An inclusive process for developing a taxonomy of keywords for engineering education research

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Abstract

Engineering education research is a broad-based, rapidly-evolving, diverse, interdisciplinary, and international field. There is a clear need for a standardized terminology and organizational system – a set of keywords – to map the field and communicate research initiatives. Such a taxonomy could provide multiple benefits, including:
- better connections between research and researchers;
- more accessible research results,
- recognition for and identification of emerging research areas,
- a way to describe the diversity of engineering education research areas, and
- a common terminology with which researchers could frame their efforts.

The goals of our NSF-funded project, then, are two fold: (1) to develop a comprehensive taxonomy of keywords that could be used to describe engineering education research projects, publications, authors, and peer reviewers, and (2) to establish an inclusive process for developing the taxonomy that invited the participation of the diverse global community.

To achieve our project goals, we used an iterative process to develop and refine a taxonomy of keywords which involved a variety of stakeholders in multiple settings. We were assisted in our efforts by a professional taxonomist and supported by an advisory board that included ten engineering education leaders and editors of several engineering education journals.

We intentionally designed an inclusive process, involving faculty, administrators, and graduate students from across the world, and we used this opportunity to develop a globally-relevant taxonomy for use in the United States. We issued open calls for participation and advertised broadly for key opportunities to be involved. We created transparent selection processes, criteria that encouraged diversity, and engaging activities that de-emphasized hierarchy and privilege of particular research areas. At workshops and conference sessions, we adapted activities to be relevant in the local context for engineering education research.

Participants were engaged in creating initial keyword outlines and in refining draft versions of the taxonomy at a two-day conference and at a series of four subsequent conference workshops (American Society of Engineering Education Annual Conference, Research in Engineering Education Symposium, European Society for Engineering Education, and Frontiers in Education Conference). After the first two workshops, nine graduate students worked on three virtual teams to further refine the taxonomy. Over 220 individuals provided additional feedback that improved the taxonomy.

Here, we describe participant selection, details of each activity, and outcomes for each phase of the project. The sections below detail the project stages in chronological order, including participants and selection procedures, details of the stage and its outcomes. Table 1 provides participant details, and Figure 1 maps the home institutions of participants.

Table 1. Details and participant demographics for taxonomy activities

Activity	Location	Date	Number US participants	Number non-US participants	Total participants
Initial keyword outlines	N/A	March 2013 – April 2013	3	3	6
Mapping the Field Conference	Ann Arbor, Michigan, USA	05/20/13 – 05/21/13	39	9	48
Workshop at ASEE Conference	Atlanta, Georgia, USA	6/25/2013	35	6	41
Workshop at REES	Kuala Lumpur, Malaysia	7/6/2013	12	47	59
Virtual workshop	N/A	August 2013	8	1	9
Workshop at SEFI Conference	Leuven, Belgium	9/20/2013	3	54	57
Workshop at FIE Conference	Oklahoma City, Oklahoma, USA	10/25/13	29	6	35
	Total unique participants*		**107**	**117**	**223**

* Some individuals participated in more than one activity, so the number of **unique** participants is not a summation of the overall participant count

Figure 1. Home institution for 223 unique participants.

Initial keyword outlines

Participant selection: The project began with an international, open call for initial keyword outlines. From the proposals submitted, we selected three teams (six individuals total) to provide keyword outlines as the basis for the initial taxonomy.

Keyword outline details: The three outlines, each consisting of keywords arranged in a two-level outline, were developed differently.

1. Outline A was derived in two phases. First, the authors analyzed bibliographic data (i.e., title, abstract, and keyword list) for nearly 900 international journal articles and conference papers from 2005 to 2008. They iteratively created a set of first-level terms (each having a clearly identifiable research area) and second-level terms. Next, from over 500 relevant journal articles and conference proceedings, the authors expanded their analysis by creating a more comprehensive set of keywords for one of the 38 categories (diversity). Their resulting outline contains 1,242 keywords categorized into 38 first level terms.

