AC 2012-4485: HOW DOES AN INTERACTIVE KNOWLEDGE PLATFORM INFLUENCE DECISION-MAKING OF NOVICE RESEARCHERS IN ENGINEERING EDUCATION RESEARCH?

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How Does an Interactive Knowledge Platform Influence Decision-Making of Novice Researchers in Engineering Education Research?

Abstract

An interactive visualization knowledge network platform iKNEER (Interactive Knowledge Network for Engineering Education Research, www.ikneer.org) was designed for researchers in the Engineering Education Research (EER) community. This platform is potentially helpful to first-year PhD students in Engineering Education. The major goal of this study is to investigate the role iKNEER could play in first-year PhD students' decision-making upon their research using a qualitative method. It also serves as a qualitative evaluation of the iKNEER platform. Providing a better understanding of how this research tool influences novice researchers' decision-making process, results of this study could inform further development and future design of such tools.

1. Introduction

Engineering Education Research is a newly emerging and highly interdisciplinary field of research[1–5]. Many researchers in this field come from an engineering background. They may encounter difficulties of shifting mindset from solving specific engineering problems to conducting rigorous educational research using educational and sociological methodologies[6]. Novice researchers in a new field usually encounter intellectual and social challenges at the point of maximum novelty[7]. For junior researchers in engineering education research, they may not only have difficulties of shifting mindset, but also have confusions regarding how they would fit their research interest to the larger knowledge body of this community, what is the appropriate theoretical framework to ground their work, what other related work has been done, what questions are worth asking in this field, and who are the go-to persons if they are interested in certain topics.

An interactive visualization knowledge platform iKNEER (Interactive Knowledge Network for Engineering Education Research, www.ikneer.org) is currently under development with the goal of supporting researchers in Engineering Education Research (EER) community to explore current state of engineering education research, identify future directions for research, and find potential collaborative partners. As of December 2011, iKNEER archives 23,181 publications from top journals and conferences in engineering education research and 123, 054 NSF grant proposals. The alpha version of iKNEER has been released June 2011 at the ASEE annual conference & exposition[8].

Built based on large-scale data mining and visualization techniques, iKNEER is potentially helpful during the decision-making process of first-year PhD students upon their research directions by providing a comprehensive overview of the current state of the field, and the insights about where are the trends going and who to follow on certain topics. However, how exactly novice researchers perceive and use this tool remains unclear. The goal of this research project is to investigate the following questions: (1) How does iKNEER influence decision-

making of novice researchers in making decisions regarding their research directions? (2) What issues can be identified during the process that could inform future development of such tools?

Researchers' decisions on research directions are made based on a much broader context than one single application can address. We are interested in looking at the role iKNEER could play in this complicated process, and this calls for a qualitative approach. We distinguish our study from website evaluation studies. Rather, we regard iKNEER as one possible influencing factor in novice researchers' decision-making processes in order to understand more about novice researchers in this new field. Instead of asking the users to perform ad-hoc tasks on the website, we put the users in real research context. We allow the users to use iKNEER at their own time for their own research, and then we conducted semi-structured interviews on their research experiences. Therefore we are able to understand the role iKNEER plays in novice researchers' research from a broader scope with real context, and also identify issues that could inform further development of this platform.

In the following section, we review literature on novice researchers, research tools, tool evaluation and web information seeking.

2. Literature Review

2. 1 Novice Researchers' Difficulties

Novice researchers in a new field usually face various kinds of challenges. Hockey[7] portrays the first year of PhD as the most crucial and difficult period because students "initially encounter and experience intellectual and social processes at their point of maximum novelty"(p1). Much research has been done about the challenges and issues first-year PhD students or junior research students face, including social isolation, productivity, financing, discrepancies with advisers, and unequal accesses to peer culture and academic culture[7,9–13]. An important area of doctoral study that has received little attention is the development of scholarship[14]. Besides challenges from the social environment, the major challenge for doctoral students is scholarly and intellectual development. Novice researchers usually come to the research field with a broad area of interest. This broad interest serves as an initial direction for exploration. They have to refine and distill this topic into specific research questions[15]. This process calls for lots of efforts in understanding the scope of the whole research field, looking for relevant literature under certain topics, trying to find a gap in the literature and use their own research project to bridge the gap.

