have been developed and implemented for a variety of education-related purposes including the (1) improvement of academic library services [13-15], (2) instruction of empathy among graduate students in a professional education program [16], (3) determination of patterns of scholarly reading among successful academics [17] and (4) development of social learning analytics for distance education students engaged in course-based online discussions [18].

Application of UCD tools within STEM education. Likewise, scholars in STEM education have begun to explore the potential usefulness of UCD approaches for the design and development of curricular experiences for undergraduates in STEM fields [For a more detailed review, see 19]. Lilley, et al. [11], for example, developed and employed distance-learner personas to improve the design of learning experiences within an online undergraduate computer science program. They found that use of personas enabled curriculum designers to create more engaging and contextually appropriate experiences for their distance learners through a deeper understanding of online students pedagogical and technological needs. Turns, et al. [9] explored ways in which personas could be used to affect positive instructional change in engineering education. By synthesizing the results from several persona-focused workshops conducted with curricular stakeholders including faculty; instructors; administrators; faculty developers; and students, the authors concluded that personas were engaging tools that were effective at

Table 1

Procedural Steps Used During Usage Model Development

Procedural Step	Sub-steps	Considerations
1. **Define the usage model framework**	Define components of each data tier that will be developed to describe contextual student "usage"	• Assumes use of Simmons (2006) usage model framework
2. **Ad-hoc pre-work** **Goals:** Develop processes Pilot processes Expose Biases	Generate ad-hoc data	• Use research team's embedded knowledge and assumptions about STEM undergraduates
	Manually cluster ad-hoc data	• Cluster data into groups/subgroups of prescribed categories: needs, wants, and scenarios
	Construct persona skeletons	• Combine individual groups/subgroups (except scenarios) across categories
	Construct persona narratives	
	Develop scenarios (one for each persona)	• Use data from scenarios category
	Reflect	
3. **Construct data-driven usage model** **Goals:** 3-5 personas 3-5 scenarios 1 user experience landing zone table	Prepare the source documents	• Deidentify and label data sources with titles and page numbers; store in an easily accessible manner.
	Mine source data	• Read data and then select/copy data excerpts • Annotate each data excerpt with an identifier that links it back to its original data source (audit trail)
	Cluster source data	• Cluster data excerpts into groups/ subgroups of prescribed categories: behaviors, needs, wants, goals, and scenarios

Procedural Step	Sub-steps	Considerations
	Construct skeletons	• Combine individual groups/subgroups (except scenarios) across categories
	Construct narrative personas	
	Cross check data representation across personas	• Regroup data excerpts into categories that emerge from the excerpts themselves • Cross check persona narratives to insure emergent categories/themes are represented • Revise current (or add additional personas) as necessary
	Develop help seeking scenarios (one for each persona)	• Start with data clustered under scenario; return to the data sources as necessary to add detail and depth
	Construct user experience landing zone related to help seeking	• Combine persona, scenarios, and landing zone preferences into a combined "usage model" templates
	Develop usage model template to combine outcomes of UCD tools	
4. **Reflect on Lessons Learned**	Compare ad-hoc personas and scenarios with data-driven usage model templates	• Compare ad-hoc and data driven personas/scenario • Ask "what similarities/differences are present between the two sets of personas?" • Ask "what do these differences tell you generally about students behaviors, goals, needs, and actions?" • Ask "what is missing?"
	Revise	

stimulating student-focused communication and reflection, especially among students themselves.

Context of Study

Research Design. In this study, we employed a concurrent, embedded, mixed-methods research design [20] wherein a veteran calculus instructor taught two sequential calculus sequences (two sections each of Calculus I and II) via synchronous broadcast over a two-year period [21]. Courses were taught in the evenings to adult and working students located throughout the state. Moreover, most participants were identified as being minimally to moderately “nontraditional,” according to the criteria proposed by [22] through their demographic survey responses [23].

The first calculus sequence (i.e., the first sequential offerings of Calculus I and II) was the control sequence and the second sequence was the treatment sequence. The treatment intervention was use of a freely available, online forum (www.piazza.com) equipped with mathematical formulae typeset capability for student-student and student-instructor help seeking. Students in treatment sections were required to post a minimum of two questions or one answer to the forum for graded credit per week. There was no upper limit on how often students could post to the forum, whether to ask questions, discuss concepts, or help one another with homework assignments. Students were encouraged to help each other in the forum; the instructor posted guidance and clarification to questions/answers posted on the forum as needed.

Methods and data. Quantitative and qualitative data were gathered during each calculus course. Quantitative data included student exam scores, posting statistics and results from an online affective outcome survey (this survey included questions on demographics and nontraditional student characteristics). Qualitative data included text-based forum posts, transcripts from targeted student interviews, observational field notes from classroom visits, and course artifacts (e.g., syllabus). Participant recruitment (n=55 across four sections), data collection, handling, and analysis, and results reporting were performed according to an approved institutional review board (IRB) protocol.

Developing the Usage Model

In the following sections, we describe our approach, as depicted in Table 1, for developing a usage model for STEM undergraduate help seeking using data collected during this study.

1. Define the usage model framework. In this work, we employed a simplified version of the usage model structure proposed by [10]. The full model consists of twelve data categories arranged in three hierarchical tiers: supporting data (personas, demographics, use conditions, ethnographic data), overview (roadmap, storyboards, concept and context diagrams, user experience landing zones), and usage details (use cases, scenarios, user task flows, operational profiles). As [10] explains, all data categories are rarely included for any single model and it is up to the developers to decide which elements will be emphasized.

For this project, we considered the “product” to be the asynchronous online forum intervention and its implementation in STEM courses (i.e., curricular design) in place of product design. To develop the simplified usage model, we selected a single data category from each tier that we considered would potentially be most useful and memorable for instructors during curricular design. After careful consideration, we selected the following data categories to represent the tiers in our usage model:

Supporting data: personas (demographics, ethnographic data)

Overview data: user experience landing zone

Usage details: scenarios

Based on our previous review of the UCD literature [19], as well as our desire to create a memorable and empathic model for instructors use, we selected personas to represent the supporting data tier. Our choice was grounded in the ability of personas to generate student empathy, interest, and focus [24, 25]. We also noted that demographic (i.e., survey results) and ethnographic (i.e., observational field notes, interview transcripts, and textual posts) would, ultimately, be transformed into the personas.

