Elevating Participation and Outcomes with Computer-Based Assessments: An Immersive Development Workshop for Engineering Faculty

Ronald F. DeMara, Baiyun Chen, Richard Hartshorne, and Richard Thripp

Abstract—Using computer-based assessments for engineering and other STEM courses is challenging because it requires authentic assessment items that support partial credit, solution composability/traceability, and creative design aspects. Fortunately, learning management systems (LMSs), such as Canvas or Moodle, can be adapted through creative means to deliver more complex assessment options, including incremental solution, multiple answer, design-by-selection, and dynamic cloning. Unfortunately, due to the complexity of STEM assessments and development interfaces, it can be overwhelming for faculty to digitize assessments without sufficient exemplars, deep coaching, and peer assistance. This paper summarizes an immersive faculty development approach designed to address such concerns. The six-week *Assessment Digitization Innovation* summer workshop covered techniques and principles of digital assessment and associated pedagogical approaches, and was completed by ten instructors in 2016 and seven in 2017. Combined with a stipend, a course release, and the resources of the university's Evaluation and Proficiency Center (EPC), a proctored testing environment allowing students to schedule their quizzes and exams during a testing window specified by the instructor, participants and their teaching assistants were set up to succeed. In post-surveys, they were "very satisfied" with the workshop and agreed that assessment digitization would save time, refocus faculty workloads from low-impact grading to high-impact structured tutoring, improve remediation, and enable them to effectively serve increasing enrollments. Whereas student laptops with lockdown browsers, unused hours of existing computing labs, and dedicated testing centers allow delivery of computer-based assessments using the techniques herein, the methods described can further help to promulgate reduced grading workloads via digitized formative and summative assessments.

Index Terms—computer-based assessment, digitization, engineering assessments, faculty development workshops, faculty perceptions, integrity, proctoring

I. INTRODUCTION

In this paper, we describe the motivation, contents, and outcomes of the faculty development and training component of a transportable effort to increase the use, efficacy, and best practices with respect to computer-based assessments in engineering curricula. A college-wide engineering digitization initiative at the University of Central Florida (UCF), the *Assessment Digitization Innovation* (ADI) workshop on digitizing and remediating STEM assessments, is described. The ADI workshop was delivered as a six-week mixed-mode format course and was administered to ten UCF faculty members in summer 2016 and seven in summer 2017. It is an important part of a viable digitized assessment ecosystem, which consists of digitization instructional pedagogies, engineering assessment design, resources (e.g., technology, personnel, infrastructure, and services) for digitized assessment delivery, and structures for dissemination of digitized assessments to other faculty. Together, these elements facilitate digitization and delivery of suitable formative and summative engineering assessments.

Instructional technologies that enable instructors to focus their efforts on teaching, rather than low-yield logistical tasks, offer substantial gains to the quality and productivity of engineering instruction. One such technology is assessment digitization, which involves computer-based delivery and automatic grading of formative and summative assessments, and has achieved widespread adoption within certain disciplines outside of engineering [1–3]. Innovations in assessment for STEM disciplines are urgently needed, in part because student enrollment in undergraduate gateway courses at some institutions has increased considerably. For example, undergraduate enrollment in the College of Engineering and Computer Science (CECS) at UCF has increased from 6,568 in Fall 2012 to 8,813 in Fall 2016—a 34.2% increase, which is much greater than the 9.4% increase that occurred university-wide in the same time period (50,982 undergraduates in Fall 2012 vs. 55,783 in Fall 2017) [4]. Nationally, many undergraduate engineering foundation courses now enroll over 100 students, yet a proportional increase in instructors and graduate assistants has not occurred. Meanwhile, the efficacy of homework assignments [5], lab reports [6], and reused exams [7] continue to be undermined by Internet search engines [8] and solution repositories [9]. However, computer-based testing innovations such as computer-generated formula-based questions for randomized and/or distinct content, rapid or even

instant remediation, and in-person, proctored testing centers offer solutions that engage learners, while preventing cheating and unauthorized dissemination of testing materials via physical attendance and dynamic questions. Overall, we surmise that the hurdles to achieving effective digitization of engineering assessments can broadly be organized into three categories: *design challenges*, *workload challenges*, and *organizational challenges*.

Design challenges include the need to deliver not only multiple-choice questions with one correct answer, but creative-design problems with multiple components that allow for partial credit, of which there are varied approaches for designing innovative assessment items in the Canvas learning management system (LMS), including multi-part questions, matching activities, and multiple-answer formats. However, it is essential for faculty to apply these techniques in their assessment design, as well as be able to customize instructional practices for the courses, such as flipped classroom approaches and "score clarification." Subsequently, content-area graduate teaching assistants (GTAs) at the EPC can strengthen learners' skills through one-on-one score clarification, with associated structured tutoring.

Workload challenges include the initial "cold start" problem of building a viable test bank of digitized questions, whereas only selected topics in engineering fields have digitized test banks available from textbook publishers. Additionally, the efforts invested to digitize, particularly with proctored in-person delivery that prevents unauthorized dissemination, can be re-used from semester to semester and even shared among other faculty members who teach the same course.

Organizational challenges relate to support and rate of change of the participants involved [10], including administrators, instructors, and students. It is by no means trivial to provide the resources to deliver the assessments, ideally within a proctored testing facility, while creating and maintaining question banks including alternate question "clones" to mitigate crosstalk among asynchronous test takers (e.g., if a three-day window is offered, clones prevent Bobby who took the exam on Wednesday from giving answers to David who is taking the exam on Friday). Moreover, it is an organizational challenge to provide instructors assistance in their digitization efforts, such as through the current workshop, technical staff, and a support helpdesk.

The ADI workshop addresses these concerns via an incentivized long-term faculty development opportunity designed to alter pedagogical conceptions through the engagement of key and influential faculty and administrators, encouraging STEM faculty to embed innovative digitizing approaches within their existing pedagogical conceptions, and to employ participating faculty as change agents for dissemination.

II. BACKGROUND

A. Changing Faculty Perceptions of CBA

Past research implies that instructors who have a greater level of computer training may have more positive perceptions of computer-based assessment (CBA) [11] and students are more likely to accept CBA if they perceive it is easy-to-use [12]. Further, recent research [13] often finds no significant differences in academic performance between CBA and paper-based assessment for equivalent STEM testing materials. However, a direct comparison is inaccurate as CBA can support dynamic questions, greater assessment of depth of understanding, machine grading to allow for increased instructional time, multiple attempts, and simplified delivery, remediation, and feedback, all of which are difficult or impossible with paper-based assessment. Unfortunately, effective implementation of CBA, which allows for realization of these benefits, is foreign to many faculty and often requires a large investment of time, effort, training, and institutional support [14].