Engineering Education incorporates methodological traditions from sociology, educational psychology, educational technology, as well as various engineering disciplines. The interdisciplinary nature of Engineering Education Research adds to the difficulty of novice researchers. As an emerging and highly interdisciplinary field of research, Engineering Education continues to explore and define its identities, goals, objectives, scopes and boundaries[2,3]. As many researchers in this field are from an engineering background, they may face the challenge of shifting mindset of solving specific engineering problem to becoming a researcher in Engineering Education. The NSF-funded workshops on Rigorous Research in Engineering Education in 2005 have identified five conceptual hurdles engineers encounter when they conduct educational research[6]: (1) framing research questions with broad appeal; (2) grounding research in a theoretical framework; (3) fully considering operationalization and

measurement of constructs; (4) appreciating qualitative or mixed-methods approaches; and (5) pursuing interdisciplinary collaboration. These conceptual difficulties were found among engineering faculty members who conduct educational research. Most first-year PhD students in engineering education also come from engineering background, and are used to solve specific engineering problems. So these difficulties may also apply to them, however, no previous research has investigated whether novice student researchers experience the same conceptual hurdles.

2. 2 Research Tools

Before the popularity of computational tools, novice researchers explore how to conduct research by consulting expert researchers, reading and manually classifying the literature, etc. With the advancement of modern technologies, many tools are being developed aiming at help researchers make sense of literature data. For example, CiteSeerx (http://citeseerx.ist.psu.edu) is a search engine and digital library for scientific papers with automatic citation indexing system[16]. CiteSeerX is often considered as the predecessor of other academic search tools such as Google Scholar (http://scholar.google.com) and Microsoft Academic Search (http://academic.research.microsoft.com). There are also various other academic databases and search engines in different disciplines documenting ever-growing amount of literature, such as IEEE Xplore (ieeexplore.ieee.org), JSTOR(www.jstor.org), SpringerLink (www.springerlink.com), to name a few. Uren et al. developed a tool named ClaiMapper to allow the users to sketch argument maps of individual papers and draw connections among them[17]. More recently, new research tools start to incorporate information visualization and machine learning techniques. For example, Apolo[18] is a tool that helps researchers make sense of citation networks combining rich user interaction and machine learning techniques. There also exists various citation management tools such as EndNote (www.endnote.com), Zotero (www.zotero.org), Mendeley (www.mendeley.com), and CiteULike (http://www.citeulike.org/) to help researchers manage citations.

However, none of these tools above have specifically addressed the engineering education research domain – neither do they allow non-experts in data mining and visualization to explore data in an intuitive way. The iKNEER platform is being designed under this circumstance. Using a theoretical model that combines large-scale data mining techniques, network mapping algorithms, and time-series analysis of knowledge product evolution, iKNEER attempts to characterize and provide insights into the topology of the networks and collaborations within engineering education research[8]. iKNEER has the potential to help novice researchers to tackle with some of the difficulties they encounter when they enter this new research field. Yet, how novice researchers use iKNEER and how this influences their decision-making processes remain unknown.

2. 3 Tool Evaluation

Many research tools developed are evaluated as effective and better than other tools in certain aspects using quantitative evaluation methods, such as usability tests and controlled experiments. Many research tools are designed by researchers from human-computer interaction (HCI) or information visualization domains. The ACM SIG CHI conference on human-computer

interactions has organized bi-annual workshops named BELIV (BEyond time and errors: novel evaLuation methods for Information Visualization) to address various issues in evaluation. In a position paper by Plaisant, she points out that "the reports of usability studies and controlled experiments are helpful to understand the potential and limitations of our tools, but we need to consider other evaluation approaches that take into account the long exploratory nature of users tasks"[20] (p. 1).

We do not position our study in this paper as an evaluation study, since we care more about how iKNEER influence researchers' decision-making process. It is not our interest to compare iKNEER with other research tools to see whether it is better or not, either. Since iKNEER is the only research platform addressing engineering education research, and our study considers the real context of researchers, so it is not possible to compare with other research tools. We do partially address the evaluation issues, because in our study, we allow users to use the tool anywhere anytime and for their own research rather than limit the study in the laboratories. In this way, we gained valuable insight on how we can improve iKNEER in the future to address researchers' real needs.

2. 4 Web Information Seeking and Researchers

In library and information science, lots of literature exists on how researchers use libraries and how libraries influence their research[21,22]. There are also studies on how people seek information on the web[23,24]. For example, studies have examined the gender differences and age differences in information seeking on the web[25–28]; other studies have investigated how IT specialists and business managers use the web[24]. However, the studies on researchers' information seeking have not quite been moved from traditional libraries to digital media yet, and researchers' decision making processes using research tools on the web have not been carefully examined yet.

