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The Role of Massive Open Online Courses (MOOCs) in Engineering Education: Faculty Perspectives on its Potential and Suggested Research Directions*

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Massive Open Online Courses quickly infiltrated higher education, leaving little time for large-group discussions on their role in engineering education. We argue that a research agenda around the role of MOOCs in engineering education is necessary for fully leveraging them in our context. While four articles published between 2011–2015 outline future directions for MOOCs research, previous studies did not gather input from the community on the most pressing research needs, corresponding corresponding questions, or the research needs unique to engineering education. The purpose of this study is to present a research agenda around the role of MOOCs in engineering education that is informed by multidisciplinary perspectives (i.e., MOOCs, learning science, and engineering researchers and practitioners). Three NSF-funded workshops took place at engineering conferences throughout 2014 to facilitate the accomplishment of this goal. Thematic analysis of 65 workshop participants' survey responses led to an agenda that includes six research foci—namely, MOOCs participants; MOOCs course design; MOOCs technology development, delivery, and adoption; the role of MOOCs across education contexts; administrative concerns involving MOOCs; and MOOCs as a platform for large-scale education research. Ten to fifteen corresponding research questions per foci are presented. Implications of this work within and beyond engineering education are also discussed.

Keywords: MOOCs; research agenda; engineering education

1. Introduction

Online education has been around for many years, but "what changed in 2011 [with MOOCs] was scale and availability" [1, p. 1]. MOOCs are a genre of cyberlearning that virtually bring together vast numbers of learners and experts to engage in a shared education experience that oftentimes mirrors the length and structure of traditional on-campus courses [2–4]. They are a venue for a heterogeneous group of learners to explore a topic area connected with a learning objective, and oftentimes lead to unique products developed by students that are unlike most educational settings (e.g., blog posts, images, videos, diagrams) [4]. Many editorials and scholarly works alike have commented on MOOCs' tremendous potential for advancing the goals of higher education and learners from "K-grey" [e.g., 3, 5–7]. One Forbes article hinted at MOOCs' transformative potential by asking, "Could high-quality MOOCs eventually do to traditional colleges and universities what Craigslist has done to classified advertising in newspapers and what Wikipedia has done to encyclopedias?" [8, p. 1]. Academic institutions are highly-motivated to engage with MOOCs because of their potential to increase access to education opportunities, promote and maintain their institution brand, improve economics (i.e., reduce cost or increase revenue), advance educational outcomes, facilitate innovative teaching practices, and provide a context for conducting research on teaching and learning [3, 4, 9–12]. Though many have cited MOOCs' potential, there are parallel conversations calling for more research on MOOCs before widespread adoption [12, 13].

Today, there is a growing body of literature on MOOCs that is beginning to address both fundamental and applied topics of interest. Most of the early research on MOOCs came in the forms of editorials and reports produced by institutions discussing their MOOCs-related activities [14–17]. Though valuable, such reports lack the rigor associated with peer-reviewed scholarly publications, which tend to have strong theoretical and methodological framework to guide insights. More recently, however, several rigorous scholarly publications have emerged on: a review of MOOCs literature [e.g., 18], the experiences and performance of MOOCs learners [e.g., 19], learning theories

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underpinning MOOCs [20], instructional quality [e.g., 21], technological considerations for scaling up [22], and articulations on how MOOCs affects diverse stakeholders in higher education (e.g., accrediting bodies, book publishers, career counselors) [23]. While the majority of these studies were not conducted with a particular disciplinary focus in mind, some disciplines are more represented in MOOCs scholarly conversation than others. The focus of this study is engineering education, with the expectations that the findings are relevant beyond the original context of interests.

2. MOOCS and engineering education

Engineering continues to be a discipline that is of national interest [24–30] and is a field that is particularly interested in integrating MOOCs into its educational ecosystem. There have been numerous calls by policymakers to reform engineering education. Of particular interest in engineering education are (1) the need to improve the quality of engineering education and (2) to increase the quantity and diversity of engineers [25–30]. Leveraging the latest technologies is one of the five major shifts in engineering education that have occurred over the last century that helps support these overarching goals to improve quality, quantity, and diversity of engineers [31]. MOOCs are just one example of the latest technologies that can help facilitate this. (The other four are: (1) shifts from hands-on and practical emphasis to engineering science and analytical emphasis; (2) shifts to outcomes-based education and accreditation; (3) shifts to emphasizing engineering design; and (4) shifts to applying education, learning, and social-behavioral sciences research.)

3. Motivation

MOOCs infiltrated higher education at such a rapid pace that there has been little time for large groups of education researchers and practitioners to gather to have meaningful conversations about its potential, drawbacks, sustainability, and research questions that need to be addressed. One of few examples of this type of activity is San Jose State University's MOOCs in STEM Education conference that was hosted in summer 2014 [32]. Without such conversations, it is possible for large groups to become busy adopting the latest education technology, and miss the opportunity to strategically leverage it to improve student learning and advance the multifaceted mission of higher education. Moreover, the integration of MOOCs in engineering education should be strategic, not simply reactive. We argue that a research agenda around the role of MOOCs in engineering education (that includes both topics of research and corresponding questions) is necessary for fully leveraging them in our context. Such would facilitate a more strategic integration of MOOCs in higher education, in general, and engineering education, specifically.

The research presented in this paper connects to a NSF-funded study on the role of MOOCs in engineering education. The three goals of the overarching study were to: (1) organize a workshop series that would bring together experts on MOOCs, learning science, and engineering education to discuss MOOCs in engineering education; (2) stimulate the development of a virtual community of engineering educators interested in MOOCs [33]; and (3) identify a set of research questions around MOOCs and student learning in engineering education. The goal of this paper is to present a research agenda around the role of MOOCs in engineering education that is informed by multidisciplinary perspectives.

