Developing an Instrument to Measure Online Engineering Undergraduate Students' Learning Experiences and Intentions to Persist

Ms. Eunsil Lee, Arizona State University

Eunsil Lee is a Ph.D. candidate in Engineering Education Systems and Design program at Arizona State University (ASU) in the Fulton Schools of Engineering, The Polytechnic School. She earned a B.S. and M.S. in Clothing and Textiles from Yonsei University (South Korea) with the concentration area of Nanomaterials and Biomaterials in Textiles. She began her Ph.D. study in Textile Engineering but shifted her path toward Engineering Education a year later. Her research interests currently focuses on engineering doctoral students in underserved populations such as women and international students.

Dr. Samantha Ruth Brunhaver, Arizona State University, Polytechnic campus

Samantha Brunhaver is an Assistant Professor of Engineering in the Fulton Schools of Engineering Polytechnic School. Dr. Brunhaver recently joined Arizona State after completing her M.S. and Ph.D. in Mechanical Engineering at Stanford University. She also has a B.S. in Mechanical Engineering from Northeastern University. Dr. Brunhaver's research examines the career decision-making and professional identity formation of engineering students, alumni, and practicing engineers. She also conducts studies of new engineering pedagogy that help to improve student engagement and understanding.

Dr. Jennifer M Bekki, Arizona State University

She teaches courses in the engineering and manufacturing engineering programs as well as programs in the Engineering Education Systems and Design PhD program. Her research interests include topics related to student persistence, STEM doctoral student experiences, faculty mentorship and development, modeling and analysis of complex manufacturing systems, and the development of new discrete event simulation methodologies. Bekki is the co-director of the interdisciplinary, National Science Foundation supported CareerWISE research program, which strives to: 1) understand the experiences of diverse women who are pursuing and leaving doctoral programs in science and engineering and 2) increase women's persistence in science and engineering doctoral programs through the development and dissemination of an online resilience and interpersonal communication training program.

Developing an Instrument to Measure Online Engineering Undergraduate Students' Learning Experiences and Intentions to Persist

Introduction

The availability of online courses and degree programs in higher education is steadily growing. The total number of college students pursuing fully online instruction in the U.S. now exceeds two million [1], underscoring the potential of the modality to increase access and eliminate boundaries to education in fields. Some studies additionally suggest that online courses may be of comparatively higher interest when compared to face-to-face courses among women and non-traditional students (e.g., [2-3]). Together, this research demonstrates the potential of online education to fulfill calls from industry, government, and academia to increase the number and type of students who choose to pursue engineering higher education [4], and yet, the acceptance and adoption of online learning in the field of engineering have generally been slower. Barriers include the difficulty of replicating hands-on activities in an online environment and a skepticism about the approach to properly educate engineering students properly [5-6]. Recently, there have been indicators that this trend is changing. ABET has accredited online undergraduate engineering or computer science degrees at five different U.S. institutions [7], and an increasing number of other undergraduate engineering programs also offer online courses.

Further investigation about the online learning modality in the context of engineering education is needed during this critical turning point. There is specifically a need to better understand student persistence in online engineering courses, as the course-level attrition rate for online learners remains at above 20 percent [8] and student retention remains a salient topic within the engineering education community [9]. This research paper aims to support such investigation by developing a survey instrument to measure student beliefs, experiences, and attitudes related to their online undergraduate engineering courses. Survey instrumentation was undertaken as part of a larger, National Science Foundation (NSF) funded project investigating the course-level persistence of online undergraduate engineering students. A Model of Online Course-level Persistence in Engineering (MOCPE) was developed by the research team to guide survey instrumentation based on theories of student motivation relevant to persistence in online and engineering education. Longitudinal survey responses from a sample of current online undergraduate engineering students will be combined with clickstream data describing their patterns of interaction with their online course learning management system (LMS) to identify factors in the model (i.e., course characteristics, student characteristics, student LMS engagement) that influence students' persistence decisions. Detailed information about the model MOCPE framework and the instrument development process and results follow.

Theoretical Framework

The hypothesized Model for Online Course-level Persistence in Engineering (MOCPE) is grounded in four theories of student motivation used to study engineering and online student persistence: the Expectancy x Value Theory of Achievement Motivation (EVT) [10], the Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivational design [11], Transactional Distance Theory (TDT) [12], and the Community of Inquiry model (COI) [13].