3. Methods

As mentioned earlier, we took a qualitative approach to answer our research questions. There was no hypothesis to be tested and we followed an open ended exploratory path.

We recruited 6 participants from a first-year PhD introductory to research methods class in an Engineering Education department. There were three males and three females. Two of them were international students. One of them had already started to use iKNEER about two months earlier. We did not collect other demographic information such as age and ethnicity, but we provide the participants' background and research interests as shown in Table 1, as we think this can provide more insight into the different perspectives they have when using iKNEER compared with regular demographic information.

Participants	Background (Teaching and Research)	Current Research Interests
P 1	About four years of teaching and mentoring experience on a community college level	The impact of mentoring on the self-efficacy of minority and under-represented groups in STEM fields
P 2	BS and MS in electrical engineering	Global engineering program
P 3	BS and MS in systems engineering; worked in industry as a software developer for three years after BS; taught in a university after MS about six years	Undecided
P 4	BS in electrical and computer engineering; undergraduate TA; four years in industry working in open source software companies	Open source communities and the engineering learning that happens in them
P 5	BS in civil engineering; minor in philosophy	Sustainability and student environmental awareness
P 6	BS and MS in computer engineering; A young faculty member of engineering	Ethical reasoning and social responsibility in engineers and developing those attributes; human-centered design; learning and assessment; interdisciplinarity and cross-cultural engineering; conceptual framework for social awareness

Table 1. Participants' backgrounds and research interests

In this introductory to research methods class, one major course assignment was to write a literature review on topics of their own interests. It is often the case that this literature review students wrote in their first year serves as a starting point of their later research career. The participants attended a 30-minute training session on how to use iKNEER. At the time they attended the training session, they had finished the first draft of the literature review. After the training session, they went back and used iKNEER for revising their own literature review or on any other topics they are interested in.

Our data collection and data analysis went through three phases. The first phase happened two weeks after the training session. We interviewed the first two participants with open-ended questions on their research interests, what difficulties they have in their research, and how they have used iKNEER (see Appendix 1 for interview questions). These two interviews lasted about 30 minutes each. We analyzed the data preliminarily, and refined the interview questions to include more specific questions on their teaching, working and research backgrounds. Another two weeks later, we conducted interviews with another three participants. The interview lengths ranged from 35 to 45 minutes. We further refined the questions to include even more details on the participants' backgrounds and how they become interested in engineering education research. One week after the second phase, we interview another participant, and the interview lasted about 50 minutes. All the interviews were voice recorded and transcribed into text verbatim.

We conducted thematic analysis[29–31] on the interview data in order to identify emerging themes. Two coders independently coded the transcriptions. We focus on the difficulties the participants have in their research, the role iKNEER plays in their research process, and how these connect to

the participants' backgrounds and research interests. We also identify usability issues and suggestions for future development. We then discuss the codes until we reach mutual agreement. We use the web-based open coding tool Saturate (http://www.saturateapp.com) to assist the open coding process. The data analysis was an iterative process, and we read the transcriptions and listened to the recordings many times to refine the codes until common patterns began to emerge (please see Appendix 2 for the coding sheet).

4. Results

We identified themes under the following four categories. The first two categories respond to our first research question and the third and fourth category responds to our second research question.

Category 1. Research Difficulties

Theme 1.1 Unable to find relevant literature

Many participants have indicated the difficulties of finding relevant literature in their research topics. Two main reasons have been identified that lead to this difficulty. One is that the researcher is very focused on engineering education, and is unaware of useful literature in other disciplines. For example, when talking about the experience of literature searching, P1 mentioned, "it was in a journal that I never would have looked at probably because I was so ENE [Engineering Education] focused". The second reason is just the opposite. The researcher is interested in a very new, broad and not well-defined topic. They are usually aware that they need to draw literature from many other disciplines, but it is very challenging to do so. For example, P4 described her bibliography "There is a bunch of econ [economics] stuff. There is law stuff. There is education stuff. There is philosophy stuff. There is cognitive stuff. Like God knows where I get these things." Both of the reasons reveal the highly interdisciplinary nature of engineering education research.