4. Literature review

4.1 Overview

The current literature on MOOCs is fragmented and covers disparate topics. Peer-reviewed scholarly articles on MOOCs began showing up in the literature in 2008 [e.g., 34] and continues to increase [see review in 18]. More recently, there have been studies outlining suggested research directions for MOOCs. Such articles serve as a starting point for unifying the literature on this topic and will be synthesized in this review.

Four articles published between 2013–2015 outline future directions for MOOCs research [18, 35–37]. One research agenda was developed as a result of conducting an analysis of the topic of MOOCs-related proposals submitted to the Bill and Melinda Gates Foundation's funding opportunity to support MOOCs research [35]. It includes five categories for future research: (i) student engagement and learning success; (ii) MOOC design and curriculum; (iii) self-regulated learning and social learning; (iv) social network analysis and networked learning; and (v) motivation, attitude and success criteria. Another collection of suggested research directions was included in the discussion section of a systematic literature review on MOOCs articles published between 2008–2012; it includes the gaps in the literature that emerged after conducting the analysis [18]. A third article was written by the Computing Community Consortium (CCC) and was the result of a workshop to "elaborate a research agenda for computing-enabled online education over the next 5–10 years" [36, p. 5], and

outlines five cross-cutting themes in their research agenda: (i) access to education; (ii) integrating cloud and campus; (iii) collaborations and community; (iv) from massive and open to ubiquitous; (v) designing MOOE for research (where MOOE stands for Massive Open, Online Education to denote an extension beyond MOOCs). Lastly, a short perspective in *Science* magazine entitled "Rebooting MOOCs Research" proposes three areas of emphasis for future MOOCs research [37].

While there are distinctions between the research agendas, there are unifying themes. These four themes will be discussed in the remainder of this literature review and provide the basis for this study on multidisciplinary researchers and practitioners' perspectives on research directions for MOOCs scholarship. The four themes are: (1) *MOOCs Participants*; (2) *MOOCs Course Design & Technology Development*; (3) *Administrative Concerns Regarding MOOCs*; and (4) *MOOCs as a Platform for Large-scale Education Research.*

4.2 MOOCs participants

Many of the proposed research directions across the four articles [18, 35–37] include an emphasis on the people participating in MOOCs. Participants include learners—both in the U.S. and abroad—and instructors. As it relates to individual learners, in general, Gašević, et al. [32] recommend research on student motivation, attitudes, engagement, success criteria, and self-regulated learning. Liyanagunawardena, et al. [18] also highlighted the need for more research on MOOCs' learners motivation, but added the nuanced focus on variations in motivation by parameters such as course, discipline, and provider. Furthermore, this research agenda also called for research on the experiences of MOOCs participants who do not complete the course [18].

While much of this research was focused on individual learners, there were a significant number of research directions focused on groups of learners. For example, Liyanagunawardena, Adams, and Williams [18] noticed a lack of qualitative studies on the use of external communications to support learner groups, and a shortage of literature on the cultural differences of MOOCs participants and their experience. Gašević, Kovanović, Joksimović, and Siemens [35] also added to this need for research on MOOCs learners as a group by highlighting the need for more MOOCs research including social network analysis and focused, networked learning, and social learning.

One last dimension of this research theme was related to broadening access to education. More specifically, Liyanagunawardena, Adams, and Williams [18] discussed the need for research on MOOCs provisions in developing countries. On the other hand, the CCC report [36] talked quite extensively about research directions at the nexus of MOOCs and access. The authors began by stating the issue this way: "The question of access to education is both alleviated and exacerbated by MOOE systems" [36, p.9]. Namely, MOOCs can be tool for improving access to educational materials, but also barrier to it as well since the prerequisite for this access is basic infrastructure (i.e., technology and otherwise) to support it. This reference to technology needs in a MOOC learning environment leads into the second of four research emphases in the literature.

4.3 MOOCs course design & technology development

Calls for research on *MOOCs Course Design & Technology Development* were discussed frequently in the articles suggesting future research directions [18, 35–37]. Course design may include anything from the content, to the assessment, and to the pedagogy [38]. While Gašević, Kovanović, Joksimović, and Siemens [35] broadly state the need for research on MOOCs design and curriculum, others mentioned more unambiguous research topics. For example, as it relates to content, Reich [37] highlight the need to experiment with open-ended problems such as design problems. Coincidently, this is the only explicit reference in the literature to a phenomenon that is integral to engineering education (e.g., engineering design, and design thinking) [31]. This call for more open-ended problems in MOOCs course designs also links to the need for future MOOCs that are developed on collaborative platforms and include more immersive environments—environments that would facilitate design thinking and collaborations among MOOCs learners. The CCC report [36] put it this way, MOOCs mediate more "compelling interactions among various levels of granularity" besides discussion forums, chat, video conferencing [36], but this potential has not been realized. This report also adds that immersive environments should become integral parts of the MOOCs technology design because it can improve characteristics like emotional engagement. These are just some examples that reveal the connection between MOOCs course design and MOOCs technology development.

One article in particular expounded on the need for more research on assessing learning in a MOOC environment. More specifically, Reich [37] calls it "Watching without learning", and goes on to discuss the need for "better assessment structures that support robust inferences about learning" [p. 34]. Such assessments should exhibit three characteristics: (a) they should take place at multiple points (with a particular emphasis on pretest); (b)

the assessment should capture multiple dimensions of learning, from procedural to conceptual; and lastly, (c) the assessments that are used should have been validated by prior research (in order to facilitate comparisons to other settings). The other articles citing MOOCs research directions rarely mentioned questions around assessing student learning.

