

# Women in Software Requirements Engineering: An Exploratory Study

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**Abstract** – In an era when women are increasingly prominent in disciplines like medicine, law, and business, the engagement of women in engineering has yet to reach its potential. One way to facilitate the recruitment and retention of women in engineering education is to introduce internationally renowned women engineers and scientists as role models. This paper presents an exploratory study on the roles women researchers play in the field of software requirements engineering (RE). RE draws on the cognitive and social sciences to provide both theoretical grounding and practical techniques for eliciting and modeling requirements. As a result, RE is inherently interdisciplinary and contributions can be made by researchers (especially women researchers) with diverse expertise, such as cognitive psychology, sociology, linguistics, computer science, and so forth. In this study, we explore the roles women play in RE by examining three well established women researchers in the field. Our study identifies trends and hypotheses to guide further investigation. The results can be readily adapted as recruiting notes or training materials for improving the engagement of women in engineering in general.

*Keywords:* Women in engineering, software engineering, requirements engineering, exploratory study.

## INTRODUCTION

Women play an increasingly prominent role in disciplines like medicine, law, and business, but their engagement in engineering has yet to reach its potential. Not only are women vastly underrepresented in engineering professions, but the increase of women in engineering education has been only modest. For example, Figures 1 and 2 show the percentage of women in the US with a Bachelor's and Master's degree in engineering over the past few years [20]. From these figures and studies done by others (e.g., [10], [17], etc.), it is apparent that engineering and technology fields encompass less numbers of women than men.

The lack of women in engineering is a serious problem because “we all have an obligation to the profession and to society to encourage girls and boys and young women and men to pursue careers in engineering and technology to ensure we have a high-performance workforce” [17]. Several organizations, such as Society of Women Engineers (SWE) and IEEE Women in Engineering program (WIE), have investigated why women tend to stray away from the engineering majors. The following list provides a few important factors revealed by the American Association of University Women (AAUW) [10].

- Negative stereotypes about girls' and women's abilities in mathematics and science persist despite girls' and women's considerable gains in participation and performances in these areas during the last few decades. Two stereotypes are prevalent: girls are not as good as boys in math, and scientific work is better suited to boys and men. These stereotypes are considered the number one factor in the lack of women in engineering.

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- A lack of confidence exists among girls and young women. Individuals must believe they have the ability to succeed in a given career to develop preferences for that career. If women do not believe they have the ability to become a scientist or engineer, they will choose to be something else.
- Lack of women faculty members in universities is another significant factor. Young women are more comfortable when there are female faculty members for them to converse with and look up to.

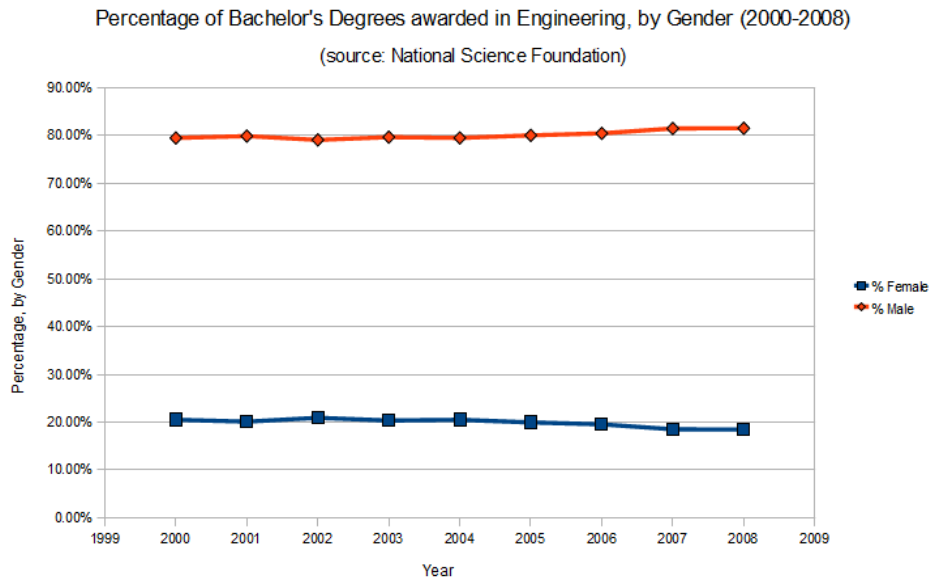


Figure 1. Percentage of women with a Bachelor's degree in engineering [20].