The ADI workshop was supported by UCF with incentives that instilled participants with the needed time and resources to succeed in implementing digital assessments and associated pedagogical practices. A key consideration in the design and development process was that participants, having self-selected, would come with an interest of moving toward proctored CBA and would begin executing this transition through active and interactive participation within the workshop series [10]. Making the workshop series six weeks, rather than a one-time meeting, allowed participants time to read assigned empirical literature, complete projects, and come together to discuss their progress, which is essential for effective CBA implementation [14] and engineering faculty development [15].

Peer coaching, where experienced faculty work with less experienced faculty on a one-to-one basis or in small groups, has provided evidence of being an effective model for faculty development [16]. In particular, coaching may help change members' perceptions of CBA as an insurmountable task to something that can reasonably be implemented in their courses [11]. Thus, the ADI workshops were designed to be small, with ten faculty participants in summer 2016 and seven in summer 2017. Consequently, they often functioned in a similar manner as peer coaching, with the authors and participants sharing their ideas, products, and expertise during in-class and online discussions of CBA and paper-based assessment issues. Moreover, the ADI workshop often functioned at the upper levels of Chi's Interactive–Constructive–Active–Passive framework [17], whereby faculty were not only actively participating, but also constructing their knowledge through practical assignments and interacting with each other and CBA-related objects in online and face-to-face modalities. These types of cognitively engaging activities may facilitate meaningful learning better than active or passive activities.

Numerous resources are required to effectively develop and implement CBA [14]. For example, pre-packaged feedback requires great time and effort to create. Over time, though, the dividends can be far greater than the costs of continuing to manually provide feedback to paper-based assessments. However, the up-front costs to an instructor may be unpalatably large. This may be particularly true for certain instructors who are inherently skeptical about the pedagogical benefits of technology [18]. Yet, we might speculate that faculty perceptions of CBA will improve if they become aware of a high level of support for CBA offered by their institution,

DEMARA et al.: ELEVATING PARTICIPATION AND OUTCOMES WITH COMPUTER-BASED ASSESSMENTS: AN IMMERSIVE DEVELOPMENT WORKSHOP FOR ENGINEERING FACULTY

3

including transition and implementation elements. The ADI workshop addresses transition and implementation support in several ways (e.g., by offering a course release to allow time to develop their CBA content).

A salient problem when utilizing CBA in STEM is that, when delivered online in an unproctored setting, cheating is common [19], affording online students an unfair advantage over their face-to-face, proctored peers [20]. The proctored, testing center approach used by our engineering department nullifies these issues, but is not something any single faculty member can implement unilaterally. Nevertheless, many universities support online teaching and professional development [21] by assisting faculty with their online courses, CBA implementation, and various technical issues, thereby providing a high level of perceived organizational support [22]. Combining institutional support with the use of peer coaching [18], discussions, and interactive learning [23], a coherent theory of change [10] emerges which may provide additional power to influence faculty members' perceptions of CBA and the digitizing process positively. Finally, even when institutional resources are lacking, our methods are at least partially transportable without faculty incentives or proctored CBA.

B. Pedagogical Benefits to Students

Fellin and Medicus [24] describe the use of multiple-choice assessments in geotechnical engineering, which elevated the performance of undergraduate students via pre-test practice, and found that students strongly prefer practice over theory in engineering content. The authors were convinced that digitized assessments used in this manner can impart long-term benefits, justifying the effort required to construct such assessments. Further, Schurmeier and colleagues [25] studied the results of 10 years of digitized assessments on over 20,000 students using the University of Utah Testing Center to address eight difficult topics in general chemistry [25]. Their efforts provide a good example of benefits to instructors derived from digitization of assessments—particularly the identification of trends in learners' comprehension. While studies have shown mixed reviews of teacher perceptions of online assessments, use of such assessments have been documented to exhibit a high degree of positive correlation with overall course grades [13]. Further, while perceptions of online vs. paper-based assessments have been mixed [11], many studies have documented the benefits of frequent online evaluation at the college-level—for example, a year-over-year summative evaluation increase from 78% to 86% in the case-study of a single course [26]. A 2009 article by Angus evaluated whether online formative assessments improved learning outcomes. Based on 1500 observation points, they surmised the administration of such assessments "robustly leads to higher student learning" [27].

C. Promoting Academic Integrity

Challenges to authenticity of authorship and academic integrity in fully online courses are pervasive in the literature.

In an attempt to deter cheating, *Proctor Hub*, *ProctorU*, *ProctorFree* and *Remote Proctor NOW (RPNow)* offer commercially available products for academic use. However, continuously monitoring students' webcam feeds for eye tracking can be intractable, and thus either a dedicated testing center or a block scheduling of an existing computer lab were the approaches recommended in the ADI workshop. Further, existing methods of reducing academic integrity violations are limited in that there are often technological workarounds, such as test takers capturing questions using cameras in the testing background, despite the requirement of using a lockdown browser. Additionally, with the release of test questions, students may only learn the answer to the question, rather than achieving understanding of core concepts, limiting learning outcomes. Consequently, in the ADI workshop, a proctored testing center shown in Figure 1 is merged with the promising aspects of an "open tutoring center," where tutors are available for targeted assistance [28] and provide the foundation of an effective, integrated, and verifiable assessment methodology. Thus, we extended pedagogies such as project-centered assistance in "electrical and computer engineering clinics" [29] with a more holistic approach using integrated testing.

D. The Testing Effect

Further rationale for the digitization of both formative and summative assessments in Engineering courses is supported by the testing effect [30], which posits that mastery learning can be facilitated for complex concepts through frequent formative assessments supported with timely and thorough feedback. Affording students with increased opportunities for formative assessments allow students opportunities to utilize feedback for reflection and growth. Specific and structured feedback that can be provided via digitized formative assessments facilitate student mastery and have a high correlation with student

Figure 1. The EPC has 120 testing stations.

achievement [13, 27]. Further, digitized formative assessments allow instructors to mine assessment results for learning gaps and misconceptions, informing modifications to instructional approaches, pace, and ordering of content. Thus, digitized formative assessments become a critical component of a comprehensive pedagogical framework, which maximizes the benefits of particular instructional strategies, while mitigating specific drawbacks.

DEMARA et al.: ELEVATING PARTICIPATION AND OUTCOMES WITH COMPUTER-BASED ASSESSMENTS: AN IMMERSIVE DEVELOPMENT WORKSHOP FOR ENGINEERING FACULTY

4

E. Digitization and Testing Centers

There are currently a number of digitization and testing center approaches for STEM programs across the nation. For example, Brigham Young University [31] and University of Utah [25] testing centers provide online testing facilities for engineering and science programs that use digitized assessments. A commonality between these and ADI is the adoption of exclusive assessment delivery within a secured environment overseen by proctors. Furthermore, students are provided with the convenience of being able to schedule appointments to avoid conflicts with their jobs or other exams.