Lastly, the articles on MOOCs research directions cite three other technological development-related needs; again, this closely links to pedagogical approaches that can be used in a MOOC context. The immense amount and types of data associated with MOOCs is one aspect of why they are defined as "massive" [4]. While tremendous potential awaits those interested, willing, and skilled to tackle MOOCs' big data, the amount of data can lead to information overload for many. In light of this, Liyanagunawardena, Adams, and Williams [18] highlight the need for research-based solutions, including technology solutions, to the information overload problem that exists in MOOCs environments for both instructors and students. Moreover, the CCC report discusses the need for design principles for the future of MOOCs. This report also speaks to a need that involves both MOOCs course design and technological development: the authors of the CCC report state that MOOCs "invigorate ideas that education and learning can be *intentionally* continuous" [36, p. 33]. In order for this to happen however, there would be a need to go "from massive and open to ubiquitous" [36, p. 33]; MOOCs need to be designed with out-of-school learning experiences in mind. The third area of emphasis in the literature shifts from the learners, courses, and technology to focus on some of the infrastructure supporting MOOCs.

4.4 Administrative concerns regarding MOOCs

The third area of research emphasis that is briefly discussed relates to the institutions partnering with MOOCs entities to offer them. While the institutions' motivations to engage with MOOCs have already been discussed in the introduction of this article, there is a need for scholarly work on both the institutional threats and opportunities [18]. Additionally, there is a need for studies surrounding how learners obtain recognition for their work, and the interplay between MOOCs and accreditation [18]. While there are many other administrative issues surrounding MOOCs, these are the two that were mentioned among the articles outlining future directions for research on MOOCs [18, 35–37]. The last area of emphasis shifts from participants and administrative issues to conducting research with MOOCs.

4.5 MOOCs as a platform for large-scale education research

The fourth research focus that frequently shows up among the research agendas is the notion of MOOCs as a tool for conducting research. Liyanagunawardena, Adams, and Williams [18] offer suggested research topics related to the data associated with MOOCs. Two ideas include research on best practices for handling MOOCs data, and an exploration of MOOCs participants' views on ethical aspects of using publicly available MOOCs data. Gašević, Kovanović, Joksimović, and Siemens [35] touch on the data issue differently by citing the need for technical and policy solutions on data sharing that allow researchers to query repositories of MOOCs data without facing privacy issues. The CCC report highlights how learning science research has advanced because of MOOCs, but add that MOOCs can be a compelling vehicle for research outside of learning science as well. For example, MOOCs can be a context to explore new computing technologies (e.g., gaming, artificial intelligence, visualizations), and broader topics like cultural blending and organizational development [36]. One distinction in the Reich [37] article is the call for more discipline-based research to understand domain-specific learning in MOOCs and argues that such insights may be a necessary condition for effectively leveraging domain-independent research. This need is part of the motivation for the current study.

In summary, the current literature on what should be the future research directions for MOOCs research focuses on participants, the course design and technological development, institutional concerns, and MOOCs as a platform for conducting research. In all four cases, the suggested research directions were informed from a review of the literature and/or the opinions of online learning experts. Because MOOCs is, by nature, an educational effort that involves collaborations across various dimensions of the higher education landscape, there is a need to be have large group conversations including multidisciplinary perspectives around the research needs if we want to be strategic about how we leverage MOOCs This study adds to the literature contributing a research agenda around MOOCs in a particular discipline and is informed from the perspectives of MOOCs, learning science, and engineering education practitioners and researchers—the kinds of people who would either serve as the MOOCs instructor and/or lead research projects focused on MOOCs. Furthermore, this study addresses this need for more focused research efforts in the context of engineering education, with the expectation that the research

findings will be useful both in and beyond the original context of interest.

5. Methods

5.1 Overview

This study brought together experts in engineering education, MOOCs, and learning science to discuss the potential for MOOCs in engineering education and suggested research directions. This was done by hosting workshops at engineering research conferences throughout 2014, and inviting participants to share research questions they think should be included in research agenda on MOOCs in engineering education. The submissions were analyzed using thematic analysis [39, 40]. Details surrounding the data collection, participants, and analysis will be discussed next.

5.2 Data collection

As part of this study, the authors of this paper organized a four-part workshop series targeting annual engineering education research conferences throughout 2014. We targeted faculty in mechanical engineering, electrical engineering, biomedical engineering, and a multidisciplinary group of people engaged in engineering education research and practice. The rationale for targeting MEED & ECEDHA was to garner the perspectives of department heads of two of the largest engineering disciplines. Additionally, we were interested in the perceptions of people who serve as lead change agents within an engineering department [41]. The motivation for hosting a workshop at ASEE was to include the perspectives of engineering education researchers and practitioners across a wide range of disciplines, levels of tenure, and people who were not tenure track faculty but were somehow engaged in engineering education research. The rationale for targeting BMES was to reach engineering faculty in one of the smallest, but fastest growing engineering disciplines [42–44]. Unfortunately, the BMES workshop was cancelled because only two people registered for the workshop. Table 1 summarizes the logistics of the workshops in the series where we collected data.

The format of each workshop was the same. It began with panelist presentations and concluded with a moderated, interactive discussion between panelists and participants. Workshop participants completed three surveys before, during, and after the workshop. When planning the study, the goal was to ensure that multiple perspectives on the role of MOOCs in engineering education were represented on the panel. To this end, each panel included 3–5 people representing three diverse perspectives: (1) at least one person with expertise and research interests in the engineering content associated with the conference and MOOCs (or another closely related cyberlearning topic), (2) someone with expertise on the science of learning—particularly in online settings; and (3) someone from one of the three major MOOCs (i.e., Coursera, edX, or Udacity). (Panelist information is included on the project website [33]. (The project website was developed to provide a forum for workshop attendees to connect and to post information related to the project (e.g., project description, panelists' presentations slides, relevant scholarly resources.) In addition to presenting highlights of their relevant research, each panelist prepared responses to two overarching questions about the potential MOOCs has for improving student learning in engineering, and the research questions we need on MOOCs to improve student learning in engineering education.

After all of the panelists completed their 15-minute presentations, there was a moderated, interactive discussion among panelists and participants. One week prior to the workshop, panelists were emailed a list of 3–5 possible questions the moderator may ask during the panel session, and were encouraged to prepare thoughtful responses. Participants were given an opportunity to ask each panelist questions about topics mentioned in their presentation during this part of the workshop. There were two scribes at each workshop to document the workshop discussions. Additionally, participants were encouraged to complete a survey at the beginning, middle, and end of the workshop.