2. Outline B was based on 2,216 peer-reviewed journal articles in five international engineering education journals from 1959 to 2012. The author studied the titles to identify an initial set of keywords then applied network analysis to identify underlying themes and relationships between them. The outline includes 256 keywords, arranged in 46 first-level terms and multiple second-level terms, as well as a time dimension and a level of connectedness (frequency of occurrence).

3. Outline C involved a keyword analyses of three separate sources: (1) the full text of research or discussion papers from journal articles during 2006-2012, conference papers from 2008-2012, and a pedagogic research statement for the field, (2) personal reflections on three related conferences and a study relevant PhD theses; and (3) meeting notes of an engineering education research special interest group from 2009 – 2013. The final outline includes 13 first-level terms and 43 second-level ones.

Outcome: From the three commissioned keyword outlines, Access Innovations (the nation's largest taxonomy creation firm) created a draft taxonomy. They integrated and refined the outlines, normalized terms, and worked to consolidate the two-level structure into a more hierarchical one. The resulting taxonomy (**version 1**) included 1,079 keywords arranged in 13 branches and seven levels.

Mapping the Field Conference

Participant selection: The Mapping the Field Conference was a two-day workshop to refine the taxonomy of keywords and the accompanying organizing structure. Email invitations were sent to several groups, including the Research in Engineering Education network, International Federation of Engineering Education Societies/Global Engineering Deans Council, and the Educational Research and Methods Division and the Engineering Libraries Division of the American Society of Engineering Education. The invitation included a link to a brief application consisting of an activity for individuals to list keywords to describe their main research area and two questions: (1) What areas of engineering education are in most pressing need of additional research and (2) How will you contribute to diversity of perspectives at this workshop?

We selected 48 conference participants from 96 applicants. We aimed to be as inclusive of the community as possible, and we selected a group of researchers and other stakeholders based on a variety of factors including:

- diversity of experience and history in the field (selecting a mix of participants ranging from graduate students studying engineering education to experienced practitioners interested in transition into the field to researchers with extensive experience in engineering education research),

- diversity of research area and understanding of the field based on application responses, and

- diversity of perspective, especially as related to international and national backgrounds.

Invited participants included nine international colleagues and 39 individuals from the US, representing 40 distinct institutions from across the world. They have broad experience levels and ranged from current graduate students and faculty new to the field to seasoned veterans with significant experience.

Conference details: The Mapping the Field Conference was held May 20-21, 2013, in Ann Arbor, Michigan. Participants reviewed sub-sections of the taxonomy in advance of the conference and worked to further refine **version 1** of the draft taxonomy. At the conference, a professional taxonomist from Access Innovations presented an introduction to taxonomies and an overview about using and maintaining taxonomies. Participants engaged in multiple breakout sessions where they discussed sub-sections of the taxonomy, suggested term-by-term revisions, and made high-level revisions to the overall taxonomy.

Outcome: Access Innovations worked with the documents produced at the conference, and through an iterative process, we produced **version 2** of the taxonomy. It included 971 total terms, arranged in 14 branches and six levels.

Annual Conference of the American Society of Engineering Education

Workshop details: We held a pre-conference workshop at the 2013 American Society of Engineering Education Annual (ASEE) Conference in Atlanta, Georgia on June 25, 2013 [1]. Any individual attending the ASEE conference was invited to participate in the pre-conference workshop. During the three-hour session, 41 participants reviewed **version 2** of the draft taxonomy, using and revising it during two separate activities.

For the first activity, we compiled six sets of five abstracts, selected from ASEE 2012 abstracts and abstracts from recent manuscripts published in *Advances in Engineering Education*, *International Journal of Engineering Education*, and *Journal of Engineering Education*. Working individually, then in small groups, participants were asked to "apply the taxonomy" by identifying four to six keywords that described each abstract. They also identified missing terms and offered suggestions for making the taxonomy easier to use. After gaining familiarity with the taxonomy, participants worked in groups to make detailed, term-by-term revisions to selected branches of the taxonomy.

Outcome: We integrated participant feedback to produce **version 3** of the taxonomy. It included 1,012 total terms, arranged in 14 branches and six levels.