EVT provides an overall framework with which to examine how personal and contextual factors influence achievement-related actions – in this case, persistence to online course completion – and has been used with good results to analyze persistence in engineering majors and careers (e.g., [14-16]). Three factors in particular influence individuals' engagement and motivation to persist in a task: perceived task difficulty (an individual's belief in how difficult a task will be to accomplish), expectancies of success (an individual's belief that they will accomplish a task), and subjective task values (the individual's belief about the importance of doing well on, and their enjoyment in completing, a task) [10]. These factors are, in turn, influenced by the individual's personal background characteristics, previous academic achievements, and perceptions of the surrounding environment.

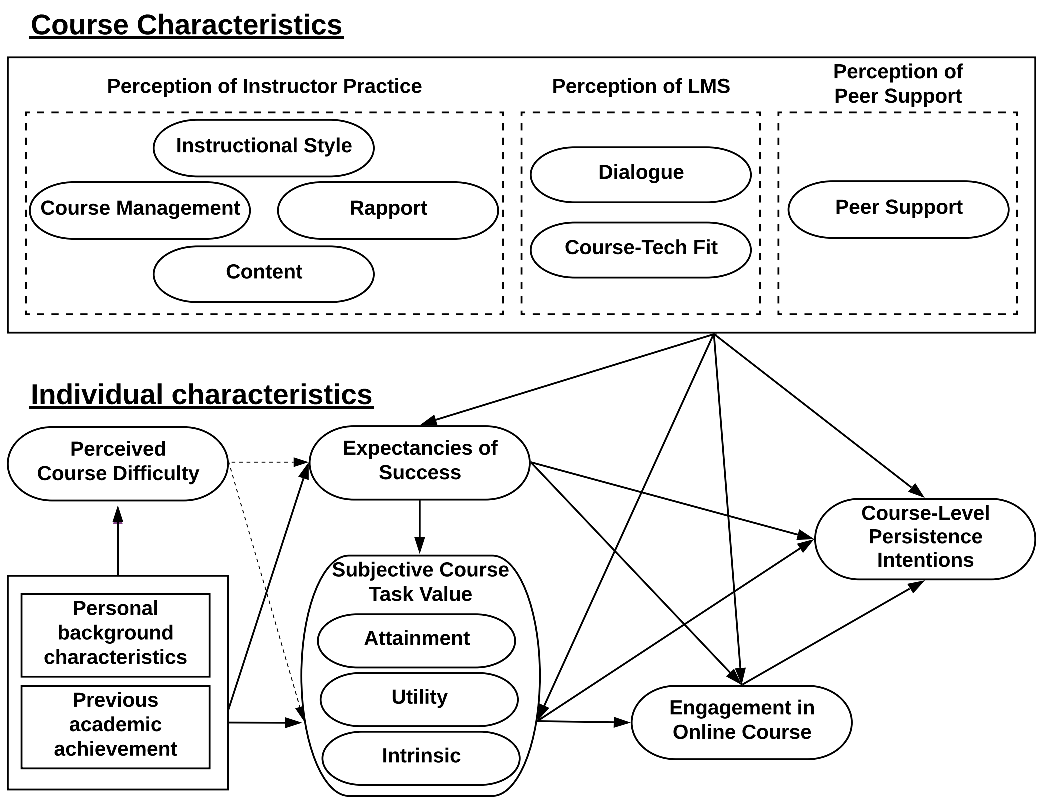

Figure 1. Model for Online Course-level Persistence in Engineering (MOCPE)

Three broad categories of course characteristics – perceptions of instructor teaching practices and behaviors, perceptions of the online learning environment, and perceptions of peer connectedness and support – were selected based on the ARCS, TDT, and COI models [11, 13, 17]. Each of these models have linked student perceptions of the instructor, LMS, and peer environment to online student motivation and satisfaction e.g., [18]-[22]). Well-designed online course experiences that lead to positive student perceptions are therefore expected to increase students' persistence intentions directly as well as indirectly, through their beliefs about the difficulty of the course, their ability to succeed in the course, and the value of the course, as per the MOCPE framework shown in Figure 1. Circles in the figure represent latent constructs that will be indirectly measured with the survey instrument, with the exception of online course engagement which will be analyzed using students' LMS clickstream data. Details of the instrument development process used to create scales for each latent construct are provided next.

Methods

1. Development of the MOCPE Instrument

The MOCPE survey instrument was developed during spring 2019 by an engineering education research team consisting of two faculty members and one Ph.D. student. The instrument is comprised of seven scales across three sections: course characteristics, student characteristics, and course-level persistence intentions (Table 1). The sections and scales in the instrument align with the dimensions or constructs of the same name in the MOCPE framework (Figure 1) and are intended to capture student beliefs, experiences, and attitudes related to their online undergraduate engineering courses. The instrument also includes a separate demographic section with questions about students' personal background characteristics (e.g., gender, age) and prior experiences taking online courses, both of which MOCPE hypothesizes influences their perceived difficulty of the course, expectancies of course success, and course task values.