Table 1. Summary of Workshop Series Logistics & Target Audience

Conference Name	Dates & Location	Target Audience
ASME Mechanical Engineering Education Leadership Summit (MEED)	March 13–15, 2014 (San Juan, PR)	Mechanical Engineering Department Heads
Electrical & Computer Engineering Department Heads Association Annual Conference (ECEDHA)	March 21–25, 2014 (Napa, CA)	Electrical and Computer Engineering Department Heads
American Society for Engineering Education Annual Conference (ASEE)	June 15–18, 2014 (Indianapolis, IN)	Faculty across Engineering Disciplines

Table 2. Summary of Workshop and Survey Participants

Conference	Total of Workshop Participants	Number of Survey Respondents
MEED	117	17
ECEDHA	25	5
ASEE	65	43
Total	207	65

Table 3. Proportion of Survey Respondents by Role

Faculty	Admin. only	Admin. & Faculty	Researcher only	Other	Anonymous	Total ($n = 65$)
29%	5%	25%	9%	11%	21%	100%

Responses to one open-ended survey question are the results in this study. The survey question of interest is: *What research do we need on MOOCs to further gains in student learning? (Provide research questions.)*

5.3 Participant information

The workshop was included in the conference bulletin, listed among all the other sessions at the conference. While Table 2 summarizes the number of participants who attended the conference and who completed the survey, Table 3 summarizes the role of the survey respondents.

Collectively, over 200 people attended the three workshops in this series. Among those who attended, nearly one third completed at least one of the three surveys distributed during the workshop. The survey responses reflect a balance of roles among tenure-track faculty, higher education administrators, and researchers (who were not on the tenure-track). Those in the "other" category include industry and/or policy personnel engaged in the engineering education community (as evidenced by their attendance at ASEE, an annual engineering education research conference).

5.4 Analysis

The results of this study include workshop participants' responses to the following survey question: *What research do we need on MOOCs to further gains in student learning? (Provide research questions.)* Thematic analysis [39, 40] was used to analyze responses to this question. Boyatzis [39] describes three approaches to thematic analysis [p. 37]; this study uses the "prior-research-driven approach" to thematic analysis. More specifically, the four themes from the literature were used as codes for analyzing the data. Again, the four main codes are: (1) *MOOCs Participants*; (2) *MOOCs Course Design & Technology Development*; (3) *Administrative Concerns Regarding MOOCs*; and (4) *MOOCs as a Platform for Large-scale Education Research.* For the instances where the suggested research questions did not fit within these codes, they were analyzed inductively (using the "data-driven approach" to thematic analysis).

Most participants' responses were submitted in the form of research questions, and others wrote topics of research questions but did not state the idea in the form of a question. Both the research questions and topics were coded using the *a priori* codes (for the responses that aligned with the existing codes), and inductively (for those that did not align).

In some instances, duplicate and similar questions and topics were among the responses. We define duplicate responses as those that reflect the same idea, but were worded slightly differently. On the other hand, we define similar responses as two responses that have many of the same ideas, but one response is an expansion of the other. In this case, the two responses were collapsed into one, and the resulting response was inclusive of all the ideas reflected in the two original responses. Provided is an example of a set of responses that include an example of both duplicate and similar responses.

Response 1: *"What are the attributes of a successful MOOC student?"*
Response 2: *"What are the characteristics of the successful MOOCs students?"*
Response 3: *"What are the characteristics of students who choose to take MOOCs and thrive in the environment?"*

All three responses were coded as "MOOCs Participants", and the resulting research question included in the results section is: *"What are the attributes of students who choose to take MOOCs and thrive in the environment?"* A secondary coder reviewed all assignments of research question to codes; coding was modified if necessary.

To accommodate the two types of responses (i.e. research foci and research questions), the Results sections of this paper includes a short summary—to

capture the patterns in ideas across the set of related responses in the form of topics—along with the research foci and their corresponding research questions.

6. Results

6.1 Results overview

Workshop participants (including panelists and attendees) in all three workshops in the series answered the question: *What research questions do we need on MOOCs to improve student learning in engineering education?* The participants submitted 79 research questions; 72 unique research questions resulted from consolidating duplicate and similar responses.

The ideas reflected in the responses center on six research foci: (1) MOOCs Participants; (2) MOOCs Course Design; (3) MOOCs Technology Development, Delivery, and Adoption; (4) Role of MOOCs Across Education Contexts; (5) Administrative Concerns Involving MOOCs; and (6) MOOCs as a Platform for Large-scale Education Research. While some of the codes used from the literature did not need to be modified to fit the responses (i.e., themes one, five and six), others needed to be modified (i.e., themes two, and three) and one needed to be added (i.e., theme four). The rest of this section includes a brief overview of the research focus and the ten to fifteen research questions corresponding to each research foci.

6.2 MOOCs participants

There is a need for research on the motivation and attributes of people who enroll and/or persists in MOOCs. Moreover, it would be useful to have more insight on MOOCs learners' perceptions of the added value of completion and attributes of MOOCs participants after completing the course (e.g., upon graduation). Apart from research on the learners, we also need to consider the instructional needs of faculty teaching MOOCs and develop open source tools to support them. Furthermore, there is a need for studies on both participants simultaneously. One example might include studies on the alignment of learning styles and instructional modes in a MOOC context, preferably according to students' demographic details (e.g., level of achievement, ethnicity). Table 4 lists the research questions associated with the "MOOCs Participants" research focus.

6.3 MOOCs course design

While there were a series of responses focused on the people involved with MOOCs, participants also shared a plethora of suggestions surrounding facets of the course and the technology to support the course design. In the literature these two ideas were linked to one theme, largely because the pedagogical practice of MOOCs instructors is closely tied to the technology that enables it. However, the two ideas were disaggregated in these results because there were enough unique ideas associated with each aspect of the theme to warrant two separate themes.