Theme 1.2 Different stages of novelty, different challenges

Although all of the participants are first-year PhD students, we realized from the interviews, it is unfair to classify them in the same "novice researchers" category. As shown in Table 1, they come from various backgrounds, and have various teaching, working and research experiences. Some of them have passed the stage of literature review difficulties. Instead, they have difficulties with research methods, especially qualitative methods. For example, P5 mentioned his undergraduate research experiences and said "I've gotten pretty good at finding literature at that point and so the difficulty right now is like I'm analyzing interview sessions, so it's very qualitative". We found that previous research experiences serves the best to overcome difficulties in literature review compared with working and teaching experiences.

Theme 1.3 Language difficulties

International students have difficulties with the English language, especially in writing. They feel engineering education research requires a lot more writing compared with their previous "equation-based" engineering experiences. For example, P2 mentioned "I am trying to write in a

language that is not mine, so my structural constructions, my grammar constructions are not as good as they are for a native speaker or for a native writer. So I am trying to improve that."

Theme 1.4 No difficulties, or care enough to overcome any difficulties

We are a little surprised to find that many participants indicate no particular difficulties shifting mindset from engineering to engineering education research. For example, when asked about whether it is difficult to shift from technical space to the social and educational space, P6 said "Oh, no, not at all. I was born for this degree. I mean, no, the concepts presented here I grasp pretty quickly. I'm an extrovert by nature. I care about people, so my talents and my skill set really lend itself toward being a social science or an educational researcher"; "I have analytical skills and, I think, critical thinking skills that lend itself toward technical research but not the passion"; "I grasp the concepts because I care about them. A lot of the research that is in engineering education really articulates things that I've been thinking anyway. I don't know if it's easy, but it's natural, I guess"; and "I was not enjoying computer engineering at all. I hated it".

In general, we found that compared with trained engineering faculty members, these student researchers do not demonstrate strong conceptual hurdles as described in Borrego's paper[6] reviewed in section 2.1, though they are from engineering backgrounds. They are usually aware of addressing their research from a broad perspective outside of the constraint of classroom and curriculum, though it may be difficult to do so. They usually appreciate qualitative methods and the social side of the research. They may have various difficulties, but they are very willing to overcome these difficulties. They feel more natural doing engineering education research than engineering research.

Category 2. iKNEER and Research

Theme 2.1 Focused scope of iKNEER can be positive

Related to theme 1.1, we found that if the researcher is very ENE focused, they usually perceived iKNEER as useful for their research, because iKNEER is specifically designed for engineering education research, and it only archives top journal and conference papers in engineering education research. For instance, P1 has decided not to pursue the "identity" topic for now because she has not found much literature on this topic in engineering education research, and this is consistent with search results on iKNEER.

For participants whose research topics are very new or addressing a very broad scope, iKNEER is perceived as less useful for their current situations, because they can not find as many as articles on iKNEER. However, they think that it is a good thing that iKNEER focuses on top engineering education publications, and do not expect it to expand. For example, P5 said "I think making sure it doesn't lose its focus of being like only including these top tier journals. You don't want to include everything. I guess stick with that", though he has indicated that he cannot find much literature on iKNEER relating to his topic. Although the participants' research topics need to draw upon many disciplines, they still like to have a focused database for top publications in engineering education research to keep updated with the top trends in the field.

Theme 2.2 Collaboration network graph is particularly useful

The most useful feature identified on iKNEER for the participants is the author collaboration network graph. It is especially useful when the participants find professors outside of the university they have long admired who have co-authored papers with professors in the university. So they go to talk with the professors in the university and make connections with other professors outside of the university. For example, P4 said "So I was looking at [professor A, P4's advisor] because I went, well, my advisor is probably a good person to know about and so I put up her page and I went, oh my gosh, she wrote something with [professor B], really, did she", and "They worked together and I can probably now talk with [professor A] in terms of getting instruction [from professor B]". The network graph on iKNEER helps new researchers make professional connections in their research.

Theme 2.3 iKNEER has a role beyond research

At the time when we conducted this study, iKNEER archives more NSF grant proposals than academic papers. Many participants indicated that they expect more papers than proposals, and they are not particularly interested in grant proposals. Grant proposals are regarded as more useful for young faculty members who just started to apply for grants, but not as useful for first-year PhD students. For example, P6 said "it's an excellent tool for engineering education researcher, particularly young faculty", and "typically, yeah, no, new students aren't thinking of grants". However, P1 indicated that she is very interested in the grant proposals because she has career interests in National Science Foundation. "It is from NSF, and I have career interests in that area." "It tells me what NSF is cataloging." Therefore we identified a role iKNEER could play in the researchers' professional career beyond research.