The research team developed initial items for the seven scales of the MOCPE instrument based on the literature and theories from education, engineering education, and educational psychology in which the MOCPE framework is grounded. Table 1 provides information about the item development for each scale, including its initial number of items, the intended meaning of the construct, the primary inspiration for the items, and example items. Response options for all constructs were arrayed on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) [23]. An overview of the scales within the instrument follows.

Table 1 Overview of Scales within the MOCPE Instrument

Scale (# of Items)	Definition of Construct	Primary Inspiration for Items	Example Items
Section 1. Course characteristics			
Perception of instructor practice (27)	Students' perceptions of the instructor's classroom practice and behavior in the online course environment	Daly et al., 2012; Finelli et al., 2014 (effective faculty teaching practices in engineering) [24-25]	• The instructor incorporates a variety of different approaches to learning • The instructor explains concepts in a way that makes them easy to understand
Perception of peer support (6)	Students' perceptions of peer connectedness and support in the online course environment	Ingram, 2012 (college student sense of belonging) [26]	• I have access to peer support in this course • I can join study groups with other students in the course if I want to

Perception of course LMS (10)	Students' perceptions of the online course learning management system	Goel et al., 2012 (Transactional Distance Theory, TDT, applied to online learning environments) [17]	• I am satisfied with the format of the material provided • I am satisfied with the technology used in this course
Section 2. Student characteristics			
Perceived course difficulty (5)	Students' perceived level of difficulty to complete the required tasks in their online course	Eccles & Wigfield, 2000 (Expectancy x Value Theory, EVT) [27]	• I find the tasks required in this course to be hard • I find that this course is difficult
Expectancies of course success (5)	The extent to which students feel confident in their ability to complete their online course		• I can meet the goals set out for me in this course • I can satisfy the objectives for this course
Subjective course task values (16)	The amount of value (importance, utility, enjoyment) that a student places on engaging in and completing their online course		• I will be proud of myself if I complete this course • The content I am learning in this course will help me succeed in future courses • I find the material covered in this course exciting
Section 3. Course-level persistence intentions			
Intentions to persist to course completion (5)	The extent to which students intend to complete their online course	Newly created for this instrument (intentions to persist in degree program)	• I intend to complete this course • I am fully committed to completing this course

Section 1. Course Characteristics

The first section of the survey, Course Characteristics, includes three scales intended to assess students' perceptions about their learning experiences in their online undergraduate engineering courses. Each scale captures a different course characteristic: perceptions of instructor practices, perceptions of peer support, and perceptions of the course LMS. The language used for the items in each scale were kept intentionally broad to apply to a range of online course formats (for example, those that involve discussion boards, collaborative learning, and student projects).

Perceptions of instructor practices: These twenty-seven items measure students' perceptions of instructor classroom practices and behaviors in their online course environment. The items capture four categories of instructional practices (i.e., building a good rapport with students, utilizing an effective instructional style, establishing the relevance of content, and setting clear goals for the course) based on a synthesis of effective faculty teaching practices for student engagement and success in engineering [24-25].

Perceptions of peer support: This scale measures students' perceptions of the connectedness and support they feel from their classmates in the course. The original six items were written based on Ingram's [26] construct of perceived social belonging in college.

Perceptions of the course LMS: This ten-item scale is informed by TDT which posits that the structural elements of a course can also contribute to the "distance" students perceive between themselves and other people in the course (i.e., their peers, the instructor), and that smaller "distances" are associated with more positive learning outcomes [12]. Items were initially developed along two different constructs – the fit between the course and the online LMS platform, and the opportunity for dialog with others (i.e., the instructor, peers) on the online platform – which Goel et al. [17] identified as significant components of students' perceptions of the LMS in their adaptation of TDT to the modern online learning environment.

Section 2. Student Characteristics

The next survey section, Student Characteristics, includes three scales: (1) students' perceived level of difficulty required to complete tasks for their online undergraduate engineering course, which included five initial items; (2) students' expectancies of success related to completing their online undergraduate engineering course, which included five initial items; and (3) students' subjective task values associated with completing their online undergraduate engineering course, which included 16 items. Each of these constructs was created based on a conceptual understanding of EVT [2] as well as published instruments that operationalize EVT within an educational context (e.g., [27]). Among the 16 items for students' subjective course task values, six items measured the extent to which they felt that completing their online course was of personal importance to them (attainment value), five items measured the extent to which they viewed completing their online course as valuable, either now or in the future (utility value), and five items measured the extent to which they expressed enjoyment in taking the course (intrinsic value).