Research in Engineering Education Symposium

Workshop details: To solicit a more global perspective on the taxonomy, we held a workshop at the 2013 Research in Engineering Education Symposium (REES) in Kuala Lumpur, Malaysia on July 6, 2013 [2]. All REES attendees were invited to attend the workshop, and 59 participants reviewed **version**

3 of the draft taxonomy during a 90-minute post-conference session. As at the ASEE conference, participants began by using the taxonomy to become familiar with it. To be relevant to the context of REES, the activity involved five sets of four abstracts, chosen from 2013 and 2011 REES proceedings and from manuscripts appearing in recent issues of the *International Journal of Engineering Education*. Participants then engaged in a broader discussion about making the taxonomy more globally-relevant and ensuring its widespread use.

Outcome: Several suggestions for refining the taxonomy resulted from the REES activities. Rather than create an updated taxonomy, these suggestions were used to inform a virtual workshop for graduate students.

Virtual workshop for graduate students

Participant selection: Graduate students were invited to apply to participate in a virtual workshop. Based on a keyword activity and responses to questions about transformative research in engineering education and contributions to diversity, we selected nine students to participate.

Workshop details: Over a one-month period, the graduate students reviewed **version 3** of the draft taxonomy and completed three activities:
1. Individual work to use and apply the taxonomy to identify keywords for five abstracts of their choosing.
2. Virtual group work (in teams of three) to revise an assigned portion of the taxonomy.
3. Virtual group work to make holistic revisions to a new version of the taxonomy.

Outcome: We incorporated feedback from the first two activities of this virtual workshop to develop **version 3a** of the taxonomy. Then, after the third activity, we developed **version 4** of the taxonomy. It included 1,057 total terms, arranged in 17 branches and six levels.

European Society for Engineering Education Conference

Workshop details: To again collect a broad, international perspective on the taxonomy, we held a workshop following the 2013 European Society for Engineering Education (SEFI) Conference in Leuven, Belgium on September 20, 2013 [3]. The 57 participants reviewed **version 4** of the draft taxonomy during a four hour post-conference workshop. Abstracts for the "applying the taxonomy" activity were chosen from 2011 and 2012 SEFI conference abstracts and manuscripts appearing in the 2013 *European Journal of Engineering Education*. Participants also offered suggestions for higher-level revisions to the taxonomy.

Outcome: We integrated participant feedback and drafted **version 5** of the taxonomy. It included 1,105 terms, arranged in 17 branches and 7 levels.

Frontiers in Education Conference

Workshop details: We conducted a three-hour pre-conference workshop at the 2013 Frontiers in Education (FIE) Conference in Oklahoma City, Oklahoma on October 23, 2013 [4]. The 35 participants reviewed **version 5** of the draft taxonomy in print (a 14-page printed document), through an MS Word

document, and via a pilot version of a keyword finder. They engaged in two activities. The first activity involved using the taxonomy to identify keywords for four abstracts selected from 2012 and 2011 FIE conferences. A second activity involved smaller groups revising one of six branches of the taxonomy.

Outcome: We integrated feedback from the FIE conference to develop **version 6** of the taxonomy. It is a significantly streamlined version, including just 452 terms organized in 14 branches and five levels.

Summary

To date, our activities have engaged more than 220 participants from 30 different countries at in-person workshops and conference sessions. Through a process of iterative community engagement and review by a professional taxonomy firm, we drafted multiple versions of the taxonomy. The sixth/current version of the taxonomy includes 14 categories and five levels of organization for the 452 terms. Next steps involve validating and finalizing the taxonomy and disseminating it.

We are hopeful that the taxonomy will be used broadly. Researchers and community members will be able to use the taxonomy to situate individual research initiatives in the broader field, see connections with others, and plan future work. Journal editors will be able to use the taxonomy to organize related research areas and to create a reviewer database. Funding agencies will be able to use the taxonomy to classify research portfolios, identify areas for capacity building, frame solicitations, and identify and recruit reviewers for panels.

Acknowledgements

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