Next, we selected the scenarios category within the usage details tier. Scenarios are narrative descriptions of real (i.e., represented in user data) or projected (i.e., futuristic) user activities. Scenarios assist designers in defining and developing individual product features and capabilities that meet user needs in innovative ways [26]. Scenarios were chosen based on their ability to depict contextualized details of use; we agreed that scenarios would be useful in conveying details about students' experiences with the online forum. We also noted the natural synergy between personas and scenarios: (1) scenarios help personas come alive through action [27] and (2) scenarios written around personas are considered more memorable and effective at maintaining user focus than scenarios written around unidentified users [28].

Last, we selected the user experience landing zone category within the overview data tier. Since user experience landing zones describe user preferences across a range of potential (help seeking) experiences, we concluded that the landing zone would serve as the bridge between generalized student personas (i.e., representing basic needs, wants, behaviors and goals of students) and the contextualized scenarios depicting online forum use (i.e., specific student interactions with the online forum).

2. Ad-hoc pre-work. Before we began constructing the usage model from our data, we invested time in ad-hoc pre-work. "Ad-hoc" is a term used to describe the development of UCD tools, namely personas, from personal assumptions and experiential knowledge about users—rather than from "real" data collected from or about users [29]. Even though we had already collected data about our student "users," we decided to invest in ad-hoc pre-work for the purposes of exposing our own biases and assumptions about STEM undergraduates [29], developing and then practicing our processes for constructing personas and scenarios before digging into our data [29], and creating empathy for the goals and needs of STEM students' among the research team [24, 25].

During our ad-hoc pre-work, we generally followed the Persona "Conception and Gestation" process described by [29]. We gathered together as a team—consisting of two engineering undergraduates, a graduate student in engineering education, and an engineering education faculty member with responsibility for teaching undergraduate engineering courses—during several work shopping sessions. During these sessions, we (1) generated ad-hoc “data,” (2) categorized the data using a manual, qualitative clustering process, (3) constructed persona “skeletons” by merging data categories, and (4) developed full personas by filling out the skeletons using data contained within the subcategories. Finally, to add life to our ad-hoc personas, we developed a contextualized scenario for each.

Generate ad-hoc data. To generate student data, we wrote our goal, “to construct a set of STEM undergraduate personas and scenarios that will be validated through research” on the whiteboard. We then brainstormed terms that are commonly used to differentiate between “types” of STEM undergraduates (i.e., disciplinary major, class level, gender, working/nonworking, first generation status, international/domestic, etc.). We wrote these terms on the whiteboard and used them to help stimulate our brainstorming process. Then, each member of the research team wrote down short descriptions of undergraduates we have known through our own experience in STEM education one per sticky note, along with a specific goal, action, need, or problem they might have or be engaged in. Examples are “a junior has anxiety concerning a high stakes exam,” “a working student can’t attend help sessions due to schedule,“ or “an international student has difficulty finding a study group.” At first, each member placed her sticky notes under the appropriate student category we had written on the white board.

Manually cluster ad-hoc data. When we could no longer generate new data (new sticky notes), we moved into a manual clustering process, also known as affinity diagramming, where we manually sorted our data (sticky notes) into the predetermine categories of student needs, wants, and behaviors. During this process, we manually moved our sticky notes around, creating and naming subcategories when the number of data excerpts placed under any one category approached eight to ten points [29]. Knowing ahead of time that we wanted to enhance each persona with a scenario, we separated sticky notes that (1) described detailed student activities experiences or (2) that did not fit neatly into a needs, wants, or behaviors cluster into a fourth cluster called “scenarios.” We set this data “aside” to be used in constructing detailed scenarios for each persona. The list of ad-hoc data needs, wants and behaviors categories and sub-categories is shown in Table 2.

Table 2

Ad-hoc data categories and sub-categories

Needs	**Wants**	**Behaviors**
• motivation ○ personal/internal ○ external • to balance coursework with… ○ work ○ family ○ health ○ other curricular activities	• money for… ○ car ○ scholarships • to be entertained in class • practical knowledge • prestige ○ degree/major ○ career	• in class ○ acting grouchy, stressed, annoyed ○ skipping class ○ being un/prepared ○ being distracted in class ○ sleeping in class ○ looking for time-saving

Needs	Wants	Behaviors
○ extracurricular activities • help with study skills • help with time management • help with course technology • help transitioning ○ from high school ○ internationally • money for… ○ Tuition ○ Food ○ Housing • social support • good grades (to get/stay in the program) • nonacademic help	• instructor involvement • positive (not negative) group work experience • what do I want? ○ major/degree ○ career	shortcuts • out of class ○ not/using course website ○ consulting with a TA ○ not/reading textbook ○ using online solution resources (Slader) ○ searching for example problems ○ working in study groups ○ arguing for points ○ doing fun things instead of studying ○ pursuing internships

Construct persona skeletons from ad-hoc data. Our next step was to inductively group the needs and wants clusters together to form ad-hoc persona skeletons. To do this, we wrote the ten needs and seven wants categories titles on the whiteboard and then collaboratively combined them into groups that we felt were congruous and able to represent a fictitious yet believable person (i.e., persona). When finished, each group represented the basic framework, or "skeleton," of one persona. While noticed that there was more than one way to group the clusters and readily conversed back and forth about the "best" way to do so, we ultimately converged on three ad-hoc skeletons (Table 3). We began the merging process not knowing how many skeletons we would construct; we settled on three skeletons simply based on how the data clustered together. We felt comfortable with three skeletons based on recommendations from the literature [12, 29]. We then added behaviors to each skeleton from the behavior cluster based on our assessment of the behaviors that best fit each skeleton. Last, we gave each skeleton a description to remind us of the thought processes we used to combine the needs and wants clusters as we did.