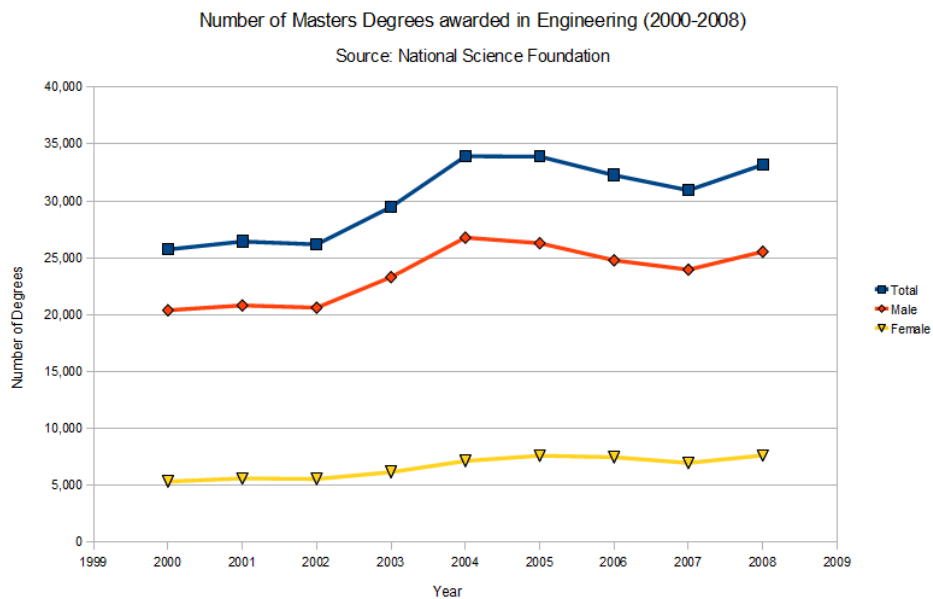


Figure 2. Percentage of women with a Master's degree in engineering [20].

Thus, one way to improve the engagement of women in engineering education is to study the stereotypes who have gained tremendous success in engineering fields. We aim to identify and examine women faculty members who are internationally renowned engineering researchers and educators. In our opinion, codifying positive stereotypes as “role models” can increase the confidence among girls and young women about their careers in engineering and technology fields. This in turn will help create a comfortable environment for the recruitment and retention of female faculty members in engineering.

In our work, we focus on a particular engineering field, *software requirements engineering* (RE). Broadly speaking, RE is the process of discovering the purpose of a software-intensive system by identifying stakeholders and their needs, and documenting these in a form that is amenable to analysis, communication, and subsequent implementation [6]. Because RE is inherently interdisciplinary, contributions can be made by researchers, especially women researchers, with diverse expertise ranging from sociology and cognitive psychology to linguistics and computer science. This paper reports an exploratory study of the roles that women play in RE. Specifically, we use purposeful sampling to study three well established women researchers in RE. Our goal is to uncover the commonalities and differences of their successes in the engineering field, offer insights into their impacts on women students and colleagues, and shed light on using these role models to improve women participation in engineering in general. In what follows, we first describe the interdisciplinary nature of RE and the different parts of RE where women tend to contribute their skills. We then present the analysis of three successful women researchers in RE, followed by a discussion of the limitations and implications of our exploratory study.

## REQUIREMENTS ENGINEERING (RE)

The interdisciplinary nature of RE makes it an ideal engineering field to research the different roles women can play. One of the clearest definitions of RE is provided in [19]: “Requirements engineering is the branch of software engineering concerned with the real-world goals for, functions of, and constraints on software systems. It is also concerned with the relationships of these factors to precise specifications of software behavior, and to their evolution over time and across software families.” In [6], the authors make a compelling proclamation about RE by stating that “whether observed at the system level or the software level, RE is a multi-disciplinary, human-centered method. The tools and techniques used in RE allure a variety of disciplines, and the requirements engineer may be expected to master skills from a number of different disciplines.”

### Disciplines upon which RE draws

It is straightforward to realize that computer science and software engineering are the focal subjects in the structure of RE. They provide the framework to assess the feasibility of requirements and the tools by which software solutions are developed [6]. The environment of RE has to be thoughtful of the people which the system interacts with and the world in which the people engage. RE, therefore, also draws on the cognitive and social sciences to provide both theoretical grounding and practical techniques for eliciting and modeling requirements. To that end, the following disciplines, along with computer science and software engineering, are fundamental to RE [6].