Section 3. Course-Level Persistence Intentions

The last section of the survey, Course-Level Persistence Intentions, measures undergraduate engineering students' intentions to persist in their online undergraduate engineering courses. Five items were newly created for this instrument.

2. Evidence of Content Validity

Evidence of content validity for the instrument was collected by subjecting all 74 items to review by faculty members external to the research team with expertise in student motivation and persistence, online education, and EVT theory. The experts provided open-ended comments on the initial items for each scale of the instrument. This feedback helped identify items that were unclear, confusing, or inconsistent with the rest of the scale, and to redefine the construct being measured in some cases.

3. Exploratory Factor Analysis

Participants and Procedure

Evidence of construct validity for the MOCPE instrument was collected by conducting a separate exploratory factor analysis (EFA) on each scale. Data for the EFA analysis were collected over a two weeks in summer 2019 with students enrolled in an online undergraduate engineering program at a large, southwestern public university. Recruitment emails to participate in the online survey were sent to students by the chair of the program. Participants were instructed to consider one particular online course when responding to the items on the survey. (Notably, most participants were only enrolled in one course.) The order in which items were shown on each scale was randomized to reduce the participant bias that can result from the order in which items are presented. Students could choose to enter a drawing for one of 250 $10 Amazon gift cards as a thank you for participating in the survey upon completion.

A total of 205 survey responses were collected, and 187 participants who provided complete responses to at least one scale within the instrument were retained for the EFA analysis. The final participant sample was 32 percent women and 23 percent veterans. The participants self-identified as White (62%), Asian (12%), Hispanic/LatinX (12%), Black/African American (4%), American Indian or Alaska Native (1%), Native Hawaiian or Pacific Islander (1%), or multiple races/ethnicities (10%). Their ages ranged from 19 to 54 ($M = 31.82$ years, $SD = 8.2$ years). Seventy-seven percent of participants were transfer students, and 38 percent were first-generation college students. Most of the participants (89%) were employed full-time or part-time. Sixty-two percent of participants reported that they were married or in a committed relationship, and 42 percent reported that they had dependent children.

Little’s test [28] was used to test the assumption that missing data for each of the seven scales were missing completely at random (MCAR). Missing data were handled using listwise deletion after all missing data were determined to be MCAR [29]. The final sample size ranged between 166 (for the subjective course task value and course persistence intentions scales) and 186 (for the perceptions of the course LMS scale). An EFA analysis was run on each scale separately, which ranged from five to 27 items. These sample sizes, therefore, met the minimum criterion of at least five to ten respondents per item [23].

Analytical Approach

The suitability for factoring of each scale was tested by conducting the Kaiser-Meyer-Olkin (KMO) test and Bartlett’s test of sphericity. The KMO test result with scores above 0.8 supports the presence of an underlying factor structure (i.e., factor analysis is possible) as the test measures the degree of shared variance among items as a function of partial correlations; higher KMO scores will result when items have smaller partial correlations because they share a common factor. Bartlett’s test of sphericity measures whether the item correlation matrix is an identity matrix (i.e., factor analysis is not possible). A significant test result ($p < 0.05$) rejects the null hypothesis, indicating that the data are factorable.

Once the factorability of the data was ensured, three methods were used to determine the number of factors to extract for each scale: parallel analysis, the Kaiser method, and the scree plot. Parallel analysis generates a large number of random data sets with the same dimensionality as the “real” data set under study, calculates the eigenvalue for each item in each random data set, and compares eigenvalues from the “real” and “random” data sets, retaining factors in the real data set with eigenvalues larger than the 95th percentile (or, in some cases, the mean) eigenvalues from the random dataset. In other words, parallel analysis helps distinguish meaningful factors from random noise. Parallel analysis is considered the “gold standard” approach for determining the number of factors to extract because it has a more rigorous methodology than other approaches, including the Kaiser method (which retains all factors with eigenvalues greater than 1) and the scree plot method (which indicates the point at which extracting additional factors will not explain substantially more variance in the data) [23]. The number of factors to extract was informed by all three approaches, in addition to the literature and theory [23].

Factor extraction was then executed in the SPSS statistical software package using principal axis factoring (PAF), the recommended approach for conducting factor analysis in social science research because it allows for the possibility of error in the measurement of latent constructs [23]. A promax rotation technique (with kappa equal to 4) was also used with multi-factor scales to account for possible correlations among factors [23].