Another significant digitization initiative is the Computer-Based Testing Facility (CBTF) at University of Illinois at Urbana–Champaign (UIUC) [32]. The CBTF is used by courses in the computer science, mechanical science, and engineering programs. In addition to online testing and proctoring services, CBTF provides interactive graphical response tools for faculty to digitize their assessments. The UIUC assessment pedagogy also allows students a second attempt to retake an assessment for credit, which replaces the previous score. Extending these examples, the ADI workshop promulgates an integrated testing and tutoring methodology, which has been adapted to support a significantly broader range of STEM programs than previous approaches. Under the ADI workshop approach, digitization enables auto-grading of assessments, which frees up graders for tutoring, a high-gain learning activity.

F. Faculty Professional Development

A multitude of research suggests that a major impacting factor on student achievement is the classroom instructor [33]. Consequently, improving the quality of instructors, as well as instructional practices, should play a critical role in any STEM reform effort. Short-term, single implementation professional development environments have not shown positive influences on changing instructor practices or attitudes toward innovative pedagogical approaches. Thus, extended professional development workshop environments are preferable, as more opportunities are provided for instructors to address aspects of their teaching practice, explore various opportunities and constraints in teaching and learning environments, and gain empowerment to change instructional practices [34]. Ultimately, this can change an instructor's attitude and confidence in implementing new pedagogical approaches, which in turn influences changes in behavior [35].

III. THEORETICAL FRAMEWORK

Instructors are the gatekeepers to meeting key aspirational goals of STEM instruction, including increasing student engagement, elevating learner outcomes and conceptual understanding, serving increasingly large enrollments, and adopting technology incrementally. While many studies have espoused the usefulness of professional development workshops in increasing instructor preparedness and effectiveness, STEM professional development workshops have not illustrated the same level of success in modifying instructor behavior as other content areas [36–37]. Thus, the ADI workshop extends successes in other areas in a holistic and comprehensive manner, including flipped and blended classroom environments, active and learner-centered professional development activities, and extensive time and resources to reflect on existing pedagogical practices and make modifications to instructional approaches to implement "best practices" in STEM instruction.

While numerous efforts have been made to address the variety of problems currently facing STEM education, such as improving workforce development, increasing the number of women and underrepresented populations in STEM programs and careers, and implementing policies, supports, and processes to support enhanced STEM teaching and learning, many such efforts fail to be adopted [38]. Often, contributory factors are the lack of a holistic design and failure to develop a comprehensive change strategy prior to implementation of the reform effort. Hence, it is critical to develop and employ a change strategy that extends the typical "best practice" approach that is common in STEM reform efforts [39]. Rather, a comprehensive change approach should be continual, coordinated, and focused, while (a) changing the pedagogical conceptions of key and varied stakeholders in a STEM instructional system and (b) affording stakeholders with an iterative cycle of performance evaluation and continual feedback [40].

To address the preceding issues, within the ADI workshop we developed and implemented a comprehensive and expansive dissemination plan derived from the Four Categories of Change Strategies model [41]. We created this plan in an effort to provide environmental support to facilitate extensive adoption of processes and pedagogical practices associated with digitizing assessments. The change strategies we employed focused on:

1. Developing extensive and expansive incentivized professional development opportunities for key faculty and administrators in an effort to alter instructional practices, policies, resources, and processes in place to support the integration of digitized assessments and associated pedagogical practices in STEM courses;
2. Employing experiential, exemplar-centric, faculty-driven, and product-based methods for aligning innovative instructional practices with the existing STEM conceptions of participating stakeholders, thus encouraging participants to explore innovative instructional approaches in a structured and measured manner;
3. Developing an extensive and iterative plan for assessing and documenting the effectiveness of the ADI workshop and accompanying pedagogical practices via stakeholder feedback;
4. Disseminating program evaluation results to varied STEM programs and stakeholders; and
5. Employing change agents to disseminate project materials and results.

Overall, the aim of this comprehensive change strategy was

DEMARA et al.: ELEVATING PARTICIPATION AND OUTCOMES WITH COMPUTER-BASED ASSESSMENTS: AN IMMERSIVE DEVELOPMENT WORKSHOP FOR ENGINEERING FACULTY

5

to result in a wider adoption of the ADI workshop content, processes, and strategies.

Learners and faculty can benefit from shifting engineering gateway courses towards computer-based test delivery for those assessments that are suitable for digitization. Using a taxonomy of online assessment instruments facilitates design problems beyond rote multiple choice including *multiple answer for partial credit*, *incremental solution multiple choice*, *creative design via selection*, and others, which offer significant comprehension differentiation beyond the benefit of grading expediency. It also provides learners with structured guidance and a hierarchy of teaching expertise. Thus, the pedagogy associated with the ADI workshop shifts instructor and GTA roles away from low-value repetitive tasks towards those having more significant impacts on learning outcomes.

IV. THE WORKSHOP

A. Acquiring Participants

Three months in advance of the ADI workshop, availability of the upcoming workshop was announced at a college-wide meeting. The objectives of the workshop were overviewed, including:

1. Constructing digitized exams for STEM subject matter;
2. Using relevant Canvas LMS question types and features;
3. Strategies to encourage academic integrity in online assessments; and
4. Composing exemplar design vignette questions to reinforce, develop, and assess connections between concepts to achieve integrative learning.

The mixed modality delivery format was identified as consisting of two online weekly modules to develop assessments for their targeted STEM course, and four face-to-face weekly modules, each two hours in duration. Next, an enrollment form, which solicited faculty participation, was provided and posted on the college website. The form requested information on the course targeted for assessment digitization including annual enrollment, number of years taught, graduate-level support currently allocated (i.e., number of GTAs), number of assessments (e.g., quizzes, exams, finals), percentage of examinations currently using Scantron, and any relevant publishers' test banks identified. Ten faculty participants were selected to participate in Year 1 and seven in Year 2, representing six engineering disciplines. In an effort to maximize active learning during the ADI workshop, the face-to-face meetings were scheduled in a high technology classroom, which provided each participant with student stations having large computer monitors to participate in workshop activities.

B. Structure and Content

The ADI workshop relied on a formal syllabus, which was correlated with a point-earning rubric for participants. The course completion reporting scale used S/U, whereby a grade of S (Satisfactory) was earned if 10 or more points (including mandatory showcase submission) were accrued by the end of Week 6, and U (Unsatisfactory) for absence of showcase submission and/or fewer than 10 points earned. As listed in Table I, the content of the ADI workshop was organized into six modules, at a rate of one module per week, plus a preparatory Week 0 module. The workshop began with an overview of the BLUESHIFT pedagogy [42] in Week 1 and then engaged the participants to plan the modularization of their target course. The immersive EPC quiz was administered in Week 2 (Figure 2) so participants were provided with the same process their students would experience. Weeks 3–4 concentrated on constructing digitized study sets using exemplar vignettes, the process of score clarification as a pedagogical approach, and the digitized question development flow. A panel discussion with graduate assistants was also held, which was well received by participating faculty, who were provided opportunities to ask questions about proctoring logistics. Week 6 culminated in a capstone showcase activity, where all participating faculty walked through and discussed their digitized assessments via PC and overhead projector, and completing faculty received a graduation certificate for their professional development records.