- *Linguistics* is the scientific study of the human language. RE is fundamentally about communication; thus linguistics is an imperative component of RE.
- *Anthropology* is the study of humanity and offers a methodological tactic to observing human activities that helps to develop a richer understanding of how computer systems may help or hinder those activities.
- *Cognitive psychology* is the study of how people think, behave, and comprehend. It provides an understanding of the complications people may have in describing their needs.
- *Sociology* is the study of society and supplies an understanding of the political and cultural changes caused by computerization.

With such a wide-ranging collection of disciplines underlying RE, a woman with proper background should find a role in contributing to the RE knowledge. No matter if a (woman) researcher’s major is in mathematics, engineering, business, or psychology, RE attracts and requires every role in order to be successful.

## Core RE Activities

RE is a set of activities concerned with identifying and communicating the purpose of a software-intensive system, and the contexts in which it will be used. Hence, RE acts as the bridge between the real world needs of users, customers, and other constituencies affected by a software system, and the capabilities and opportunities afforded by software-intensive technologies. Core RE activities include: (1) plan and elicit requirements, (2) model and analyze requirements, (3) communicate and negotiate requirements, and (4) realize and evolve requirements [6].

Understanding these activities allows several options for women to be involved in RE. A positive aspect about RE is that the process does not require for each participant to be knowledgeable in all four practice areas. Women can choose the area that interests them the most and concentrate on that particular subject to contribute to the RE knowledge base. Referring to the underlying disciplines of RE enumerated earlier, the following list illustrates how (women) researchers can leverage their diverse skill sets to conduct the core RE activities [19].

1. *Plan and elicit requirements*: A crucial stage in the RE process is to elicit the desires of the stakeholders for the software system to be developed. Elicitation techniques are used to discover what problems within a boundary is essential to be resolved. These techniques include, but are not limited to, surveys, interviews, questionnaires, observation, and prototyping. The elicitation step defines who the stakeholders are and what goals need to be reached. In situations where stakeholders have difficulty expressing their exact goals and expectations for the system, *cognitive psychologists* can step in and help present different scenarios of the system being used and determine tasks the stakeholders want the users to perform in order to accurately determine the goals for the system.
2. *Model and analyze requirements*: Modeling is the assembly of mental descriptions that are amenable to analysis, communication, and implementation. Being a fundamental part of RE, modeling tactics are used to prompt additional information about the goals and tasks of the system being constructed. The key question to ask for any RE modeling approach is ‘what is it good for?’, and the answer should always be in terms of the kind of analysis and reasoning it offers [6]. *Anthropology* can contribute to requirements modeling by developing an understanding of how software systems affect human activities.
3. *Communicate and negotiate requirements*: An important role that *linguistics* plays in RE is to facilitate effective communication of the requirements among different stakeholders. On one hand, linguistic analyses have changed the way in which natural language such as English is used in specifications, for instance to avoid ambiguity and to improve comprehensibility. On the other hand, the linguistic aspects of requirements (e.g., requirements documentation) are instrumental in making sure that the requirements can be understood, analyzed, and validated. In this context, validation refers to the process of ensuring that the requirements and models elicited deliver a precise account of stakeholder goals.
4. *Realize and evolve requirements*: Successful software systems always evolve as the environment in which these systems operate changes and stakeholder requirements change. In software engineering, it has been demonstrated that focusing change only on program code leads to a loss of structure and maintainability. Thus, each proposed change needs to be evaluated in terms of existing requirements and software architecture so that the trade-off between the cost and benefit of making a change can be assessed. In this respect, *sociology* offers a systematic examination of the changes caused by computerization, e.g., introducing a new software system or adding a new set of requirements may change the nature of the work carried out within an organization, affect the structure and communication paths within that organization, or even change the original needs that it was built to satisfy.

## ROLES OF WOMEN IN RE

Given the multi-disciplinary and human-centered processes of RE, together with the multi-faceted activities involved in RE, we speculated that women researchers have found ways to shine in the roles they hold in RE. We applied purposeful sampling by browsing the proceedings, as well as the organizing and programming committees, of recent editions in the IEEE International Requirements Engineering Conference series (requirements-engineering.org). We identified three women faculty members working in the US who are leading RE researchers and educators.