As it relates to course design, participants spoke often about the need for research related to the content, assessment, and pedagogy that take place in a MOOC environment. Content-related ideas centered on identifying the subjects that might be best suited for MOOCs, learning objectives, and the possibility of using MOOCs to generate concept inventories. The assessment-related ideas focused on the need to develop ways to assess learning in a MOOC, and continual, formative feedback at scale.

Table 4. Research questions for "MOOCs Participants"

Subgroup	Research Questions
Characteristics	• What are the attributes of people who chose to enroll in MOOCs and thrive in the MOOC environment? • What distinguishes domestic learners from international learners enrolled in MOOCs?
Factors for Success	• What factors make the difference for student success in a MOOC? • What can be done to improve interactivity and interdependence among learners in a MOOC? • How do we train future faculty in engineering education AND cyberlearning?
Motivation	• How do we improve student motivation to complete MOOCs? Is completion important outside of accreditation-/credit-based context? • What benefits are seen by learners who do not desire/intend to complete MOOCs in the traditional style (i.e., "a la cart" learners)? • What persuades learners with college degrees to contribute to MOOC courses? How can platforms encourage more to enroll? • When given comparable options, how do people decide which MOOC to enroll in?
Outcomes	• Are MOOCs reaching the demographic that needs educational support? • In what ways should the next version of MOOCs be designed to adapt to students' varying learning capabilities in order to be effective for different skill levels? • What impact does MOOCs have on students' long-term academic performance?

Table 5. Research questions for "MOOCs Course Design"

Subgroup	Research Questions
Content	• How can MOOCs be used to generate concept inventories? • Is there a classification of subjects that work better/worse for MOOCs? What styles of MOOCs can be tuned to student learning styles and subject matter (rather than determining the "best style")? • Can we develop content and/or study how to best present content for various engineering disciplines (e.g., Chemical Engineering, Biochemical Engineering)? • How can we tailor the course logistics to promote flexibility in scheduling while ensuring that students successfully attain the desired competencies in a designated amount of time?
Assessment	• How can course objectives be described in a way that specifies key competencies and informs course grades given the typical MOOCs completion rates? • What combinations of valid and reliable assessments need to be developed and/or used to study the attainment of learning outcomes in a MOOC environment? • How can MOOCs evaluations work in ways that are most useful to potential or current employers of MOOCs learners?
Pedagogy	• In what ways should MOOCs pedagogy be designed to incorporate higher order thinking skills (e.g., problem identification, innovation in design, critical thinking, metacognitive skills), hand-on learning activities, and promote engagement throughout the course? • What are the optimal teaching styles that are most compatible with MOOCS? Are there teaching methods that could be combined with MOOCs to give students a better learning experience? What MOOCs instructors do students love or hate, and why? • In what ways does MOOCs present an opportunity to engage students throughout the course? • How can MOOCs be to leveraged to support hands-on learning, anytime, anywhere? • How might we take advantage of what is known about how people learn to inform the course design in MOOCs? • What in-class activities best supplement MOOCs? • What are natural/inevitable consequences of employing the MOOCs format?

Suggested research ideas related to pedagogy highlighted the need for research on how to engage the learners, provide hands-on activities, promote interactions among students, and enable mentoring in a MOOCs setting. Table 5 lists the research questions associated with the "MOOCs Course Design" research focus.

6.4 MOOCs technology development, delivery and adoption

Participants shared research topics and questions about designing courses on the MOOC platform, adopting existing MOOCs technology for a new context, and metrics for evaluating MOOC developments. Table 6 lists the research questions associated with "MOOCs Development, Delivery, and Adoption".

6.5 Administrative concerns regarding MOOCs

Apart from sharing research ideas and questions related to the MOOCs participants, courses, and technology, there was another set of survey

Table 6. Research questions for "MOOCs Course Development, Delivery, & Adoption"

Subgroup	Research Questions
Development	• How do we develop virtual laboratories and hand-on activities for MOOC environments that work across disciplines? • In what ways does MOOCs cause us to rethink the metrics for evaluating the efficacy of a course, curriculum, and students performance? What should be the standard metrics for evaluating a MOOCs' effectiveness? • What new pedagogical approaches does the MOOCs platform afford? • What can be done to improve the interaction and interdependence among MOOCs learners and instructors? • Is MOOCs content fully open-source and modular? What are the implications of this? • How much time do you have to spend on developing a MOOC? What kinds of expertise need to be on the development team?
Adoption	• What role can federal funding agencies (e.g., NSF) play in facilitating adoption and developing a repository of effective MOOCs and MOOCs-related resources?
From Development to Adoption	• How do we get around the bottleneck of proctored, in-person exams? How do we best implement them; and will the implementation differ based on discipline and topic? • How do you move from development to implementation more efficiently? What templates are needed for efficient adoption/adaptation? • What are the best practices for MOOCs development, implementation and adoption across topics and disciplines? • What are best practices for MOOCs design, delivery, adoption, and management? How can MOOCs data analytics improve the way MOOCs are designed and delivered? • How can Bess' model of team teaching [45] be helpful when developing and implementing MOOCs?

responses focused on administrative issues associated with MOOCs. More specifically, participants mentioned the need for research that focus on MOOCs as part of admissions decisions, credentialing students taking MOOCs from other universities, accreditation of MOOCs courses, and academic integrity among MOOCs learners. Others mentioned the need for empirical research and case studies providing models of financial aid packages to students enrolled in MOOCs, cost-benefit analysis, return on the investment, and insights on who owns the intellectual property of data associated with MOOCs. The research questions corresponding to "Administrative Concerns Regarding MOOCs" are listed in Table 7.