As promulgated in the ADI workshop (see Table I), each digitized study set typically focused on a single technical content area and/or principle. Engineering problems were then decomposed into detailed subsections to enable partial credit formulation within the existing capabilities of the Canvas LMS.

Figure 2. Faculty experiencing an EPC-delivered assessment.

The guidance provided in the ADI workshop focused on identifying governing equations for each sub-step of the

problem, in an effort to address varied partial credit approaches. As a result, solutions can exhibit approaches and precise calculations, which are required for solving the given problems. Further, in the ADI workshop, "flipped" classroom pedagogical practices were modeled by providing out-of-class homework with open solutions, but without submission, allowing credit to be earned by completing a corresponding quiz for a study set.

The ADI workshop covered the design, development, construction, and LMS integration of various types of questions for digitizing a quiz, including *multiple choice*, *multiple answers*,, and *formula* questions that are shown in Figs. 3(a), 3(b), and 3(c), respectively. The quiz questions were constructed using incremental assessments with partial credit to enable the precise evaluation of comprehension and problem-solving ability of the students, while also exemplifying the diverse nature of question types supported by the LMS. The ADI workshop also explored digitized assessment administration logistics, and advocated assigning a multiple-day window for completing the exams, maximizing the pedagogical benefits of utilizing several clones of each question, each based on various versions of a core problem, and designed to avoid different students receiving identical problems.

Table II summarizes points available for faculty to earn within the workshop. Points were accrued by participants completing three categories of assigned weekly activities:

1. **Non-Showcase Class Meetings** (up to 3 points total). The regular in-class meetings occurring during Weeks 1, 2, and 4 accrued points in either of two ways:

   a. 1 point for each regular live class attended with active participation, or alternatively,

   b. 1 point for each live class makeup conducted via viewing the class video recording and then posting a 100-word or more discussion post in the corresponding week's "Makeup" discussion thread detailing the actions gleaned for their targeted course.

TABLE I
COURSE AGENDA AND ANTICIPATED EFFORT OF PARTICIPANTS

Week	Agenda	Effort
0 – Web	Course Logistics: Syllabus, Policies, Background, Instructor Profiles	2 hours
1 – F2F	BLUESHIFT Pedagogy: Digitized Course Walkthrough, EPC Procedures, Study Set on SI units, Schedule EPC Quiz Appointment using website	4 hours
2 – F2F	Modularization Planning: EPC Experience, BLUESHIFT paper, Immersive Quiz in EPC	6 hours
3 – Web	Exemplar Vignettes and Score Clarification: Vlogger Paper [43], read Peer Review, EPC Policies & Procedures, Syllabus Starter with EPC Guidelines, Laboratory Digitization	4 hours
4 – F2F	Structuring Creativity/Design/Soft (CDS) questions: Question Development Flow, Canvas Quizzes Tool, GSA Panel Discussion, Respondus	6 hours
5 – Web	Support Resources: Fellin and Medicus [24] Paper on Multiple Choice in STEM, Canvas Guide, Managing Academic Integrity & Honesty, IRB—Approved Research, Screencasting Procedures, Hybrid Modality Lecture Capture Procedures	4 hours
6 – F2F	Showcase and Graduation: Enrollees present Quiz and Study Set, Course ends with overview of Automated Extraction of Question Content	14 hours
	Total	**40 hours**

The course lasts six weeks and includes four face-to-face meetings of about two hours each, with additional online materials, and two fully online weeks.

2. **Assigned Submissions** (up to 9 points total). Elements assigned during each module accrued:

   a. 1 point for each satisfactory submission before the due date (e.g., homework upload, take-home quiz, or assigned, non-makeup discussion post), and

   b. 2 points for completion of an immersive quiz delivered in the EPC, where each faculty participant completed the quiz under identical testing conditions that students would experience, including use of scrap sheets, lockers, and supplied calculators.

TABLE II
ADI WORKSHOP ACTIVITIES AND POINTS SCHEDULE

Week	Mode	Participation Activity / Submission	Points	Percent of Participants Achieved
0	Web	**Discussion post:** Most significant advantages and challenges to digitizing assessments within your targeted engineering course?	1	100%
1	F2F	**Class attendance** or make-up by viewing class video and posting discussion of elements learned that week	1	90%
2	F2F	**Class attendance** or make-up by viewing class video and posting discussion of elements learned that week	1	90%
2	F2F	**Immersive quiz on SI units:** Schedule appointment on website to take a quiz in the EPC as a student	2 *	100%
2	F2F	**Modularization plan:** Submit module design and assessment map for targeted course using template provided or in own format	1	70%
3	Web	**Discussion post:** Lessons learned from panel of Tutor / Cloner / Proctor	1	90%
3	Web	**Study set submission:** Submit a flipped homework for targeted course	1	100%
4	F2F	**Class attendance** or make-up by viewing class video and posting discussion of elements learned that week	1	80%
4	F2F	**Discussion post:** Non-digitized quiz in targeted course with solution	1	90%
5	Web	**Discussion post:** Pedagogy article on validity and potential value of multiple choice in STEM content	1	70%
5	Web	**Take-home quiz:** Identify question formats supported and their use	1	100%
6	F2F	**Showcase presentation:** Each instructor presents and defends a digitized assessment module in targeted course using LMS interface	3 *	100%
		Total Points Available (* denotes mandatory activity)	**15**	
		Minimum Points Required for Satisfactory Grade	**10**	**100%**

Participants were required to take a mock quiz in the EPC and to give a final showcase presentation, but chose how to earn five or more of ten other points.