To address our overall research question, “the roles women play in RE,” we examine each woman researcher’s educational background and specialties in RE. For research disseminations, we not only overview each woman’s publication and citation records over the past few years, but also provide some in-depth analysis of each researcher’s publishing experiences in the field of RE. In particular, we study a representative paper from the researcher’s early involvement in RE and one publication from her recent RE endeavor. We also pay attention to the impacts of these “role models” in terms of coauthoring with women students and collaborating with other women researchers.

### Ann Hickey

Ann Hickey, a well-known figure in the realm of RE, has established herself through highly respected published papers and presentations. Her work experience began with working as a Systems Analyst in Installations and Services Activity from 1978 to 1983 [4]. Her next job was as a Program Manager and Senior Business System Analyst in Communication Security Logistics Activity from 1984 to 1995 [4]. The following is a list of Hickey’s academic background [4]:

- Ph.D., University of Arizona, Management Information Systems, 1999
- M.S., University of Arizona, Management Information Systems, 1990
- B. A., Dartmouth College, Mathematics, 1977

Hickey’s education in mathematics and business is an exemplar scenario of women working in RE who do not have engineering backgrounds. One of her first published papers was in 1998 entitled “Enabling the Effective Involvement of Multiple Users: Methods and Tools for Collaborative Software Engineering” [12]. This paper presented a framework of the Collaborative Software Engineering Methodology that contains mechanisms to support three layers of user involvement [12]. These layers include: selected user representatives, user groups, and the broader user community [12]. This publication has become the cornerstone of Hickey’s career [3]. From 1998 to 2009 Hickey has published 13 papers, which have been cited numerous times by other researchers [3]. Figure 3 shows the number of times each of Hickey’s publications has been cited. These large numbers of citations is a reflection of the influence Hickey has in the RE world. Hickey has a soft side to her publications. Her papers on elicitation modeling tend to have a social approach to them [1, 11, 2]. Her publications tend not to include many complicated formulas or theories [1, 11, 2].

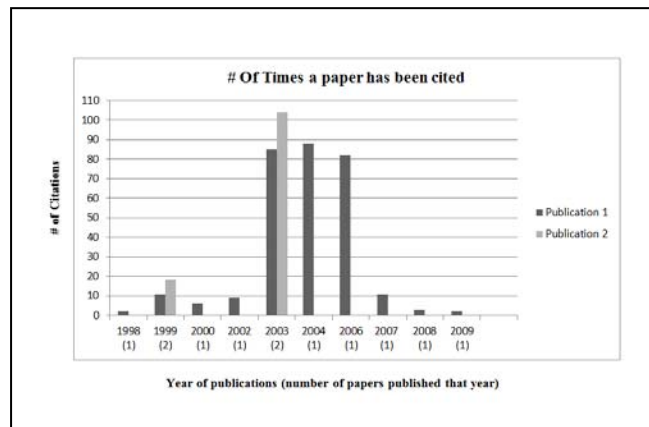


Figure 3. Ann Hickey’s publications and citations [3].

Hickey has received a few honors such as induction into Beta Gamma Sigma in 2001, The Outstanding Service Award at College of Business at University of Colorado at Colorado Springs (UCCS) for 2000 -2001, and the AABY (Altruistic Attitude & Behavior Yardstick) Award from the College of Business at UCCS in 2001 [3]. Hickey has not only established herself as a renowned researcher in RE, but also broadened her impacts as an educator and an administrator. She currently holds the position of Associate Dean and Associate Professor of Information Systems at the UCCS. Hickey is a great role model and an inspiration to many young women and men throughout the RE community.

## Betty Cheng

Betty Cheng, a professor of Computer Science and Engineering at Michigan State University, is another well-known name in the world of RE. She has an interest in formal methods for software engineering, component-based software development, object-oriented analysis and design, embedded systems development, and distributed computing [8]. Her academic background is as follows [8]:

- Ph.D., Computer Science, University of Illinois-Urbana Champaign, 1990
- M.S., Computer Science, University of Illinois-Urbana Champaign, 1987
- B.S., Computer Science, Northwestern University, 1985

Cheng has a strong technical engineering background which has helped her publish 115 papers from 1992 to 2011 [7]. Out of these papers, a large percentage concentrates on modeling [7]. Her first published paper was titled “Using Automated Reasoning Techniques to Determine Software Reuse” [16]. The paper proposes an approach to organize, classify, and retrieve reusable software components [16]. The paper included several mathematical functions and equations, which is common in most of Cheng’s publications. Cheng typically includes various mathematical and logical theories to present different approaches and methods to concepts in RE [9, 5]. Figure 4 shows Cheng’s published papers and the numerous times they have been cited.