The EFA factor structure for each scale was revised until all items with low loadings (loadings < 0.4) on all factors or cross-loadings (loadings > 0.3) on multiple factors, were removed from the structure [30]. Factors with a large number of items were further reduced down, considering the potential for survey fatigue that can be caused by asking participants to respond to too many items. The eight items with the highest factor loadings were retained for scales with a unidimensional factor structure; the four items with the highest factor loadings were retained per factor for scales with a multidimensional factor structure.

Lastly, the internal consistency for each factor was evaluated using Cronbach’s coefficient alpha of which indicates whether a set of items can be expected to load onto the same factor consistently [31]. Cronbach’s alpha values of 0.70 or higher are generally accepted in social science research, although alpha values of 0.80 and above are considered desirable [23].

Results

Overall strong evidence of validity and reliability emerged from the analyses for each scale in the MOCPE instrument. The final items for each scale (along with the final item loadings and Cronbach’s alpha for the scale) are provided in the appendix. The results of the EFA and internal consistency reliability analyses for each scale are summarized below.

Course Characteristics

Perceptions of instructor practices: Both the KMO test (score = 0.96) and Bartlett’s test (p = 0.000) determined that the item correlation matrix for this scale was factorable. Parallel analysis, Kaiser’s criterion method, and the scree plot each suggested that a two-factor model should be extracted. This result is notably inconsistent with the four-factor structure that the research team hypothesized would emerge and wrote items around based on the literature of effective teaching practices in engineering [24-25]. Items from all four dimensions loaded randomly onto each factor in the two-factor solution, comprised of 18 and eight items, respectively, instead. The research team decided to retain only the factor with the greater number of items and higher factor loadings, to reduce the possibility of survey fatigue occurring. The final scale, therefore, contains eight items and measures students' perceptions about a broad range of instructor practices (e.g., building a good rapport with students, utilizing an effective instructional style, providing students with high-quality and timely feedback, and setting clear goals for the course) in their online undergraduate engineering course. Factor loadings for these eight items ranged from 0.73 to 0.89. The internal consistency reliability for this scale was 0.95, which is considered a high internal consistency among the items.

Perceptions of peer support: The factorability of the item correlation matrix for this scale was confirmed by the KMO test (score = 0.89) and Bartlett's test ($p = 0.000$). All three methods for determining the number of factors to extract (i.e., parallel analysis, Kaiser's criterion method, and the scree plot) supported a unidimensional factor structure. The final solution consisted of all six original scale items, with factor loadings between 0.75 and 0.83, and captured students' perceived connectedness and support from the peers in their online course environment. There was a high internal consistency among the items, with a Cronbach's alpha value of 0.90.

Perceptions of the course LMS: Both the KMO test (score = 0.94) and Bartlett's test ($p = 0.000$) indicated that the item correlation matrix for this scale was factorable. A two-dimensional factor structure was suggested by all three methods for determining the number of factors to extract (i.e., parallel analysis, Kaiser's criterion method, and the scree plot). The two resultant factors each had five items, and corresponded to the fit between the course and the online LMS platform and the opportunity for dialog with others (i.e., the instructor, peers), respectively. The research team decided to retain only the four highest-loading items for each factor, once again, to reduce the possibility of survey fatigue occurring. The first factor related to fit between the course and the online LMS platform had factor loadings between 0.71 and 0.82. The second factor associated with the opportunity for dialog with others (i.e., the instructor, peers) had factor loadings between 0.76 and 0.91. The two factors had Cronbach's alpha values of 0.87 and 0.92, indicating acceptable internal consistency among both sets of items.

Student Characteristics

Perceived course difficulty: The KMO test (score = 0.91) and Bartlett's test ($p = 0.000$) determined that the item correlation matrix for this scale was factorable. All three methods to determine the number of factors to extract (i.e., parallel analysis, Kaiser's criterion method, and the scree plot) supported a one-factor structure as hypothesized. All five original scale items were retained in the EFA analysis to capture students' perceived difficulty in completing the tasks associated with their online undergraduate engineering course. The items had factor loadings ranging from 0.83 to 0.92 and a Cronbach's alpha value of 0.94, which represents a high internal consistency of the factor structure.

Expectancies of course success: The factorability of the item correlation matrix for this scale was confirmed by the KMO test (score = 0.86) and Bartlett's test ($p = 0.000$). The hypothesized unidimensional factor structure was supported by parallel analysis, Kaiser's criterion method, and the scree plot. The original five scale items measuring students' beliefs about their ability to complete their online undergraduate engineering course were retained. Factor loadings for these items ranged between 0.72 and 0.96. The items had high internal consistency reliability, as indicated by a Cronbach's alpha value of 0.93.