Theme 2.4 Researchers' decision on research directions are made in a broad context

iKNEER only plays a very small role in the researchers' whole decision-making processes, the researchers' decisions on whether to pursue certain topics are made in a much broader context. The participants have mentioned advisors, other professors, conferences, workshops, libraries and librarians, authors' personal websites, and other research tools such as Google Scholar. For example, P6 said "At that conference, I met [professor C] and that was when I first decided, at that conference, that I may go back, do my Ph.D. in engineering education". In general, the decisions on pursuing certain research topics are usually finalized by talking with experts, rather than using computational tools and reading papers.

Category 3. Usability Issues

Overall, the participants felt iKNEER is pretty straightforward to use. We identified two major usability issues:

Theme 3.1 Unable to find search bar

One recurring theme on the usability of iKNEER is that the participants oftentimes were unable to find the search bar, if they have a small computer screen (small laptop, netbook or tablet). Because the search bar of current version of iKNEER is at the upper right corner, and the width is designed for wide screen, so if the users have a small screen, they are often not aware that they have to scroll over to the right to find the search bar.

Theme 3.2 Collaboration network needs improvement

Despite being the most useful feature, the author collaboration network is confusing to the users sometimes because the dots (represent authors) and lines (represent co-authorships) are too dense. Also the "degree of separation" button is not obvious to some users. It needs to be designed in a way that is easier to navigate.

Category 4. Suggestions for Future Design

Under this category, we present the suggestions participants have provided for the future design of iKNEER. Overall the users prefer more freedom to navigate, manipulate, and link with environment outside of iKNEER, rather than being restricted in a closed environment. These suggestions can be useful for researchers and designers of research tools. However, they should be carefully considered in future design of research tools, because not everything everybody wants can be and should be implemented. There are always trade-off that need to be properly examined.

Theme 4.1 Allow users to upload their own data

One suggestion is to allow the users to upload their own data. This feature if incorporated offers a myriad of possibilities to the iKNEER framework on the whole. It offers a functionality serving the needs of the researcher whose research topics need to draw upon a variety of resources. There is a possibility that iKNEER could be used along each and every step of the literature review not just the initial phase of identification of useful literature.

Theme 4.2 Connect with citation management tools

The issue to be addressed is the ability of iKNEER to synergize with existing citation management tools of EndNote, Zotero, and Mendeley. It would be very useful on behalf of the user if they are able to export literature on iKNEER directly to their citation libraries.

Theme 4.3 Click edge to get the co-authored papers

The fourth suggestion focuses on the design of the network graph on iKNEER. There was a desire to view the number of papers co-authored in the network graph. This could be implemented by allowing the users to click the network edges between the nodes in the network graph and show the papers co-authored by the two connected authors.

Theme 4.4 Link grant proposals with papers

Participants have expressed their experience that they found more grant proposals than papers on iKNEER and they wish they could know specifically the papers that published under the support of a certain grant.

Theme 4.5 Open source

The users wish the system could be open source, which is the iKNEER team is trying to achieve now. Overall, users want more freedom to manipulate through, and link iKNEER with environment outside of iKNEER, rather than be restricted in a closed environment.

5. Limitations

The number of participants in this study is limited partially because we initially had a small pool of possible participants. There are altogether less than 20 first-year PhD students in the engineering education department where we recruited. Future longitudinal work can be done to track multiple cohorts of PhD students and their scholarly development. Also, because of the time constraint of the study, the participants only used iKNEER for a few weeks before attending the interviews under the condition that they had already finished a draft of the literature review. We have peeked into the research difficulties of the novice researchers and identified some influences iKNEER has on their research, however, these influences maybe partial and not significant due to the limitations. We were also not able to depict the details of the researchers' decision-making processes of choosing research topics and conduct literature review.

6. Conclusion

Despite the limitations described above, we have provided a preliminary view into the difficulties encountered by novice researchers in engineering education research. We found that the novice student researchers in engineering education research are different from engineering faculty members who conduct educational research in the sense that they have weaker conceptual hurdles in shifting mindset from engineering to educational research. They usually appreciate qualitative methods, and enjoy exploring the social and educational space. We also conclude that iKNEER has some influences on novice researchers' research process, especially in building professional network and depicting the focus area of engineering education research, but the researchers' decisions on pursuing certain research topics are made under a much broader context and usually finalized by communicating with experts. We also identified usability issues and suggestions for the future design of iKNEER and similar research tools. We acknowledge that the sample size of this study may not be sufficient to draw any generalizable conclusion, but the results can be of interests to researchers who are interested in scholarly development of novice researchers in interdisciplinary field, as well as researchers and designers of research tools.