Table 3

Ad-Hoc Skeletons

Skeleton 1: Description: A young, academically gifted student who is unsure of his/her degree/career path	**Skeleton 2:** Description: A successful, driven, and performance-oriented student	**Skeleton 3:** Description: A older student who struggles yet remains intent on earning a degree
Needs: • internal motivation • personal/nonacademic help • extracurricular activities balance • high school transition help	**Needs:** • money • time management help • physical health balance	**Needs:** • help with study skills • help with technology • good grades to get/stay in the program

Wants: • to be entertained (in class) • instructor involvement • a plan for the future **Behaviors:** • distracted in class • doesn't read textbook	**Wants:** • prestige • industry experience **Behaviors:** • looks for time-saving shortcuts to problem solving • falls asleep in class due to overextended schedule	• social support • family/work balance **Wants:** • group work experience • money **Behaviors:** • works in a study group • consults the course TA

Construct persona narratives from ad-hoc data. Before starting writing persona narratives, we decided to transition from a physical data clustering process (via sticky notes) to an electronic data clustering process. While we had catalogued images of our clustered sticky note data, we needed an electronic means of clustering data when using the "real" data that was already in electronic form (i.e., interview transcripts, survey results, textual form posts). After a bit of brainstorming, we decided to transfer our ad-hoc, sticky note data into a free for educational use concept mapping software called Cmap (https://cmap.ihmc.us). By constructing a separate concept map for each data category (i.e., needs, wants, behaviors, and scenarios) in Cmap and entering each piece of sticky note data individually, we recreated the clusters we had previously made with sticky notes within the software. Once our data was input into the software, Cmap allowed us to graphically sort and categorize our data, display it in hierarchical form, and keep it easily accessible yet safely stored within our university's secure data repository. Last, once all data was transcribed and the categories were complete within the software, we sequentially labeled each subcategories within each concept map so that we could "code" important elements of the written narratives in order to trace them back to their original data source (e.g., the code N-E 3.1 stands for Needs category, subcategory E, sub-subcategory 3, data excerpt 1).

Once the data was categorized and labeled in Cmap, we started to construct the personas narratives by adding "flesh" [29] to the skeletons. We found details to add each skeleton by re-reading the data excerpts clustered under each of the needs, wants, and behaviors categories for each skeleton and then, creatively and iteratively, weaving together details into a narrative depiction of the persona. To make each persona more believable, we gave each a name, age, and gender based on our experiences and what seemed to make sense for that persona.

Develop scenarios from ad-hoc data. Once the persona narratives were developed, we read through the data excerpts under the scenarios category. By adding together data excerpts, we constructed contextualized scenarios for each persona. The scenario was added to the end of each persona narrative. An example of the ad-hoc persona/scenario developed for skeleton 1 is shown in Figure 1.

Jordan

Jordan is a 19-year-old college freshman who is starting his second semester. While he was awarded a rather generous academic scholarship, Jordan admits he didn't have to work that hard to get good grades in high school. He is not too worried about his grades since his family is able to support him, even if he lost his scholarship. Although Jordan has always been academically "gifted," the (lack of) structure of college life feels foreign to him.

Jordan got the idea to major in engineering from his uncle, a systems engineer at Bigelow aerospace, whom Jordan admires greatly [W-E 4] [W-D 2] [W-D 4] [W-D 5]. During Jordan's first semester, however, it became clear that he hasn't yet developed a strong internal drive to pursue engineering as a career. In fact, if Jordan doesn't have an impending test or quiz to generate a sense of urgency, he will spend much of his time in class on social media [N-D 1.3], only occasionally paying attention when new material is presented or when the teacher emphasizes a specific point [B-A 4][W-E 2]. He also tends to skip reading assignments if they are not graded [B-B 4][N-H 6] [N-H 9] [N-D 1.7].

Despite limited interest in his current courses, Jordan finds he performs better when he feels like the instructor cares about him and the material [N-D 1.2]. These perceptions, based on the quality of the interactions he has with his professors, are likely to determine if Jordan continues to study engineering [W-B 2]. While he gets easily distracted in class, Jordan has found that playing sports or games periodically helps him focus better [N-E 3.1]. He enjoys playing basketball with his roommates during the week and, sometimes, he indulges in long video-gaming sessions during the weekends [W-E 1][N-H 2].

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Jordan got an A- on his latest Physics test. Because of that, he decided that physics class was not an immediate priority and skipped class the next day to go play basketball with his roommates instead. While Jordan realizes that missing class will put him at a disadvantage when the next homework assignment is due, he feels like he can easily rely on a TA to bring him back up to speed when that time comes [S-11].

Figure 1. Ad-hoc persona with scenario narrative.

Reflect on ad-hoc pre-work. The goals of the ad-hoc pre-work were to (1) develop and pilot our persona/scenario development processes and to (2) reflect on our assumptions and potential biases about STEM students before constructing the data driven usage model. In reviewing our ad-hoc personas and scenarios, our obvious bias toward engineering students was evident. We agreed that two of our personas, persona 1 and persona 2, might be considered engineering stereotypes. Persona 3, we felt, represented the more nontraditional engineering student that is somewhat common at our university. In order to reflect STEM students more broadly going forward, we realized we needed to pay particular attention to the ways in which students who were pursuing STEM fields other than engineering were represented in our data.

In addition to realizing our bias toward engineering students, we noticed an emphasis on the depiction of negative classroom and/or study behaviors. This realization signaled to us that, as a research team, we needed to be more cognizant of positive aspects of student classroom and study behaviors, or at least to make more effort toward providing sufficient context around the negative students behaviors we represented. We agreed that doing so would help to ensure that our data driven personas would be less stereotypical and more empathetic. Finally, we felt our ad-hoc personas were missing critical information about STEM student motivations and long-term goals and that this lack of information made the personas less appealing, interesting, and empathetic. Therefore, we decided to emphasize these aspects more deliberately during the development of our data driven usage model.