Subjective course task values: Both the KMO test (score = 0.91) and Bartlett's test (p = 0.000) supported the use of EFA to analyze the item correlation matrix for this scale. Parallel analysis supported a four-factor structure to the data, while Kaiser's criterion method, the scree plot, and the MOCPE framework supported a three-factor structure, so the research team decided to extract a three-factor structure, which produced all three hypothesized subjective course task values: a five-item attainment value with factor loadings ranging from 0.48 to 0.95, and a Cronbach's alpha value of 0.85; a four-item utility value factor with factor loadings ranging from 0.63 to 0.92, and a Cronbach's alpha value of 0.92; and a five-item intrinsic value factor with factor loadings ranging from 0.66 to 0.94, and a Cronbach's alpha value of 0.92. A total of fourteen of the 16 original scale items were retained in the three-factor structure, which measured the perceived importance, utility, and enjoyment students associated with engaging in and completing their online undergraduate engineering course.

Course-level Persistence Intentions

Intentions to persist to course completion: The factorability of the item correlation matrix for this scale was confirmed by the KMO test (score = 0.82) and Bartlett's test (p = 0.000). All three methods of determining the number of factors (i.e., parallel analysis, Kaiser's criterion method, and the scree plot) to extract suggested a unidimensional factor structure. The original five scale items were retained with factor loadings ranging between 0.73 and 0.84 and a high level of internal consistency reliability, as determined by a Cronbach's alpha value of 0.88. The items measure students' intentions to remain enrolled in their online undergraduate engineering course to completion.

Conclusions

This paper presented the design of an instrument to measure students' perceptions about the characteristics of their online undergraduate engineering courses (i.e., instructor practices, peer support, and the online course LMS), as well as their perceived level of course difficulty, expectancies of course success, subjective course task values, and intentions to persist in their online course to completion. A rigorous and iterative process was taken to generate items and establish evidence of content validity, construct validity, and internal consistency reliability for each of seven constructs in the hypothesized Model for Online Course-level Persistence in Engineering (MOCPE) framework, which was developed to explain the factors related to online course-level persistence among engineering undergraduate students. The results supported the hypothesized factor structure for each scale except one. The analysis of students' perceptions of instructor practices yielded a unidimensional factor structure even though four different latent dimensions had been hypothesized. The final factor structure for each scale showed strong evidence of construct validity and internal consistency reliability. All factors had loadings of at least 0.48 and above, and a Cronbach's alpha value between 0.85 and 0.95.

Efforts to further develop the instrument are ongoing and include broader administration of the survey and confirmatory factor analysis (CFA) for each scale with data from multiple online engineering degree programs. There is also the opportunity to collect additional data from online engineering students at different institutions. Future work could also focus on revising the items used to measure students' perceptions of instructor practices to capture different aspects of student-instructor engagement, such as building a good rapport with students and providing students with high-quality and timely feedback.

The research team intends to use the MOCPE instrument in the context of a larger, NSF-funded project investigating the persistence of online undergraduate engineering students. The instrument will be administered longitudinally, over a semester, and combined with students' LMS clickstream data to model the relationships between their background characteristics, academic achievements, perceptions of course characteristics, expectancies of course success, course task values, and course-level persistence. Given the length of the instrument, survey administration will be designed to avoid survey fatigue. For example, each participant will be asked to complete the survey twice a week about one particular online course they are taking that has been assigned to them before data collection (vs. all the online courses in which they are enrolled that semester). Results from this work have the potential to generate new insights into how to retain engineering students, and particularly, women and non-traditional engineering students [2-3]. The instrument may also be of use to other researchers interested in studying the population of online students within and outside of engineering.

References

[1] E.I. Allen, J. Seaman, R. Poulin, & T.T. Strout, "Online Report Card: Tracking Online Education in the United States," https://www.onlinelearningsurvey.com/reports/onlinereportcard.pdf, 2016 (Accessed January 2019).

[2] A.P. Rovai, & J.R. Downey, "Why some distance education programs fail while others succeed in a global environment," *The Internet and Higher Education*, vol. 13, no. 3, pp. 141-147, 2010.

[3] D. Xu, & S.S. Jaggars, "The impact of online learning on students' course outcomes: Evidence from a large community and technical college system," *Economics of Education Review*, vol. 37, no. 46-57, 2013.