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Reference

1. Borrego, M. Development of engineering education as a rigorous discipline: A study of the publication patterns of four coalitions. *Journal of Engineering Education* **96**, 5-18 (2007).
2. Jesiek, B., Newswander, L.K. & Borrego, M. Engineering education research: Discipline, community, or field? *Journal of Engineering Education* **98**, 39–52 (2009).
3. Streveler, R.A. & Smith, K.A. From the Margins to the Mainstream: The Emerging Landscape of Engineering Education Research. *Journal of Engineering Education* **99**, 285-287 (2010).
4. Haghighi, K. Quiet no longer: Birth of a new discipline. *Journal of Engineering Education* **94**, 351–353 (2005).
5. Engineering Education Research Colloquies The Research Agenda for the New Discipline of Engineering Education. *Journal of Engineering Education* **95**, 259-61 (2006).
6. Borrego, M. Conceptual Difficulties Experienced by Trained Engineers Learning Educational Research Methods. *Journal of Engineering Education* **96**, 91–102 (2007).
7. Hockey, J. New territory: Problems of adjusting to the first year of a social science PhD. *Studies in Higher Education* **19**, 177–190 (1994).
8. Madhavan, K. *et al.* Understanding the Engineering Education Research Problem Space Using Interactive Knowledge Network. *Proceedings of ASEE Annual Conference & Exposition* (2011).
9. Ali, A., Kohun, F. & Levy, Y. Dealing with Social Isolation to Minimize Doctoral Attrition- A Four Stage Framework. *International Journal of Doctoral Studies* **2**, 33–49 (2007).
10. Ali, A., Kohun, F. & Cohen, E. Dealing with isolation feelings in IS doctoral programs. *International Journal of Doctoral Studies* **1**, 21–33 (2006).
11. Deem, R. & Brehony, K.J. Doctoral Students' Access to Research Cultures-are some more unequal than others? *Studies in Higher Education* **25**, 149-165 (2000).
12. Nettles, M.T. & Millett, C.M. *Three magic letters: getting to Ph. D.* (Johns Hopkins Univ Pr: 2006).
13. Wright, J. & Lodwick, R. The Process of the PhD: A Study of the First Year of Doctoral Study. *Research Papers in Education* **4**, 22–56 (1989).
14. Benge, C.L., Onwuegbuzie, A.J., Mallette, M.H., Instruction, S.I. & Burgess, M.L. Doctoral Students' Perceptions of Barriers to Reading Empirical Literature: A Mixed Analysis. *International Journal of Doctoral Studies* **5**, (2010).
15. Dreher, N. & Dreher, H. Empowering Doctoral Candidates in Finding Relevant Concepts in a Literature Set. *International Journal of Doctoral Studies* **6**, (2011).
16. Li, H., Councill, I., Lee, W.C. & Giles, C.L. CiteSeerx: an architecture and web service design for an academic document search engine. *Proceedings of the 15th international conference on World Wide Web* 883–884 (2006).
17. Uren, V., Buckingham Shum, S., Bachler, M. & Li, G. Sensemaking tools for understanding research literatures: Design, implementation and user evaluation. *International journal of human-computer studies* **64**, 420–445 (2006).
18. Chau, D.H., Kittur, A., Hong, J.I. & Faloutsos, C. Apolo: making sense of large network data by combining rich user interaction and machine learning. *Proceedings of the 2011 annual conference on Human factors in computing systems* 167–176 (2011).
19. Cairns, P. & Cox, A.L. *Research Methods for Human-Computer Interaction*. (Cambridge University Press: 2008).
20. Plaisant, C. The challenge of information visualization evaluation. *Proceedings of the working conference on Advanced visual interfaces* 109–116 (2004).
21. Haglund, L. & Olsson, P. The impact on university libraries of changes in information behavior among academic researchers: a multiple case study. *The Journal of Academic Librarianship* **34**, 52–59 (2008).
22. Kuhlthau, C.C. Seeking meaning: A process approach to library and information services. (2004).
23. Kari, J. & Savolainen, R. Towards a contextual model of information seeking on the Web. *New Review of Information Behaviour Research* **4**, 155–175 (2003).
24. Choo, C.W., Detlor, B. & Turnbull, D. Information seeking on the Web: An integrated model of browsing and searching. *First Monday* **5**, (2000).
25. Agosto, D.E. A model of young people's decision-making in using the Web. *Library & Information Science Research* **24**, 311–341 (2002).
26. Bilal, D. & Kirby, J. Differences and similarities in information seeking: children and adults as Web users. *Information Processing & Management* **38**, 649–670 (2002).