DEMARA et al.: ELEVATING PARTICIPATION AND OUTCOMES WITH COMPUTER-BASED ASSESSMENTS: AN IMMERSIVE DEVELOPMENT WORKSHOP FOR ENGINEERING FACULTY
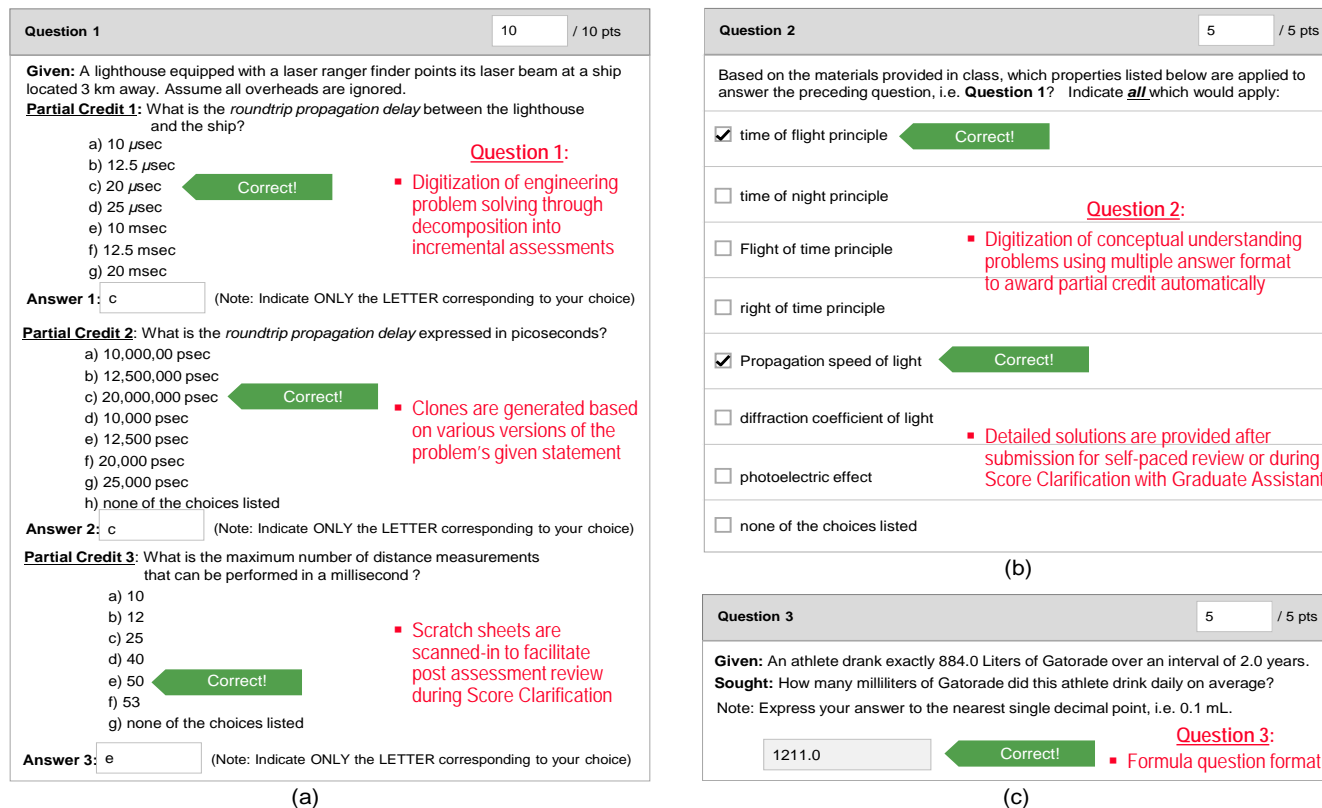
7

Figure 3. Sample question formats adapted for digitization, including (a) incremental solution, (b) multiple answer, and (c) formula-based problem solving.

3. **Showcase Presentation** (3 points). The purpose of the face-to-face showcase meeting during the final class session in Week 6 was to present the digitized assessment developed throughout the workshop for each participant's target course along with appropriate study set materials, with both loaded into the Canvas LMS. Showcase submission was mandatory and accrued up to 3 points, based on the completeness, robustness, and pedagogical innovation of each showcase submission.

At least 10 points had to be earned in order to satisfactorily complete the course, including the mandatory showcase submission during Week 6, consisting of a completed digitized quiz and corresponding study set loaded into the Canvas LMS and addressing the material covered in each targeted STEM course, attaining 10 or more points. The rightmost column of

Table II indicates the overwhelming majority of 2016 participants achieved a satisfactory or better submission for each activity.

A sample discussion activity is depicted in Figure 4 for a panel session of EPC proctors, tutors, and cloners, along with its corresponding discussion post. This was designed to engage faculty in debate and to elicit their consideration of the implications of the methods presented in the ADI workshop and the relevance to their targeted course(s). Faculty discussions were very active from this mechanism with some topics receiving as many as 43 posts. The summative course event included a showcase class meeting, which consisted of a symposium-style event in which each person enrolled in the course presented a fully digitized assessment developed for his or her course(s). Another primary goal of the ADI workshop was for participants to develop a study set for their course(s),
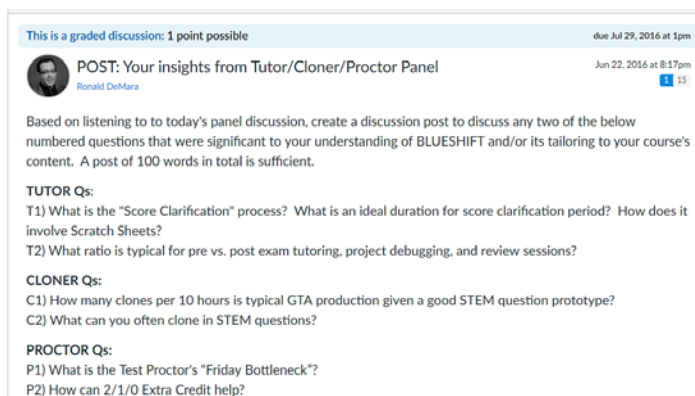

Figure 4. EPC staff panel in ADI workshop, where faculty interacted with EPC proctors and clone composers, and corresponding discussion for faculty.

with at least four solved problems. Participants were advised that effective study set questions might (a) impart sufficient confidence for students, allowing them to complete a digitized quiz without assistance, and (b) be designed as a pedagogical tool to replace corresponding graded homework. Second, participants were required to create a quiz based on the previously developed study set, providing questions that contain either partial-credit or multi-part strategies. Faculty were also required to provide at least one clone for one of their quiz questions, allocating appropriate points to each question. Finally, participants presented selected elements from their quiz and/or study set to other faculty and graduate assistant participants, while also providing brief summaries of design challenges encountered, as well as solutions in developing their digitized quiz and study set.

C. Participants and Incentives

Participants were faculty from UCF who volunteered to participate, and were incentivized with (a) a course release they could use in the upcoming fall or spring semester (both cohorts), (b) a certificate of completion (both cohorts), and (c) a $5,000 credit to hire a teaching assistant to assist with digitizing courses for one semester (Summer 2016 cohort only). Faculty from various fields within UCF's College of Engineering and Computer Science (CECS) participated, including civil, computer, electrical, industrial, and mechanical engineering, as well as computer science and information technology. Each participant targeted a single high-enrollment required undergraduate core course for which they would digitize assessments. Participants included first-year assistant professors, instructors, lecturers, tenure-track faculty, and tenured faculty up to and including full professors. Faculty members' level of experience with digitized assessments varied, but everyone learned information and techniques that were new to them. While faculty were encouraged to bring their teaching assistants to attend, questionnaire responses were only solicited from faculty.