[4] L.L. Long, & J. A. Mejia, "Conversations about diversity: Institutional barriers for underrepresented engineering students," *Journal of Engineering Education*, vol. 105, no. 2, pp. 211-218, 2016.

[5] D. Lawton, N. Vye, J. Bransford, E. Sanders, M. Richey, D. French, & R. Stephens, "Online learning based on essential concepts and formative assessments," *Journal of Engineering Education*, vol. 101, no. 2, pp. 244-287, 2012.

[6] S. Badjou, & R. Dahmani, "Current status of online science and engineering education," *Journal of Online Engineering Education*, vol. 4, no. 1, 2013.

[7] ABET, Inc., "Online programs accredited by ABET," https://amspub.abet.org/aps/online-search, 2020 (Accessed January 2020).

[8] J. Frydenberg, "Persistence in university continuing education online classes," *The International Review of Research in Open and Distance Learning*, vol. 8, no. 3, pp. 1-15. 2007.

[9] American Society for Engineering Education, "American Society for Engineering Education Databytes," http://www.asee-prism.org/databytes-mar-apr/, 2016 (Accessed January 2020).
[10] A. Wigfield, & J. S. Eccles, "Expectancy-value theory of achievement motivation," *Contemporary Educational Psychology*, vol. 25, no. 1, pp. 68-81, 2000.
[11] J.M. Keller,"Development and use of the ARCS model of motivational design," *Journal of Instructional Development,* vol. 10, no. 3, pp. 2-10, 1987.
[12] M. G. Moore, "Theory of transactional distance," *Theoretical Principles of Distance Education*, vol. 1, pp. 22-38, 1993.
[13] D. R. Garrison, T. Anderson, & W. Archer, "The first decade of the community of inquiry framework: A retrospective," *The internet and higher education*, vol. 13, pp. 5-9, 2010.
[14] B. D. Jones, M. C. Paretti, S. F. Hein, & T. W. Knott, "An analysis of motivation constructs with first-year engineering students: Relationships among expectancies, values, achievement, and career plans," *Journal of engineering education*, vol. 99, no. 4, pp. 319-336, 2010.
[15] Q. Li, D. McCoach, H. Swaminathan, & J. Tang, "Development of an instrument to measure perspectives of engineering education among college students," *Journal of Engineering Education,* vol. 97*,* no. 1, pp. 47-56, 2008.
[16] H. M. Matusovich, R. A. Streveler, & R. L. Miller, "Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values," *Journal of Engineering Education*, vol. 99, no. 4, pp. 289-303, 2010.
[17] L. Goel, P. Zhang, & M. Templeton, "Transactional distance revisited: Bridging face and empirical validity," *Computers in Human Behavior*, vol. 28, no. 4, pp. 1122-1129, 2012.
[18] D.U. Bollinger, & T. Martindale, "Key factors for determining student satisfaction in online courses," *International Journal on E-Learning*, vol. 1, pp. 61-67, 2004.
[19] V. P. Dennen, A. A. Darabi, & L. J. Smith, "Instructor-learner interaction in online courses: The relative perceived importance of particular instructor actions on performance and satisfaction," *Distance Education*, vol. 28, no. 1, pp. 65-79, 2007.
[20] T. Gallien, & J. Oomen-Early, "Personalized versus collective instructor feedback in the online courseroom: Does type of feedback affect student satisfaction, academic performance, and perceived connectedness with the instructor?," *International Journal on E-Learning,* vol. 7, no. 3, pp. 463-476, 2008.
[21] M. Herbert, "Staying the course: A study in online student satisfaction and retention," *Online Journal of Distance Learning Administration*, vol. 9, no. 4, 2006.
[22] J. M. Keller, & K. Suzuki, "Use of the ARCS motivation model in courseware design," in *Instructional Designs for Microcomputer Courseware,* D. H. Jonassen, Ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1998, pp. 401-434.
[23] D. B. McCoach, R. K. Gable, & J. P. Madura, *Instrument development in the affective domain*. New York, NY: Springer, 2013.
[24] S. R. Daly, C. Finelli, A. B. Al-Khafaji, & M. J. Neubauer, "Student perspectives of faculty classroom practices," in *Proceedings of the American Society for Engineering Education Annual Conference*, San Antonio, TX, June 2012.
[25] C.J., Finelli, S.R. Daly, & K.M. Richardson, "Bridging the research-to-practice gap: designing an institutional change plan using local evidence," *Journal of Engineering Education*, vol. 103, no. 2, pp. 331-361, 2014.
[26] D. Ingram, "College students' sense of belonging: Dimensions and correlates," Ph.D. dissertation. Stanford University, Stanford, CA, 2012.