3. Construct data-driven usage model. Once we had completed the ad-hoc pre-work, we proceeded with the development of the usage model using data gathered among STEM students in Calculus I and II.

Table 4

Data source documents.

Data Source	Description
Demographic and attitudinal survey results (QUAN)	Calculus I, Fall 2013: 14 participants (10 male, 4 female) Calculus II, Spring 2014: 11 participants (8 male, 3 female) Calculus I, Fall 2014: 19 participants (14 male, 5 female) Calculus II, Spring 2015: 11 participants (10 male, 1 female)
Exam Scores (QUAN)	Calculus I, Fall 2013: scores for 14 participants Calculus II, Spring 2014: scores for 11 participants Calculus I, Fall 2014: scores for 19 participants Calculus II, Spring 2015: scores for 11 participants
Transcribed student Interviews (QUAL)	Calculus I, Fall 2013: 3 student interviews Calculus II, Spring 2014: 1 student interview Calculus I, Fall 2014: 3 student interviews Calculus II, Spring 2015: 3 student interviews
Observational field notes (QUAL)	Calculus I, Fall 2013: 15 class periods observed Calculus II, Spring 2014: 20 class periods observed Calculus I, Fall 2014: 11 class periods observed Calculus II, Spring 2015: 16 class periods observed
Online forum posts (QUAL)	Calculus I, Fall 2014: 1115 individual posts Calculus II, Spring 2015: 593 individual posts

Prepare the source documents. All data source documents were stored electronically. Before using the data sources, we first needed to prepare them for analysis. To prepare them, one team member took on the task of de-identifying all of the data contained in the documents and then labeling each source with a title and page numbers. These steps were necessary to ensure that pieces of data extracted from the original source data were handled anonymously and yet could be easily traced back to its original source document. Once prepared, team member placed the data sources within a secured electronic repository that was accessible by all team members. The mixed data sources (quantitative and qualitative) that were used during the usage model development are described in Table 4.

Mine and cluster source data. We manually clustered data from each data source using Cmap software. First, we made individual concept maps for each of the predetermined categories established during our ad-hoc process: needs, wants, behaviors, and scenarios. This time, we added a fifth category (concept map) called “goals” in order to extract data that could define the long-term vision of each of our data-driven personas, as we felt that this facet had been lacking in our ad-hoc personas. Because we found data mining to be a time consuming process, we divvied up data sources among the team members, as suggested by [29], and then individually mined each data source for data excerpts pertaining to each of the predetermined categories. The networked nature of the Cmap software allowed us mine data as a team in a workshop environment, each member working at an individual computer and adding data to the concept maps simultaneously. We felt that this was an important feature of the software since it allowed team members to work collaboratively while mining data from different sources yet adding data to the same concept maps in real time. Once a pertinent data excerpt was identified, that piece of data was copied verbatim and pasted into the appropriate concept map. In addition, the title of the data source and the page number where the excerpt was found was annotated below the excerpt in order to create an audit trail from the source documents to the data clusters stored in the concept maps.

Table 5

Source data categories and sub-categories

Needs	**Wants**

• access to resources for help in the subject
  ○ individual resources
  ○ opportunities for work with peers
  ○ quick, responsive resources
• to overcome a lack of interest in a particular subject
  ○ required course for major
• to overcome curricular barriers to degree completion
  ○ completing prerequisites
  ○ course failures/repeats
• more programmatic course options
	• social recognition/acceptance among peers
	• support from
	  ○ expert/instructor
	  ○ peers
	• student-centered learning environment
	  ○ empathetic /involved/caring
	  ○ interesting
	  ○ learning outcome oriented
	• practical instruction
	  ○ fair assessments
	  ○ pedagogy that is oriented toward applications (not too theoretical)

Behaviors	**Goals**

• engagement behaviors
  ○ in class
  ○ out of class
• disengagement behaviors
  ○ in class
  ○ out of class
• distractions in distance education courses
  ○ social
	• to earn a degree/diploma in a field of interest
	• to advance a current/chosen career path
	• to attain financial security through a career in STEM

○ personal technology ○ educational technology • help seeking /giving behaviors ○ for personal needs ○ for/with others • changing perceptions of instruction based on experiences • openness to/skepticism for new teaching tools	

Once all of the source documents had been mined for excerpts, we worked as team to review the data posted under each category (concept map), moving data excerpts between categories as necessary and/or copying data excerpts that seemed to fit in more than one category. We then examined each individual category, creating and naming sub-categories and sub-subcategories as needed. The list of first and second level sub-categories developed from the source data is shown in Table 5.

Table 6

Data-driven skeletons

Skeleton 1	**Skeleton 2**	**Skeleton 3**
Goal: To earn a degree in a field of interest	**Goal:** To gain financial security through a career in STEM	**Goal:** To advance a career in a chosen/current field
<u>Needs:</u> • to overcome a lack of interest in a required subject • socially oriented resources **<u>Wants:</u>** • interesting instruction • peer driven support • group interaction/social recognition **<u>Behaviors:</u>** • disengaged in class • engaged out of class • distracted by personal electronics in class • help giver (social) • skeptical of new teaching tools	**<u>Needs:</u>** • more programmatic course options • individually accessible resources **<u>Wants:</u>** • empathetic instruction • expert support • practical assessment **<u>Behaviors:</u>** • engaged in class • affected by social distractions in class • help seeker (personal/social) • open to new teaching tools	**<u>Needs:</u>** • to overcome curricular requirements/barriers • timely resources **<u>Wants:</u>** • learning outcome-oriented instruction • practical pedagogy oriented toward application **<u>Behaviors:</u>** • engaged/disengaged in class • distracted by distance educational technology • help seeker (personal) • open/skeptical of new teaching tools

Construct skeletons from source data. Once the source data had been mined and clustered, we developed skeletons using the same inductive process used to create the ad-hoc skeletons. Once again, our data resulted in three skeletons. This time, the number of skeletons was clearly dictated by the number of goal subcategories (i.e., three) that we identified in the data. Had we identified additional goal subcategories, we can surmise that we may have ended up with additional skeletons. Still, in this case three skeletons seemed to capture most of the data subcategories we had developed. The resultant data-driven skeletons are shown in Table 6.