D. The Evaluation and Proficiency Center

A critical purpose of the workshop series was to familiarize faculty with the CECS's Evaluation and Proficiency Center (EPC), which is a testing center where students can schedule and take digital assessments in a proctored environment, and even receive remediation via "score clarification" for missed questions. Using the Canvas LMS's Internet protocol (IP) filtering function, faculty can restrict accessibility of their assessments to the EPC's IP address. Students can "walk in" or schedule an appointment to take an assessment at the EPC during a testing window chosen by the instructor (e.g., Wednesday–Friday). Principally, the EPC reduces or eliminates the need for faculty to create new questions each semester, proctor exams, manually grade students' work, or entertain extensive office visits from students.

V. EXPLORING FACULTY PERCEPTIONS

In an effort to examine faculty perceptions of the content, processes, support, and pedagogical approaches implemented in the ADI workshop series, we designed an exploratory case study of experiences and perceptions. The primary source of information for evaluating the ADI faculty workshop was data received from post-workshop survey results. Our goals were to examine the effectiveness of the ADI workshop on influencing changes in faculty assessment and instructional approaches, disseminate program evaluation results to varied programs and stakeholders, reflect on our instructional practice, and both improve and extend future deliveries. The specific research questions were:

1. How did faculty participants perceive the benefits of digitizing assessments?

2. What changes can we make to future workshops to improve participants' perceptions and integration of digitized assessments?

A. Methods

Data from this study was derived from responses to a brief Qualtrics questionnaire disseminated via email solicitation on "digitization perceptions" 10 days following completion of the workshops. In addition to demographic information and a free-response prompt, items used a five-point Likert scale and were organized around perceptions of computer-based testing, mixed-mode delivery (e.g., flipped classrooms), and human resources.

VI. RESULTS

A. Q1: How Did Faculty Participants Perceive the Benefits of Digitized Assessment?

The post-workshop survey results were overwhelmingly positive. All respondents were "very satisfied" with the in-class sessions, the facilitators of the workshops, and the online modules. Specifically, they rated the program topics, examples, and resources provided to be highly relevant. The majority of the respondents agreed that the workshop will impact their future course design and development in beneficial ways, such as time-savings, convenience, student remediation, and the ability to serve large enrollments, as shown in Table III. Respondents indicated unanimously ($n = 13$) that the assessment digitization techniques presented were applicable to their targeted courses. Promisingly, 92% ($n = 12$) agreed that the digitization methods would improve their ability to serve large enrollments and enhance the convenience of assessment delivery in their course, and 77% ($n = 10$) agreed that the techniques can impart valuable time savings for themselves and their GTAs, meaning the freed-up GTA hours can be allocated to tutoring and increase their ability to identify areas for remediation. The majority ($n = 10$) also indicated valuable integrity benefits and the potential to increase learning outcomes.

Only a minority of ADI workshop participants ($n = 5$) responded that they perceived benefits to students' soft skills. We speculate this is because such benefits can vary significantly by degree program, and require a commitment to utilize score clarification procedures. Some participants preferred to opt out of score clarification whereby GTAs could discuss solution attempts documented on scratch sheets to

DEMARA et al.: ELEVATING PARTICIPATION AND OUTCOMES WITH COMPUTER-BASED ASSESSMENTS: AN
IMMERSIVE DEVELOPMENT WORKSHOP FOR ENGINEERING FACULTY

9

consider limited partial credit, and preferred to pilot this option before large-scale deployment in their course.

B. Q2: What Changes Can We Make to Future Workshops to Improve Participants' Perceptions and Integration of Digitized Assessments?

The open-ended answers from the post-workshop survey suggested areas to improve future deliveries to meet participants' needs and improve perceptions of digitizing assessments. A central focus of the workshop was to translate creative multi-part question types that are unique in STEM disciplines into digitized questions that an automated system can easily grade and at the same time provide a personalized support system to students in large-enrollment courses. In addition to these strategies, the participants were also interested in other assessment methods, such as free response questions, essay questions, computer programs, and other student-generated answers. A few participants also expressed interest in learning about collaborative assessments and peer-review strategies that are applicable to large classes. These are elements we plan to address in future workshops.

VII. Discussion

The post-workshop survey results indicated a high level of satisfaction among participants in the extensive and expansive incentivized professional development workshop. Participants were receptive to opportunities to integrate digitized assessments into their courses, as well as the altering instructional practices to maximize the pedagogical effectiveness of digitized assessments. Thus, the ADI workshop has achieved the goals we set at the beginning in terms of changing faculty perceptions of CBA, enhancing academic integrity in gateway engineering classes, and promoting the use of the EPC approach for high-gain learning activities, such as personalized tutoring and score clarification procedures. The

Figure 5. Digitization and the EPC explained to visitors from Cape Peninsula University of Technology and Tshwane University of Technology.

pedagogical benefits to students remain to be measured in follow-up research studies. We believe that the resources and lessons we obtained from this faculty workshop will not only

TABLE III
POTENTIAL IMPACT OF TWO ADI WORKSHOP COHORTS

Course Converted via ADI Workshop	Annual Enroll.	GTA Contracts Harvested
COP3223: Intro to C Programming	2227	5
EGN3321: Engr. Analysis – Dynamics	1126	3
EGM3601: Solid Mechanics	1100	1
EGN3343: Thermodynamics	970	2
EGN3310: Engineering Analysis – Statics	875	1
CDA3103: Computer Logic & Org.	650	2
EML3034: Modeling Methods in MMAE	550	1
EML4142: Heat Transfer	454	2
EEL3004: Electrical Networks	420	1
EEE3342C: Digital Systems	350	1
CAP4104: Human & Tech. Interaction	340	2
COP4331: Object-Oriented Software	300	0.75
ESI4234: Quality Engineering	150	0.75
CGN3700C: Civil Engr. Measurement	140	0
EEL4781: Computer Networks	140	0.5
ESI4221: Empirical Methods Ind. Engr.	125	1
CWR3201: Engineering Fluid Mechanics	110	0
Total	**10,027**	**24**

We have delivered the ADI workshop twice, to a total of 17 faculty members who implemented digitization in 17 courses across six degree programs. This has the potential to impact 10,027 students if all sections of every course are converted.

help us as we continually improve our future workshop offerings, but also provide faculty, instructional staff, and administrators of other higher educational institutions with new and reliable tools and strategies for designing and delivering faculty development programs for STEM disciplines.

A. Faculty Development Strategies

The participants' satisfaction is largely a result of the community-building activities throughout the workshop, including peer coaching, small-group discussions, and peer-review activities. One of the main instructors of the workshop is a tenured professor who has taught gateway engineering courses for over 20 years. Participants could easily relate to him and the resources that he has shared in the workshop. In the 2017 workshop, we also invited one graduate of the 2016 cohort to present her course materials and shared her digitization experiences in one of the class meetings. Therefore, participants had multiple opportunities to see how their colleagues implemented digitized assessments in teaching, and learned what works and what does not from real engineering courses. In addition, exchanges of ideas and suggestions were present throughout the program, both in the face-to-face classes and in the online discussions. For example, during the symposium-style showcase event, each participant presented a fully digitized assessment for the cohort. Participants provided rich feedback to each other and learned new tools and strategies. These collaboration activities were integrated throughout the workshop, providing opportunities for interaction, peer feedback, and building professional collegial relationships between participants and facilitators that may persist beyond the conclusion of the faculty development program. Employing these experiential, exemplar-centric, faculty-driven, and product-based methods for aligning innovative instructional

practices with the existing STEM conceptions of participating stakeholders were integral to participant satisfaction.