6.6 Role of MOOCs across education contexts

The last two themes take another shift from focusing on a particular MOOC at a particular institution to situating MOOCs in a broader context. This collection of suggested research ideas and questions are about how MOOCs can play a strategic role in K-12 education, higher education, informal learning, and workforce development. There are also questions focused on the relationship between MOOCs and other forms of cyberlearning. The research questions associated with the "Role of MOOCs Across Education Contexts" research theme are listed in Table 8.

6.7 MOOCs as a platform for large-scale education research

One participant succinctly articulated the need associated with this theme in the following way, "We need more coordinated, comprehensive research studies and sharing of data." Some areas of emphasis for this research focus include understanding the MOOCs' experiences from the perspective of instructors and learners, the development of data analysis methods for analyzing large qualitative and quantitative data sets, and using MOOCs as a venue for improving our understanding of how

Table 7. Research questions for "Administrative Concerns Regarding MOOCs"

Subgroup	Research Questions
Administrative Decisions & Concerns	• What are the institutional barriers to adopting MOOCs in courses and programs? • How do schools brand their project if they use a MOOC deployed by an instructor at another institution? • Who owns the intellectual property of MOOC elements (e.g., discussion boards content)? • Should MOOCs faculty be provided full-time hire status by their home institution?
Credentialing & Accreditation	• Considering the extreme resource requirement to develop new MOOCs, is it possible to pool resources and collaborate to develop an inter-institutional MOOC credits that are recognized by accrediting bodies or integrated into on-campus courses? • What does it take for MOOCs to be accepted by accrediting bodies? • What are effective and efficient ways to address academic integrity issues in MOOCs?
Financial	• What new business models will effectively combine instructional quality, lower costs, and increase access to quality education? • What financial models make MOOCs a viable option for more than select institutions? • What is the relationship between the initial investments in setting up a MOOC and its effectiveness?

Table 8. Research questions for "Role of MOOCs Across Education Contexts"

Subgroup	Research Questions
Role Across Formal Education	• How can MOOCs be used to expose K-12 students to institutions of higher learning, STEM domains, and prepare first-year students before they arrive on campus? • How can MOOCs be used to personalize the learning experience in core engineering classes to students in other majors (e.g., Industrial Engineering students taking Thermodynamics courses; Mechanical Engineering students taking Circuits)? • In what ways does MOOCs present an opportunity to diversify the engineering student population and enrich the engineering curriculum? • What can MOOCs provide as a department cultural media? • How is MOOCs causing higher education to rethink how to use face-to-face time? • How can MOOCs help advance the mission of the university? • How can MOOCs be used to build communities around topics/courses across institutions? How would faculty be rewarded for participating in this kind of activity?
Role in Informal & Lifelong Learning	• In what ways might MOOCs make higher education more accessible to people in the workforce? • How do MOOCs fit into the overall educational experience of students? • In what ways does the need for Internet access and social networking skills pose issues for the digital divide?
Role in Online Learning	• How might MOOCs serve as a repository and organizing structure for the vast array of online content? • Is it possible to keep MOOCs research separate from research on flipped classrooms? • What are the differences between online learning or e-learning and learning in a MOOC? What should be done to transfer online learning and e-learning content to a MOOC?

Table 9. Research questions for "MOOCs as a Platform for Large-scale Education Research"

Subgroup	Research Questions
Participants' Experiences	• What impact does a discussion board with multiple perspectives have on comprehension of the course material? What are common misconceptions, most missed questions, or difficult concepts to learn? • How do MOOCs experiences for traditional age, on-campus students affect maturity, self-efficacy, and lifelong learning orientations? • What is the nature of the lived experience of instructors and learners in a MOOC? • What is the quality of student participation while online? • What are the patterns of MOOC students' study? Do MOOCs students spend more time in study or is the amount of time they spend equivalent to that of face-to-face students?
Employing Diverse Research Methods	• How might ethnographic studies provide insights on successful experiences of communication, interaction and collaborations among MOOCs students? • How might linguistic analysis be used to study a MOOC phenomenon?
Advancing Discovery	• How can the big data generated from MOOCs be leveraged to enhance our understanding of how people learn? • In what ways does MOOCs represent a nexus for brain science, cognitive science, and education research? • What changes in scholarship/research/pedagogy are involved with creating MOOC learning exercises (not just lecture/content delivery)? • What aspects of effective teaching and learning do MOOCs intrinsically support? • Are virtual laboratories as effective as in-person laboratories? • How do MOOCs facilitate pedagogical research that is difficult to perform otherwise? • Do MOOCs improve quality, not just quantity of instruction? • How does learning in a MOOC present obstacles to effective teaching and learning?

people learn. Table 9 includes the last set of research questions, which correspond to the research focus "MOOCs as a Platform for Large-scale Education Research".

7. Discussion

Massive Open Online Courses quickly infiltrated higher education, leaving very little time for large-group discussions among researchers, practitioners, administrators and developers on their role in engineering education. One of few examples of this type of activity is San Jose State University's MOOCs in STEM Education conference [32]. Without such conversations, it is possible for the engineering education community to become busy adopting the latest education technology, and miss the opportunity to strategically leverage MOOCs to improve student learning and advance the multifaceted mission of higher education. Existing publications that outline future directions for MOOCs research [18, 35–37] were a good start to a conversation on how we can be more strategic about the integration of MOOCs in higher education. This study advances the literature on this topic.

The results of this study include six research foci for future research on MOOCs in engineering education. In summary, the six themes are: (1) MOOCs Participants; (2) MOOCs Course Design; (3) MOOCs Technology Development, Delivery, and Adoption; (4) Administrative Concerns Involving MOOCs; (5) Role of MOOCs Across Education Contexts; and (6) MOOCs as a Platform for Large-scale Education Research. While there are many points of alignment with the existing literature, the findings in this study add to the literature as well.