Construct persona narratives. As was done with the ad-hoc skeleton, we found details to add flesh to each skeleton by re-reading the data excerpts clustered under each of the needs, wants, and behaviors categories for each skeleton and then, creatively and iteratively, weaving together details into a narrative depiction of the persona. This time, we consulted demographic data in adding names, ages, and genders to the personas. For example, approximately two thirds of the participants were male and three persona narratives were constructed. Consequently, two of the three narratives were given a male gender. An example of the data-driven persona narrative developed for skeleton 1 is shown in Figure 2.

Once we had developed narratives for each skeleton, we decided take of all the data from the goals, needs, wants, and behaviors categories and clustered them thematically. Two researchers did this process independently. After each researcher clustered the data according to emerging themes, we met together and crosschecked our results, making a list of the themes we found. We then went back through our narratives to see if the themes were present. In the end, we felt that the themes were well represented by the narrative and that we did not need to construct a fourth persona.

Taylor

Taylor is 21 years old. Although he delayed college for two years after graduating from high school, he is now a full-time student living in an off-campus apartment with some friends. While Taylor earns money to pay for most of his school expenses through part-time jobs and scholarships, his parents help out by paying for his food and incidentals.

During middle school, Taylor began telling people that he wanted to become an electrical engineer based on his early interest in computers and programming. After taking an introductory circuit class [G-A:2] last semester, however, Taylor switched his intended major from electrical to engineering to computer science [B-E:1] which Taylor feels best suits his overall interests, academic strengths, and long-term goals.

Taylor is now in his second year of engineering study and is completing his required humanities and fundamental engineering science courses. Currently, Taylor expresses limited genuine interest [N-D:1] in most of these courses and hopes that his studies get more applied as he moves further along in the program. Taylor finds that his motivation for attending class is difficult to maintain. While he blames his lack of motivation on his courses, Taylor also admits that his passion for video gaming often gets in the way of attending classes, too. Admittedly, Taylor finds it difficult to manage his time when he allows himself to game as much as he likes. [W-C:2.1]. To help with time management and to have a more flexible course schedule overall, Taylor has started taking distance education class offerings when they are available.

While Taylor enjoys the flexibility that distance education courses provide him, he is somewhat frustrated by them, too. Taylor prefers working with classmates in person instead of over the phone, via email, or even using online discussion boards that may be available in distance education courses. [B-G:1.1] [N-A:1.1]. Taylor prefers seeing and speaking directly with his classmates and finds it difficult to learn and communicate using only text-based messages. Taylor would be more open to collaborating with classmates virtually by using video chat tools, such as Skype or Face Time [W-A:2.4].

In his math and science courses, Taylor relies heavily on working with in-person study groups to complete homework assignments and prepare for exams [W-A:2.1]. Taylor feels he learns best when working in these groups, since it often happens that one classmate is able to walk the rest of the group through particularly difficult problems [N-A:1.3]. Taylor appreciates the time and frustration he saves himself by working in groups.

In addition to working in groups, Taylor also enjoys socializing with his engineering classmates. His social image is important to him and he takes great care of his looks and wears trendy, fashionable clothing [W-B:1]. When he has difficulty engaging during class, he often turns to his phone—especially social media —before attempting to refocus on the class[B-D:2.2]. Although Taylor is often late to class, he is comfortable missing parts of his lessons [B-A:1.1] because he feels he can always talk to one of his friends to find out what he missed.

While Taylor's behavior has come across as indifference to some of his instructors in the past, Taylor is a bright student who actually enjoys solving problems and puzzles [B-B:2.5]. He has a "lateral" way of thinking which allows him to rapidly apply newly acquired knowledge to seemingly unrelated fields [B-B:2.6]. In high school, Taylor was able to get by doing only a fraction of the studying that other students did for the same results. Taylor, however, is more involved in his studies out of class than he is in class. He enjoys working with and helping classmates whenever he has the opportunity [B-F:2.1]. Taylor finds that explaining concepts and problems solving to others helps to reinforce his understanding of the material, and thinks he learns more working with others than by simply listening to the instructor [B-F:2.2].

Figure 2. Data-driven persona narrative. (Footnotes are used to link to data sources not included during initial data mining and clustering exercises and/or to document reasonings for details presented.

Develop data-driven scenarios. Once the persona narratives were developed, we read through the data excerpts under the scenarios category. Early on, we had decided that the scenarios would be contextualized around student help seeking and, in particular, their use of the online forum since exploring the use of the online forum was the underlying purpose of the study. Using excerpts identified in the scenarios category, we returned to the data to help round out descriptions of distinct situations and preferences that involved participant use of the online forum. By combining the data excerpts with new insights gained by returning to the data, we constructed a contextualized scenario about online forum help seeking for each persona narrative. An example of the scenario developed for skeleton 1 is shown in Figure 3.

> Taylor perked up in class when his calculus instructor announced they'd be using an online forum for question and answer support. "Does it have video chat?" Taylor asked, thinking that making text-based posts would become very tedious over a long semester. At first, Taylor posted quick questions, just to get the points for the assignment. He also posted anonymously, so no one would think that he didn't understand something. Over time, Taylor starting to post more often and even "in the open" when he could confidently answer a question posted by another student. He liked to track how many times his answers were liked by classmates or, better yet, endorsed by the instructor. To improve his "stats", Taylor started trying to improve the answers he gave. As time went on, he noticed that the better his answers were, the more his stats improved and the more confidant he became with the material.

Figure 3. Data-driven scenario.