VIII. CONCLUSION

Embracing assessment digitization with the holistic approach conveyed via the ADI workshop has achieved several benefits. These include (a) increased student engagement by fortifying the integrity and impact of homework and exams, (b) elevating learning outcomes via tutoring and score clarification procedures facilitated by reduced grading loads, (c) increased ability to serve large enrollments using a hierarchical infrastructure and dedicated testing facility, and (d) the ability to adopt the instructional technology incrementally starting with individual quizzes progressing to summative assessments and laboratory integration.

We also see potential for significant cost savings while simultaneously improving pedagogical and research practices. For example, in Table III we see that the faculty who have participated in the ADI workshops potentially affect 10,027 students, which could harvest $600,000 of tutoring capacity at a per-GTA expense of $25,000 per year including stipend and prorated tuition. Then, these GTA contracts could be re-allocated toward high-gain research and teaching activities, benefiting graduate students and the research profile of the university, rather than being chiefly dedicated toward repetitive grading work. To further promote efficiency, smart scheduling enables the EPC to accommodate students during non-conflicting testing windows to maximize use of 120 available testing stations. As more faculty fully integrate the EPC into their courses, the EPC will be expanded to meet capacity.

Our results echo other research that has espoused the benefits of formative assessments, but extended this through tools and processes that allow for more robust formative assessment processes through digitization. This case study reflects the potential for extended professional development and technology experiences related to ways in which assessment digitization can positively impact teaching and learning in large-enrollment STEM courses. While additional research is needed, particularly related to the impact of digitized assessment on student performance and the long-term influence on faculty instructional and assessment practices, initial results have been promising and, consequently, the university has approved a third ADI workshop during the summer 2018 semester. Moreover, plans to expand the scope to other STEM disciplines, dissemination to visitors (Figure 5) and in broader venues, and collaborations with other institutions are being formulated to extend impactful and innovative pedagogical reform efforts in STEM, as well as explore the impacts of such reform efforts on faculty assessment and instructional approaches, as well as student achievement.

REFERENCES

[1] J. S. Krajcik and K. Mun, "Promises and challenges of using learning technologies to promote student learning of science," In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (1st ed.), Mahwah, NJ: Lawrence Erlbaum Associates, 2007, pp. 337–360.

[2] T. Miller, "Formative computer-based assessment in higher education: The effectiveness of feedback in supporting student learning," *Assessment & Evaluation in Higher Education*, vol. 34 no. 2, pp. 181–192, 2009.

[3] E. D. Britton and S. A. Schneider, "Large-scale assessments in science education," In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (1st ed.), Mahwah, NJ: Lawrence Erlbaum Associates, 2007, pp. 1007–1040.

[4] University of Central Florida Institutional Knowledge Management (2017). *Enrollment Statistics*. [Online] Available: https://ikm.ucf.edu/facts-and-reports/enrollment-statistics/

[5] L. B. Nilson, *Teaching at its best: A research-based resource for college instructors* (3rd ed.). San Francisco, CA: John Wiley & Sons, 2010.

[6] R. F. DeMara, S. Salehi, N. Khoshavi, R. Hartshorne, R., and B. Chen, (2016, June). "Strengthening STEM laboratory assessment using student-narrative portfolios interwoven with online evaluation," *American Association for Engineering Education Southeastern Conference*.

[7] W. Dick, L. Carey, and J. O. Carey, *The systematic design of instruction.* Upper Saddle River, NJ: Pearson Education, 2015.

[8] J. Walker, "Measuring plagiarism: Researching what students do, not what they say they do," *Studies in Higher Education*, vol. 35 no. 1, pp. 41–59, 2010.

[9] S. Şendağ, M. Duran, and M. R. Fraser, "Surveying the extent of involvement in online academic dishonesty (e-dishonesty) related practices among university students and the rationale students provide: One university's experience," *Computers in Human Behavior*, vol. 28 no. 3, pp. 849–860, 2012.

[10] B. Burbaugh, M. Seibel, and T. Archibald, "Using a participatory approach to investigate a leadership program's theory of change," *Journal of Leadership Education*, vol. 16, pp. 192–204, 2017.

[11] M. Jamil, R. Tariq, P. Shami, and B. Zakariys, "Computer-based vs. paper-based examinations: Perceptions of university teachers," *TOJET: The Turkish Online Journal of Educational Technology*, vol. 11 no. 4, pp. 371–381, 2012.

[12] V. Terzis and A. A. Economides, "The acceptance and use of computer based assessment," *Computers & Education*, vol. 56, pp. 1032–1044, 2011.

[13] A. A. Prisacari and J. Danielson, "Rethinking testing mode: Should I offer my next chemistry test on paper or computer?" *Computers & Education*, vol. 106, pp. 1–12, 2017.

[14] J. C. W. Debuse and M. Lawley, "Benefits and drawbacks of computer-based assessment and feedback systems: Student and educator perspectives," *British Journal of Educational Technology*, vol. 47, pp. 294–301, 2016.

[15] R. Brent and R. M. Felder, "A model for engineering faculty development," *International Journal of Engineering Education*, vol. 19, pp. 234–240, 2003.

[16] T. Huston and C. L. Weaver, "Peer coaching: Professional development for experienced faculty," *Innovative Higher Education*, vol. 33, pp. 5–20, 2008.

[17] M. T. H. Chi, "Active–constructive–interactive: A conceptual framework for differentiating learning activities," *Topics in Cognitive Science*, vol. 1, pp. 73–105, 2009.

[18] T. J. Kopcha, L. P. Rieber, and B. B. Walker, "Understanding university faculty perceptions about innovation in teaching and technology," *British Journal of Educational Technology*, vol. 47, pp. 945–957, 2016.

[19] M. Srikanth and R. Asmatulu, "Modern cheating techniques, their adverse effects on engineering education and preventions," *International Journal of Mechanical Engineering Education*, vol. 42, pp. 129–140, 2014.

[20] A. Fask, F., Englander, and Z. Wang, "Do online exams facilitate cheating? An experiment designed to separate possible cheating from the effect of the online test taking environment," *Journal of Academic Ethics*, vol. 12, pp. 101–112, 2014.

[21] E. Baran and A. -P. Correia, "A professional development framework for online teaching," *TechTrends*, vol. 58, no. 5, pp. 96–102, 2014.