Three of the six themes were consistent with the ideas already mentioned in the literature and did not need to be modified. These three themes were: MOOCs Participants; Administrative Concerns Regarding MOOCs, and MOOCs as a Platform for Large-scale Education Research. Similarly, Course Design and Technology Development are closely connected to ideas in the literature. However, these two big ideas were teased out in the results of this study and led to more nuanced research ideas for each area of emphasis. One research focus that was unique from the others in the literature was focused on the Role of MOOCs Across Education Contexts. This set of questions included ideas that linked MOOCs with the broader education contexts including other parts of higher education, K-12, and online learning.

Two research topics that were mentioned in the literature and show up in the results as well is the need for research on MOOCs learners' motivations and the need to parse research results by demographic details [18]. What this study adds to this literature are specific questions that need to be addressed in relation to each of these topics—research questions informed from researchers, education practitioners, and engineering education administrators. Although assessment was a focus in one of the articles included in the literature review supporting this study [37], it was an idea that showed up in several questions proposed by the participants in this study. The notion of credentialing is consistent with Liyanagunawardena, Adams, and Williams' [18] idea of recognizing students for their work. Several of the ideas associated with

large-scale research in the literature [35–37] were consistent with those in the results as well.

Although members of the engineering education community were the main contributors to this data set, most of the research needs and questions included in the survey responses were not unique to engineering education. In general, research topics and questions related to things like MOOCs participants, course design, and technology are not unique to engineering education. Similarly, research topics related to administrative concerns surrounding MOOCs, connections between MOOCs and other parts of the education spectrum, and large-scale education research that can be performed with MOOCs is not unique to engineering education either. Specifics that are more unique to engineering education are research questions that mention specific engineering disciplines, or pedagogies that are commonly used in engineering education. This result speaks to the generalizability of the research findings. Said differently, because many of the findings were not unique to engineering education, they are not only relevant to members of the engineering education community interested in MOOCs, but to the broader community of researchers, practitioners, and administrators interested in MOOCs as well.

In short, this study builds on and extends existing literature on this topic by gathering input from members of the MOOCs and engineering education research community to determine the most pressing research needs. Moreover, the results of this study not only outlines the topics of research that need further study, but also articulate over 70 specific research questions that can be readily addressed. Such specificity not only help galvanize the community a specific set up a needs, but also give direction on specific actions and immediate next steps. Lastly, this study adds to the body of literature by ascertaining which research needs seem unique to the engineering education community and which are more broadly applicable.

8. Conclusion

One motivation for this study was the desire to promote a more strategic reaction to the integration of MOOCs in engineering education, and not simply a reactive one. We acted on this motivation by organizing the first series of large-group discussions among engineering education practitioners and researchers, learning scientists, and MOOCs experts to address the purpose of this study: to develop a research agenda around the role of MOOCs in engineering education that is informed from multidisciplinary perspectives. The resulting research agenda includes six research foci and corresponding questions that, if addressed, will improve the role of MOOCs within and beyond engineering education.

Some limitations of this study relate to data collection and the comprehensiveness of the results. For example, the goal of the study was the gather input from the community as part of developing a research agenda around the role of MOOCs in engineering education. This objective was accomplished by was organizing a three-part workshop series that took place at engineering education conferences throughout 2014. While disciplines and the anticipated role of participants was the primary motivation for the workshop locations, the proverbial engineering education "ecosystem" is made up of different stakeholders (e.g., researchers, practitioners, administrators, industry personnel, policymakers) in a wide range of disciplines—all of which who do not regularly attend annual research conferences in this field. Thus, it is possible that the data collected during as part of this study does not fully represent the needs and inquiries of all stakeholders in the engineering education ecosystem. By extension, it is possible that the results of the study do not speak to the MOOCs-related research needs and questions of important stakeholders in engineering education who do not engage in research (e.g., non-tenure track faculty, personnel in academic support services).

Despite these limitations, this work advances the literature on what are the major research needs surrounding MOOCs, both in engineering education and more broadly. If acted upon, the research agenda resulting from this study has the potential to spawn activities that will lead to a more deliberate and strategic incorporation of MOOCs not only in engineering education, but higher education and beyond. Finally, although engineering education was the original context of interest in this study, the majority of the findings are not unique to engineering education, and as a result, are may be useful to researchers, practitioners, administrators far beyond engineering education communities.

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References

1. A. Ng and J. Widom, Origins of the Modern MOOC (xMOOC): Article contributed by Andrew Ng and Jennifer Widom, in *MOOCs: Expectations and Reality*, F. M. Hollands and D. Tirthali (Eds), Center for Benefits-Cost Studies of Education: Teachers College, Columbia University, 2014.
2. D. Cormier and G. Siemens, Through the open door: open courses as research, learning, and engagement, *EDUCAUSE Review*, **45**(4), 2010, pp. 30–39.
3. J. Kay, P. Reimann, E. Diebold, and B. Kummerfeld, MOOCs: So Many Learners, So Much Potential... *IEEE Intelligent Systems*, **28**(3), 2013, pp. 70–77