Construct a student (user) experience landing zone related to help seeking. Within the field of UCD, a user experience landing zone is a table that describes acceptable regions of user experience (i.e., minimum, target, outstanding product performance) for each form of product usage (i.e., way in which a single product can be used) in a manageable, easy to read format. According to Simmons [10], "Landing zones are a general tool; other landing zones for a system might contain quantified quality requirements, financial goals, system features, or other similar data. However, all landing zones have [this] similar [tabular] structure."

We extended the idea of a user experience landing zone to undergraduate experience during help seeking by constructing a "student experience landing zone" based on participants' behaviors (i.e., from online forum posts) and preferences (i.e., from interviews) related to help seeking (Figure 4). In considering the various help seeking behaviors and preferences depicted in our data, we discerned five overarching characteristics or *dimensions* that we deemed were important for describing how participants in this study sought help. The help seeking dimensions we identified include response time, (use of) interactive resources, (use of) static resources, nature of help request, and the interaction style.

By mapping the varied behaviors/preferences that were exhibited by participants onto each help-seeking dimension, we constructed a table that defines the range of participant help seeking behaviors/preferences across all help seeking dimensions. We called this table our student help-seeking landing zone since each of the participants in our study "landed" somewhere on the table for each help seeking dimension. The difference between our landing zone and other UCD landing zones is that the behaviors/preferences documented within each dimension of our

Dimensions of Help Seeking	**Student Behaviors/ Preferences**					
Response time	**1 Week**	**48h**	**24h** [S-E:4] [W-A:1.5]	**12h** [S-E:1]	**1h<** [S-E:2]	**Real Time** [W-A:2.4] [B-F:2.5]
Interactive Resources (human resources)	**Others:** Seeking help from family members, other professors, or friends. [N-A:3.3]	**General tutors:** Seeking help from tutors not affiliated with a specific course. [B-F:1.1] [B-F:1.3]	**Other students:** Seeking help from students who are not currently in the class.	**Course Peers:** Seeking help from students in the class. [B-F:2.1-2.2]	**Course TA/Tutors:** Seeking help from an appointed class TA/tutor. [W-A:1.1]	**Course Instructor:** Seeking help directly from the class instructor. [W-A:1.4] [W-A:1.1]
Static Resources (non-interactive)	**Solution manuals:** Seeking help from a publisher's or instructor's solution manual (usually accessed online). [B-F:1.7]	**Solution website:** Getting Seeking help from a website that provides solution procedures. (Chegg, Slader, etc.) [B-F:1.6]	**Instructional video:** Seeking help by watching a tutorial video tutorial online (i.e., Khan Academy).	**Online content:** Seeking help from content material provided on websites (i.e., Wikipedia).	**Course material:** Seeking help by reviewing materials provided in a course. [B-B:2.2] [B-A:2.3]	**Course Textbook:** Seeking help by learning the concepts from the textbook. [N-A:3.1]
Nature of Request	**Administrative:** The student has questions related to the conduct of the course and not the content material (i.e., schedule, assessment, etc.)	**Answer check:** The student has an answer that she wants to check for correctness. [B-F:2.4]	**Solution debug:** The student has a solution and wants to go through the steps to find mistakes. [B-F:2.4]	**Missing concept:** The student "gets stuck" because she is missing a step tied to a concept. [N-A:1.3]	**Not knowing how to begin:** The student cannot start a problem due to a limited conceptual understanding. [N-E:3]	**"What if":** After completing the assignment, the student reflects on the deeper meaning of the problem solution or answer. [B-B:2.6]
Interaction Style	**Public online (anon):** Posting a question on a public online forum. [S-B:1]	**Course-based, online (anon/non-anon):** Using a course based online discussion tool to ask questions to classmates/TAs/tutors or instructors about. [B-F:2.4] [B-H:1.1] [B-H:3.1]	**Individual, online (non-anon):** Using email, chat, text, or instant message to ask a question to a TA/tutor, Instructor, or peer. [W-A:2.3] [B-F:1.8]	**Individual, face-to-face (non-anon):** Meeting in person with a tutor/TA or instructor to get help. [W-A:1.1]	**Group based, face-to-face (non-anon):** Getting help by gathering with classmates and/or friends for help. [N-A:1.1]	**Course based, face-to-face (non-anon):** Asking a question during class. [B-F:1.5]

Figure 4. Help seeking landing zone. Grey shading indicates instances found in data. White shading indicates ad-hoc instances.

landing zone cannot be considered acceptable to all/most students (users); rather the behaviors/preferences documented within each dimension together depict the combined set of individual behaviors/preferences (i.e., set of individual landing pads) exhibited by the participants.

While we found the landing zone useful for depicting the range of help seeking behaviors exhibited by participants, we soon realized that the discrete, discontinuous nature of most dimensions (i.e., all dimensions except response time) made it difficult to concisely depict generalized trends across dimensions. We wanted to be able to depict behavioral preferences within each help seeking dimension for each persona; the discrete nature of most dimensions made it difficult to convey the information in a compact and succinct format. To improve our ability to easily communicate information about help seeking behaviors for each persona, we took a deeper look across each dimension, searching for ways to represent (most of) the data contained within each dimension using a related dichotomous characteristic. After careful consideration, we chose to represent the data contained in each dimension on a sliding scale (i.e., spectrum) depicting the individual help seeking preference(s) represented by that dimension. The spectra of help seeking preferences that were developed to represent each help seeking dimension represented by the landing zone (Figure 4) are provided in Table 7.

Table 7

Spectra and categories of participant help seeking preferences developed from landing zone data

Help seeking Dimensions (Figure 4)	Help seeking Preference Spectra	Help seeking Preference Category
Response Time	Delayed <--> Real Time	Support Mode
Interactive Resources	Friends/Others <---------Classmates--------> Instructor	
Static Resources	Electronic <--------------------------------------> Physical	Resource Nature
Nature of Help Request	Procedural <-------------------------------------> Conceptual	
Interaction Style	Anonymous <-----------------------------------> Identified	Interaction Style
	Group <---> Individual	

Developing usage model template. In order to effectively communicate the resultant UCD-inspired model of student help seeking, it was necessary to develop a set of documents that could, on one hand, quickly communicate the information that may connect instructors with student help seeking preferences and behaviors during curricular design and, on the other hand, provide enough “audit trail” information for instructors to dig deeper if they desire.