[27] J. S. Eccles, & A. Wigfield, "Motivational beliefs, values, and goals," *Annual Review of Psychology,* vol. 53, no. 1, pp. 109-132, 2002.
[28] R. J. Little, "A test of missing completely at random for multivariate data with missing values," *Journal of the American Statistical Association*, vol. 83, no. 404, pp. 1198-1202, 1988.
[29] R. J. Little, *Statistical analysis with missing data*. New York, NY: Wiley, 2002.
[30] T. Hong, S. Purzer, & M. E. Cardella, "A psychometric re-evaluation of the Design, Engineering and Technology (DET) Survey," *Journal of Engineering Education*, vol. 100, no.4, pp. 800-818, 2011.
[31] L. J. Cronbach, "*Coefficient alpha and the internal structure of tests*," *Psychometrika*, vol. 16, no. 3, pp. 297-334, 1951.

Appendix. Exploratory Factor Analysis Results

Scale (# of items)	Item	Factor loading	Cronbach's alpha
Section 1. Course characteristics			
Perceptions of instructor practices (8)	The instructor explains concepts in a way that makes them easy to understand.	0.89	0.95
	The instructor helps to keep students engaged.	0.88	
	The instructor incorporates a variety of different approaches to learning.	0.87	
	The instructor delivers course content in a way that keeps things exciting.	0.87	
	The instructor shows enthusiasm about student success.	0.85	
	The instructor solicits student ideas and feedback about the course.	0.83	
	The instructor gives helpful examples to support class concepts.	0.82	
	The instructor has made an effort to get to know me as an individual.	0.73	
Perceptions of peer support (6)	I have access to peer support in this course.	0.83	0.90
	I can join study groups with other students in the course if I want to.	0.80	
	I am part of a community in this course.	0.79	
	I am connected to other students in the course.	0.77	
	I have been able to get to know other students in the course.	0.75	
	I can ask questions of other students in the course.	0.75	
Perception of course LMS: Fit between course and online platform (4)	I am satisfied with the technology used in this course.	0.82	0.87
	I am satisfied with the format of the material provided.	0.79	
	I am satisfied with the resources provided (e.g., links, materials, resources) to support learning.	0.79	

	I am satisfied with the way that content is delivered.	0.71	
Perception of course LMS: Opportunity for dialog with others (4)	I feel comfortable using the course Canvas site to converse with others.	0.91	0.92
	I feel comfortable using the course Canvas site to ask questions to others.	0.91	
	I feel comfortable using the course Canvas site to initiate conversations with other students.	0.85	
	I feel comfortable using the course Canvas site to participate in the course discussions.	0.76	
Section 2. Student characteristics			
Perceived course difficulty (5)	I find the tasks required in this course to be hard.	0.92	0.94
	I find that this course is difficult.	0.90	
	The content presented in this course is hard to understand.	0.87	
	This course is more difficult than I expected.	0.84	
	The tasks required in this course are challenging for me.	0.83	
Expectancies of course success (5)	I can meet the goals set out for me in this course.	0.96	0.93
	I can satisfy the objectives for this course.	0.91	
	I can successfully earn credit for this course.	0.87	
	I can pass this course.	0.85	
	I can master the knowledge and skills taught in this course.	0.72	
Subjective course task values: Attainment value (5)	I will be proud of myself if I complete this course.	0.95	0.85
	Completing this course means a great deal to me.	0.81	
	It is important to me that I finish this course.	0.77	
	Completing this course will make me feel good about myself.	0.57	
	I would be upset if I did not finish this course.	0.48	
Subjective course task values: Utility value (4)	The content I am learning in this course will help me succeed in future courses.	0.92	0.92
	What I am learning in this course will be useful for my career.	0.83	
	The material I am learning in this class is relevant to my life.	0.82	
	I will learn a lot of useful skills by taking this course.	0.63	
Subjective course task values: Intrinsic value (5)	I find the material covered in this course exciting.	0.94	0.92
	I have fun working on the assignments for this course.	0.88	
	I enjoy learning about the topics covered in this course.	0.86	
	I find taking this course to be stimulating.	0.74	
	I am interested in the content of this course.	0.66	
Section 3. Course-level persistence intentions			
Intentions to persist to course completion	I am fully committed to completing this course.	0.84	
	I intend to complete this course.	0.79	0.88

(5)	I am not thinking about dropping from this course.	0.78
	I do not see any reasons to withdraw from this course.	0.77
	I plan to be still enrolled in the course next week.	0.73