27. Hupfer, M.E. & Detlor, B. Gender and Web information seeking: A self-concept orientation model. *Journal of the American Society for Information Science and Technology* **57**, 1105–1115 (2006).
28. Rowlands, I., Nicholas, D. & others Information behaviour of the researcher of the future. *London: University College of London* (2008).
29. Aronson, J. A pragmatic view of thematic analysis. *The qualitative report* **2**, 1–3 (1994).
30. Owen, W. F. Interpretive themes in relational communication. *Quarterly Journal of Speech* **70**, 274–287 (1984).
31. Howitt, D. & Cramer, D. *Introduction to research methods in psychology*. (Prentice Hall: 2008).

Appendix 1: Interview Protocols

Phase 1: (some questions ended up not being asked specifically, because the interviewee already touched upon them)
1. How often do you use iKNEER?
2. What is your background and research interest?
3. What difficulties you had in your research?
4. What are the tools, platforms or methods you generally use in writing your literature review before using iKNEER? (not specifically asked)
5. What expectation you have before using iKNEER?
6. What is your first impression about iKNEER? (not specifically asked)
7. After using iKNEER, did you find out what you expected?
8. What is your overall impression about iKNEER?
9. How do you actually use iKNEER? (not specifically asked)
10. Do you have any difficulties while using iKNEER? (not specifically asked)
11. What are your suggestions for future development of iKNEER?

Phase 2: (based on the data from phase 1, we refined the interview protocol mainly to include more details of participants' backgrounds)
1. How often do you use iKNEER?
2. What is your background regarding teaching, working and research experiences, and what are your current research interests?
3. What difficulties you have in your research as a new researcher in this field?
4. How you deal with these difficulties in general?
5. What expectations you have before using iKNEER?
6. What happened when you start to use iKNEER?
7. What difficulties you have when you use iKNEER?
8. What is your overall impression to iKNEER?
9. What are your suggestions to the future of iKNEER?

Phase 3: (based on the data from phase 2, we refined the interview protocol again mainly to include why and how the participants become interested in engineering education research)
1. What is your background regarding teaching, working and research experiences, and what are your current research interests?
2. Why and how you become interested in engineering education research?
3. What difficulties you have in your research as a new researcher in this field?
4. How you deal with these difficulties in general?
5. What expectations you have before using iKNEER?
6. What happened when you start to use iKNEER?
7. What difficulties you have when you use iKNEER?
8. What is your overall impression to iKNEER?
9. What are your suggestions to the future of iKNEER?

Appendix 2: Coding Sheet

Interviewee Statement	Code	Category
P1: relating it to mentoring and especially underrepresented groups, there is not a lot [literature]	*Unable to find literature*	*Research difficulties*
P3: there were many difficulties because there are not too many [literature]	*Unable to find literature*	*Research difficulties*
P4: There is really nothing there. No one has published on this before, so that's what I've been finding	*Unable to find literature*	*Research difficulties*
P1: I was so ENE focused	*Researcher's narrow scope in literature searching*	*Research difficulties*
P3: I am trying to write in a language that is not mine	*Language difficulties for international students*	*Research difficulties*
P3: It's very difficult [to recruit interview participants]	*Difficult in research methods*	*Research difficulties*
P5: I've gotten pretty good at finding literature at that point and so the difficulty right now is like I'm analyzing interview sessions, so it's very qualitative	*Good at literature review because of previous experiences, difficulty in qualitative research methods*	*Research difficulties*
P6: Oh, no, not at all. I was born to be in this degree. I hated it [computer engineering]. The journal papers [in engineering] were just so dry.	*Hated engineering, love engineering education, no particular difficulties, or care enough to overcome any difficulties*	*Research difficulties*
P1: even with this system, identity doesn't seem to be a huge area or topic that is researched [so I am not pursuing this direction now]	*Confirmation of adjustment in research direction*	*Usefulness of iKNEER on research*
P1: I expected, not so much more money or the grant, I expected more articles [grant proposals more than paper]	*iKNEER's narrow scope on papers*	*Usefulness of iKNEER on research*
P2: I couldn't find many papers here	*iKNEER's narrow scope on papers*	*Usefulness of iKNEER on research*
P3: There were more grant proposals than papers, I am not interested in grant proposals.	*iKNEER's narrow scope on papers*	*Usefulness of iKNEER on research*
P4: I think it's a really cool tool, but it's kind of not useful for me right now because it doesn't cover what I need it to cover and I cannot put that in there.	*iKNEER's narrow scope on papers*	*Usefulness of iKNEER on research*
P5: No, I didn't find it on here, so I just went into Google and searched it and I found it	*iKNEER's narrow scope on papers*	*Usefulness of iKNEER on research*
P5: I think making sure it doesn't lose its focus of being like only including these top tier journals. You don't want to include everything. I guess stick with that.	*iKNEER's narrow scope is good, it's focus*	*Usefulness of iKNEER on research*
P2: a network link, it's very helpful. I like to see the graph	*Collaboration network is useful*	*Usefulness of iKNEER on research*
P4: I would sit through and click on that because it's valuable to be able to generate that network.	*Collaboration network is useful*	*Usefulness of iKNEER on research*
P6: as far as learning about people, I found this to be a very fascinating tool. So who are people that I follow who are they following. This tells you pretty directly	*Collaboration network is useful*	*Usefulness of iKNEER on research*
P1: It is from NSF, and I have career interests that	*iKNEER usage beyond*	*Usefulness of*