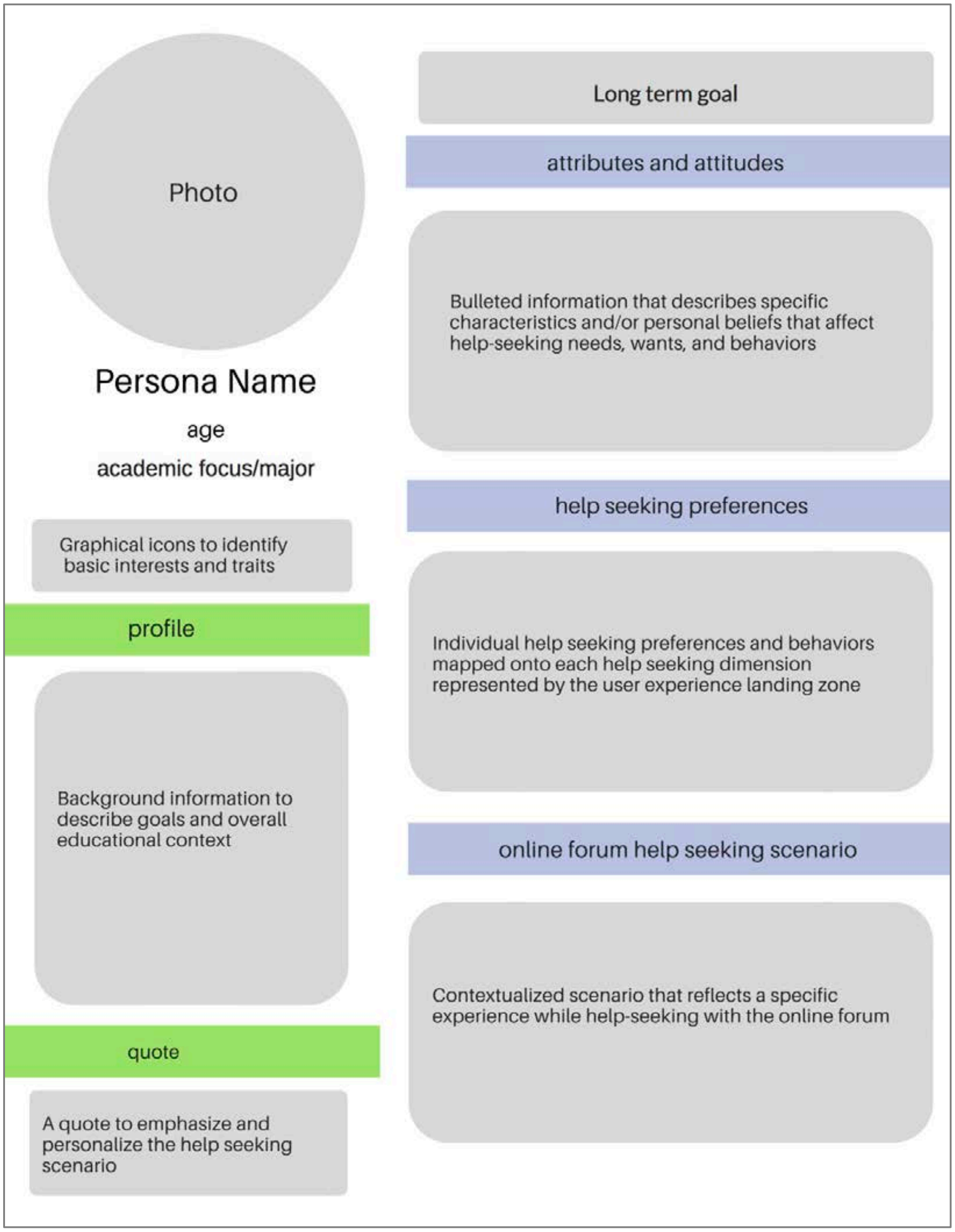

Figure 5. Template used to combine three UCD tools (i.e., personas, scenarios, and the user experience landing zone) as a usage model.

For the first purpose, we developed a usage model template within which we merged the most important information detailed in each of the three user centered design tools (i.e., personas, scenarios, and the user experience landing zone). The template was designed to synthesize essential elements of the personas, scenarios and landing zone preferences to create an easy to read and engaging informational sheet describing the characteristics of STEM student help-seekers represented by our data using free graphic design website (canva.com). The usage model template combined many of the features found in graphical or dashboard persona formats (i.e., name, photo, representative quote) [see e.g., 9, 11, 29, 30]. However, our template is unique in its attempt to combine information from multiple UCD tools to form a contextualized model of usage. The usage model template is shown in Figure 5. An example of a populated template is provided in Figure 6.