[22] J. N. Kurtessis, R., Eisenberger, M. T., Ford, L. C., Buffardi, K. A., Stewart, and C. S. Adis, "Perceived organizational support: A meta-analytic evaluation of organizational support theory," *Journal of Management*, vol. 43, pp. 1854–1884, 2017.

[23] M. T. H. Chi and R. Wylie, "The ICAP framework: Linking cognitive engagement to active learning outcomes," *Educational Psychologist*, vol. 49, pp. 219–243, 2014.

[24] W. Fellin and G. Medicus, "Multiple choice tests: More than a time saver for teachers," *International Journal of Engineering Pedagogy*, vol. 5, no.3, pp. 15–24, 2015.

DEMARA et al.: ELEVATING PARTICIPATION AND OUTCOMES WITH COMPUTER-BASED ASSESSMENTS: AN IMMERSIVE DEVELOPMENT WORKSHOP FOR ENGINEERING FACULTY

11

[25] K. D. Schurmeier, C. G., Shepler, G. J., Lautenschlager, and C. H. Atwood, "Using item response theory to identify and address difficult topics in general chemistry." In D. M. Bunce (Ed.), *Investigating Classroom Myths Through Research on Teaching and Learning*, Washington, DC: ACS Publications, pp. 137–176, 2011.

[26] K. B. Lyle and N. A. Crawford, "Retrieving essential material at the end of lectures improves performance on statistics exams," *Teaching of Psychology*, vol. 38, no. 2, pp. 94–97, 2011.

[27] S. D. Angus and J. Watson, "Does regular online testing enhance student learning in the numerical sciences? Robust evidence from a large data set," *British Journal of Educational Technology*, vol. 40, no. 2, pp. 255–272, 2009.

[28] T. Yi and J. Mogilski, "A lesson learned from course re-design for flipped classroom," In *WSEAS Conference Proceeding, 13th International Conference on Education and Educational Technology*, pp. 21–26, 2014, 2014.

[29] P. M. Jansson, R. P. Ramachandran, J. L. Schmalzel, and S. Mandayam, "Creating an agile ECE learning environment through engineering clinics," *IEEE Transactions on Education*, vol. *53*, no. 3, pp. 455–462, 2010.

[30] K. A. Rawson, "The status of the testing effect for complex materials: Still a winner," *Educational Psychology Review*, vol. 27, no. 2, pp. 327–331, 2015.

[31] S. Magleby, (2010). *Statics: CE EN 103 Assessment Procedures* [Online]. Available: https://www.physics.byu.edu/faculty/magleby/index_files/General%20 index%20files/CE%20EN%20103%20Syllabus%20F2010S2.pdf.

[32] C. Zilles, R. T. Deloatch, J. Bailey, B. B. Khattar, W. Fagen, C., Heeren, D., Mussulman, and M. West, "Computerized testing: A vision and initial experiences," In *Proceedings of American Society for Engineering Education National Conference*, Seattle, WA: ASEE, 2015.

[33] L. Darling-Hammond, "Teacher quality and student achievement: A review of state policy evidence," *Education Policy Analysis Archives*, vol. 8, pp. 1–44, 2000.

[34] P. W. Hewson, "Teacher professional development in science." In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (1st ed.), Mahwah, NJ: Lawrence Erlbaum Associates, pp. 1179–1203, 2007.

[35] P. J. Tilgner, "Avoiding science in the elementary school," *Science Education*, vol. 74, no. 4, pp. 421–431, 1990.

[36] J. Kahle, "Teacher professional development: Does it make a difference in student learning?" *Draft testimony for US House of Representatives Committee on Science*, 2000.

[37] D. H. Monk, "Subject area preparation of secondary mathematics and science teachers and student achievement," *Economics of Education Review*, vol. 13, no. 2, pp. 125–145, 1994.

[38] P. D. Fisher, D. M. Zeligman, and J. S. Fairweather, "Self-assessed student learning outcomes in an engineering service course," *International Journal of Engineering Education*, vol. 21, no. 3, pp. 446–456, 2005.

[39] C. Henderson, A., Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature," *Journal of Research in Science Teaching*, vol. 48, no. 8, pp. 952–984, 2011.

[40] D. Pundak and S. Rozner, "Empowering engineering college staff to adopt active learning methods," *Journal of Science Education and Technology*, vol. *17, no.* 2, pp. 152–163, 2008.

[41] M. Borrego and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *Journal of Engineering Education*, vol. *103*, no. 2, pp. 220–252, 2014.

[42] R. F. DeMara, N. Khoshavi, S., Pyle, J., Edison, R., Hartshorne, B., Chen, and M. Georgiopoulos, "Redesigning computer engineering gateway courses using a novel remediation hierarchy." In *Proceedings of American Association for Engineering Education National Conference*, New Orleans, LA: ASEE, 2016, June.

[43] R. F. DeMara, S., Salehi, and S. Muttineni, "Exam preparation through directed video blogging and electronically-mediated realtime classroom interaction." *American Association for Engineering Education Southeastern Conference*, 2016, March.

Ronald F. DeMara (S'87–M'93–SM'05) is a Professor of Electrical and Computer Engineering at the University of Central Florida where he has been a faculty member since 1992. His educational research interests focus on classroom and laboratory instructional technology, and the digitization of STEM assessments. He has completed roughly 225 technical and educational publications, 40 funded projects as PI/Co-PI, and established two research laboratories. He serves as the founding Director of the Evaluation and Proficiency Center (EPC) at UCF, and is an iSTEM Fellow. He received the Joseph M. Bidenbach Outstanding Engineering Educator Award from IEEE in 2008.

Baiyun Chen is an Instructional Designer at the Center for Distributed Learning at UCF. She designs and delivers faculty professional development programs and teaches graduate courses on Instructional Systems Design. Her research interests focus on using instructional strategies in online and blended teaching and learning, professional development for teaching online, and application of emerging technologies in education. She has published 15 peer-reviewed journal articles and book chapters, delivered more than 50 presentations at international and local conferences and events, and served as the Co-Managing Editor of the Teaching Online Pedagogical Repository.

Richard Hartshorne is an Associate Professor and Coordinator of the Instructional Design & Technology program in the College of Education & Human Performance at UCF, with 13 years of university-level faculty experience. His teaching, research, and service interests are rooted in virtual teaching and learning environments, technology and teacher education, and the integration of emerging technology into the K–post-secondary curriculum. He has authored or co-authored 29 manuscripts, 12 book chapters, and co-edited two books. Additionally, he has over 110 conference and workshop presentations, and has written or co-written educational research grants totaling over $1.2M.

Richard Thripp is a Ph.D. student in Education, Instructional Design and Technology at University of Central Florida, having earned a B.S. in Psychology and M.A. in Applied Learning and Instruction from UCF in 2014 and 2016, respectively. His research interests are financial literacy education, and, secondly, the use of technology to improve the productivity and effectiveness of learners and educators. Presently, he instructs two sections of EME 2040: Introduction to Technology for Educators at UCF.