area. It tells me what NSF is cataloging.	*research*	*iKNEER on research*
P1: It was helpful just for me to get a snapshot of what's going on in my areas of interest.	*Impression of iKNEER*	*Usefulness of iKNEER on research*
P2: It's powerful. It's very inclusive	*Impression of iKNEER*	*Usefulness of iKNEER on research*
P1: I thought it was different	*Impression of iKNEER*	*Usefulness of iKNEER on research*
P1: I have to ask my advisor	*Advisor*	*Other environmental factors on research*
P3: We meet every two weeks with the advisor, and other professors and we meet once a week with the research team.	*Advisor, other professor and the research team*	*Other environmental factors on research*
P4: I've been working with faculty, but these were technical faculty. These were computer science, software engineering, engineering faculty, not in engineering education really.	*Previous experiences working with engineering faculty*	*Other environmental factors on research*
P6: At that conference, I met [professor's name] and that was when I first decided, at that conference, that I may go back, do my Ph.D. in engineering education rather than computer engineering	*Previous conferences experiences*	*Other environmental factors on research*
P3: the librarian P4: institutional repository, the librarian P5: I mean we have the library over at [building name] and I really I like it, so usually if I find a book it's over there. P6: the librarian	*Library and librarian*	*Other environmental factors on research*
P4: I'm tracking people rather than publications	*Authors' personal webpages*	*Other environmental factors on research*
P1-P6: Google Scholar, P1: Mendeley, EndNote P3: Zotero P6: Compendex	*Other research tools*	*Other environmental factors on research*
P1: I kept looking for, where's the Search [cannot find search box with a small netbook screen]	*Search box*	*Usability issues*
P1: I tried the network button. I was confused.	*Network graph confusing*	*Usability issues*
P1: Isn't there a way to click on something and it does something different, like it takes away some layers	*Network graph confusing*	*Usability issues*
P1: it will be useful if you search a grant and maybe click this grant, you get all the papers published out of this grant	*Grant proposals connect papers*	*Suggestions to future development*
P2: I think this characteristics should be up here on every author not just my interesting authors	*Tree maps for every author*	*Suggestions to future development*
P3: It could be useful if you just said okay I am interested only in research proposals or articles	*Be able to choose to view papers or grant proposals*	*Suggestions to future development*
P3: Export to Zotero	*Connect with citation management tool*	*Suggestions to future development*
P3: Users want to feel like they are the bosses. So if they feel constricted in a way they will not like it. [click the paper title should be able to link to university library for the full text or to Google Scholar, rather than restricted here]	*Provide full text*	*Suggestions to future development*
P6: It [iKNEER] is not something to use if you are crunched on time, because you want something	*Provide full text*	*Suggestions to future development*

that'll give you directly into the PDF		
P4: I would be happy to provide my own data, but if you have some way that users could load data into the system because it's a really great	*Allow user upload data to expand the scope*	*Suggestions to future development*
P6: I'd want to see all the papers they authored just by clicking on that, clicking on that node, clicking on that edge	*Show co-authored papers by clicking edges in the collaboration network*	*Suggestions to future development*