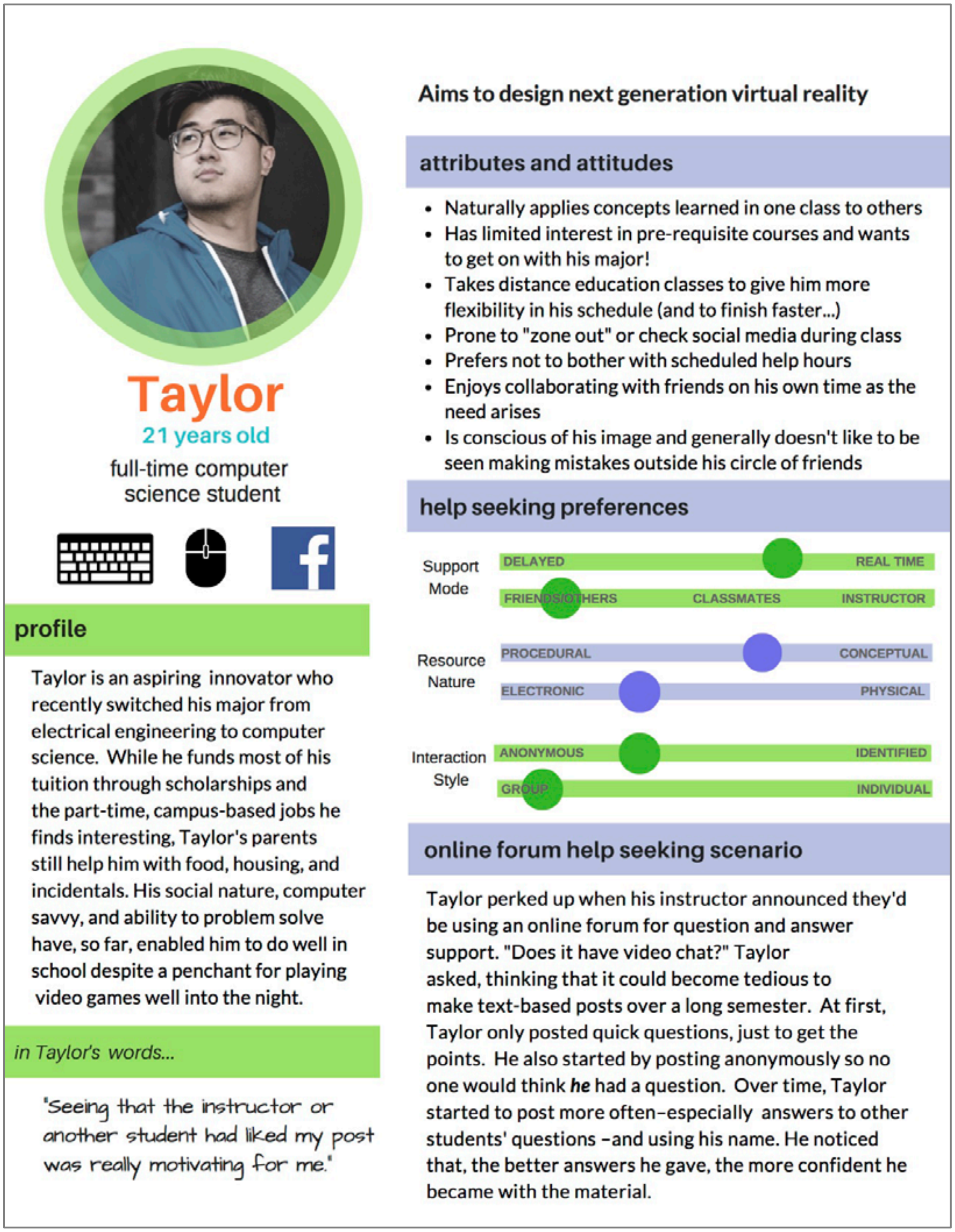

Figure 6. Populated usage model template developed to present findings related to STEM undergraduate help seeking.

To augment the templates, we collected the information contained in the individual UCD tool documents (i.e., persona narratives, scenarios, and user experience landing zone documents) and the concept map clusters to provide a package of audit trail documents that can be used to trace our usage model back to the original data. The data in the concept maps were put into a hierarchical tabular form in order to be accessible (i.e., not requiring unique software to access) and easy to read.

4. Reflect on Lessons Learned In this work we present our process for constructing an undergraduate help seeking usage models form data gathered among undergraduates students enrolled in calculus. Conclusions from this work are presented in the form of the lessons we learned as we developed our processes.

Lessons Learned

Lessons Learned During Usage Model Development
1. Going through an Ad-hoc persona development before constructing UCD tool using student data was useful for understanding the persona development process and made the data driven process go more smoothly. Moreover, by reflecting on our personal assumptions, we were able to state explicitly the changes we needed to make or considerations we needed to be aware of during the data driven process.
2. The process of physical sorting of "sticky note" or "cards" during ad-hoc development was made more efficient and secure through the use of concept mapping software. Physically sorted ad-hoc data were difficult to store for future sessions without "losing" data. Having the study data (transcripts, posts, survey results, demographics) in electronic form allowed us to cut and paste excerpts into concept mapping software and then easily move excerpts between categories, and subcategories as needed.
3. Qualitatively clustering of data takes sufficient time and is better accomplished in a workshop environment by a team than by a single individual.
4. Developing a protocol for linking each data point back to its data source is essential for documenting an audit trail back to the data.
5. Creating the skeletons (combining data across categories, groups, and subgroups to create bulleted lists that represent hypothetical users) is an open-ended and creative step. Care should be exercised during this phase to ensure that skeletons "make sense" as hypothetical users before proceeding to developing persona narratives.
6. Use of contextualized student data during analysis resulted in more multi-faceted and, thus, empathetic personas.
7. Initial development of the usage model template was time consuming and required much iteration. Once we converged on a design, however, the template allowed us to quickly add to our model by populating additional templates. In hindsight, collaboration with a graphic designer may have served to speed up the template development process.
8. Including "users "(i.e., undergraduate STEM student researchers) during the usage model development process provided the research team with an ability to perform "sanity checks" at critical junctures in the process.

Significance and Future Directions

This work adds to the growing literature base related to the application of UCD tools for curricular design in postsecondary STEM education. Moreover, this study also adds to literature focused on research-to-practice and provides an example of translating research using UCD techniques for the purpose of aiding the transfer of research evidence to practitioners. It is hoped that, through continued use UCD tools and techniques, STEM education researchers can increase the fidelity of research transfer and affect improvements in STEM instructors' capabilities to adapt to and/or apply contextualized findings within their own course settings. We suggest that a UCD approach to data analysis and research dissemination may improve the accessibility of research findings by improving visibility to and understanding of the goals, wants, needs, and behaviors of their students within stated educational contexts. Future work will gather insights about the help seeking usage model from instructors and students in order to assess its usefulness and potential for impact.

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