4. F. M. Hollands and D. Tirthali, MOOCs: Expectations and Reality, Teachers College, Columbia University, Center for Benefits-Cost Studies of Education, 2014, Retrieved from http://cbcse.org/wordpress/wp-content/uploads/2014/05/MOOCs_Expectations_and_Reality.pdf.
5. D. Haynie, Experts Debate the Impact of MOOCs on Education. *U.S. News & World Report*, 2014.
6. D. Haynie, 5 Reasons International Students Should Consider MOOCs. *U.S. News & World Report*, 2013.
7. D. Haynie, Learn for Free with MOOCs. *U.S. News & World Report*., 2013.
8. S. Adams, Is Coursera the Beginning of the End for Traditional Higher Education? *Forbes Magazine*, 2012 July 17 Available: http://onforb.es/ObgnUw.
9. Online Education: More than MOOCs: A Selection of Inside Higher Education articles and essays, *Inside Higher Ed*, December 2013.
10. D. Matthews, The Tuition is Too Damn High, Part IX: Will MOOCs save us? in *Wongblog*, Washington, DC: Washington Post, 2013
11. MOOCs Forum. MOOCs Impact at Duke University: An Interview with Peter Lange, Provost, *MOOCs Forum*, **1**(1), pp. 2–5, 2013
12. PCAST, PCAST Letter to the President on MOOCs, Washington, DC: President's Council of Advisors on Science and Technology, 2013
13. G. Siemens, V. Irvine and J. Code, Guest Editors' Preface to the Special Issue on MOOCs, *MERLOT Journal of Online Learning and Teaching*, **9**(2), 2013.
14. L. Pappana, The Year of the MOOC, in *The New York Times*, New York: The New York Times, 2012.
15. G. Kahn, How Georgia Tech's new, super-cheap online master's degree could radically change American higher education, *Slate*, 2013.
16. N. Anderson, Harvard-MIT venture edX teams with Google on platform for free online courses in *The Washington Post*, Washington, DC, 2013.
17. A. McAuley, B. Stewart, G. Siemens and D. Cormier, The MOOC model for digitial practice, elearningspace.org, 2010.
18. T. R. Liyanagunawardena, A. A. Adams and S. A. Williams, MOOCs: A Systematic Study of the Published Literature 2008-2012, *The International Review of Research in Open and Distance Learning*, **14**(3), 2013.
19. L. Breslow, D. E. Pritchard, J. DeBoer, G. S. Stump, A. D. Ho and D. T. Seaton, Studying learning in the worldwide classroom: Research into edX's first MOOC., *Journal of Research & Practice in Assessment,* **8**, pp. 13–25, 2013.
20. G. Siemens, Connectivism: A Learning Theory for the Digital Age, *International Journal of Instructional Technology and Distance Learning*, **2**(1), pp. 3–10, 2005.
21. A. Margaryan, M. Bianco, and A. Littlejohn, Instructional quality of Massive Open Online Courses (MOOCs), *Computers & Education*, **80**, pp. 77-83, 2015.
22. J. London, *Key Aspects of Cyberlearning Resources with Compelling Results*, American Society for Engineering Education Conference Preceedings, 2013, Atlanta, GA.
23. M. J. Dennis, The Impact of MOOCs on Higher Education, *College & University: Educating the Modern Higher Education Administration Professional*, **88**(2), pp. 24–30, 2012.
24. National Academy of Engineering (NAE), Changing the Conversation: messages for Improving Public Understanding of Engineering, Washington, D.C.: National Academies Press, 2008.
25. NAE, Educating the Engineer of 2020: Adapting Engineering Education to the New Century, Washington, D.C.: National Academies Press, 2005.
26. *NAE, National Academy of Engineering, The Engineer of 2020: Visions of Engineering in the New Century, Washington, D.C.: National Academies Press, 2004.*
27. National Academy of Engineering, Engineering in K-12 education: Understanding the status and improving the prospects, Washington, D.C.: The National Academies Press, 2009.
28. NAE, Grand Challenges for Engineering, Washington, D.C.: The National Academies Press, 2008.
29. NAE, Raising Public Awareness of Engineering. Washington, D.C.: The National Academies Press, 2002.
30. NAE, Messaging for Engineering: From Research to Action: The National Academies Press, 2013.
31. J. E. Froyd, P. C. Wankat and K. A. Smith, Five Major Shifts in 100 Years of Engineering Education, *Proceedings of the IEEE*, **100**, pp. 1344–1360, 2012.
32. San Jose State University's *MOOCs in STEM Education* conference Website: http://engineering.sjsu.edu/mooc.
33. MOOCs in Engineering Education Website: https://moocsinengineering.wordpress.com.
34. S. Downes, Places to go: Connectivism & connective knowledge, *Innovate*, **5**(1), 2008.
35. D. Gašević, V. Kovanović, S. Joksimović and G. Siemens, "Where is Research on Massive Open Online Courses Headed? A Data Analysis of the MOOC Research Initiative," *The International Review of Research in Open and Distance Learning*, **15**(5), 2014.
36. Computing Community Consortium (CCC), Report on the CCC-CRA Workshop on Multidisciplinary Research for Online Education, Washington, DC, 2013.
37. J. Reich, Rebooting MOOCs Research, *Science*, **347**(6217), 2015 pp. 34–35.
38. National Research Council, *Knowing What Students Know: The Science and Design of Educational Assessment*, Washington, D.C.: National Academy Press, 2001.
39. R. E. Boyatzis, *Transforming Qualitative Information: Thematic Analysis and Code Development*, Thousand Oaks, CA: Sage, 1998.
40. V. Braun and V. Clarke, Using Thematic Analysis in Psychology, *Qualitative Research in Psychology*, 2006, **3**(2), pp. 77–101.
41. L. Jamieson; J. Lohmann, Creating a Culture for Scholarly and Systematic Innovation in Engineering Education: Ensuring U.S. Engineering has the Right People with the Right Talent for the Global Society., Washington, D.C.: American Society for Engineering Education, 2010, Available at *http://www.asee.org/about/board/committees/CCSSIE/.*
42. B. Yoder, Engineering by the Numbers. Washington, D.C: American Society for Engineering Eduction, 2014, Available: https://http://www.asee.org/papers-and-publications/publications/14_11-47.pdf.
43. L. Alton, 6 Engineering Fields with High Growth. *EngineeringJobs.com*, 2014, Available: http://www.engineering.com/Jobs/JobArticles/ArticleID/8486/6-Engineering-Fields-with-High-Growth.aspx.
44. Occupational Outlook Handbook, 2014–15 Edition, Washington, DC: United States Department of Labor, Bureau of Labor Statistics, Available online at: http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm.
45. J. L. Bess and Associates, Integrating autonomous professionals through team-teaching, in *Teaching alone, teaching together: Transforming the structure of teams for teaching*, J. L. Bess, Ed., ed San Francisco: Jossey-Bass, 2000, pp. 203–235.

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