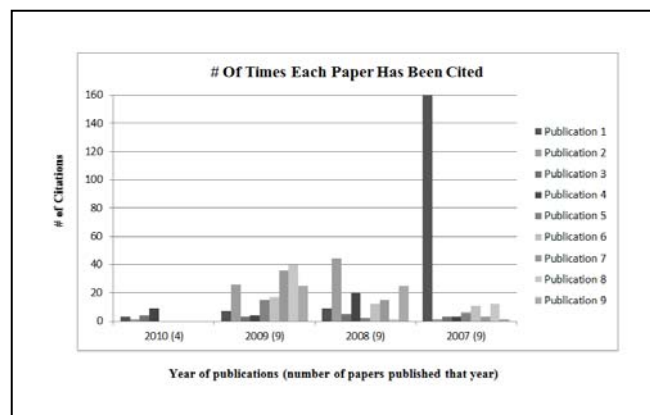


Figure 4. Betty Cheng’s publications and citations [7].

Cheng’s numerous publications and the amount of times each paper has been cited proves the extreme influence Cheng has in the RE community. Cheng’s hard work continues to pay off. Recently, she was selected to serve the following roles in leading software engineering conferences:

- 33rd ACM/IEEE International Conference on Software Engineering (ICSE 2011), Waikiki, Honolulu, Hawaii, Program Committee Member and Mentoring Program Chair [8].
- 6th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS 2011), Program Chair [8].
- Program Co-Chair, IEEE International Conference on Software Engineering (ICSE 2013), San Francisco, California, Program Committee Co-Chair [8].

Cheng’s role as Program Chair or Co-Chair for the premier conferences in the field is a wonderful accomplishment for her and for all women in RE. She is an impeccable role model and has paved the way for young women to succeed and shine in an area traditionally dominated by men.

## Jane Cleland-Huang

Jane Cleland-Huang is an internationally renowned woman researcher in the RE community. She received her Ph.D. in computer science from the University of Illinois at Chicago [15]. Her research area encompasses applications of machine learning and data mining techniques to software engineering problems such as trace retrieval, collaborative

requirements engineering, and feature analysis [15]. Cleland-Huang is a member of the IEEE Women in Engineering and IFIP 2.9 Working Group on RE [15]. She has over fifty well respected publications [14]. One of her first published papers was entitled “Function-Class Decomposition: A Hybrid Software Engineering Method” [14]. This paper was coauthored with a young lady named Annie Kuntzmann-Combelles. Throughout Cleland-Huang’s publications, she continues to mentor and direct other young women in her work. Recent published papers such as “Lessons Learned from Open Source Projects for Facilitating Online Requirements Process” coauthored with Paula Laurent, and “Ready-set-transfer! Technology Transfer in the Requirements Engineering Domain” coauthored with Daniela Damian, are prime examples of Cleland-Huang’s involvement with women students and colleagues in RE [18, 13]. Figure 5 shows Cleland-Huang’s many publications and the number of times each paper has been cited.

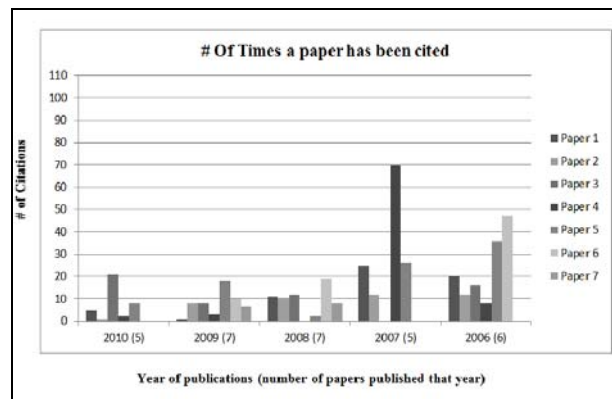


Figure 5. Jane Cleland-Huang’s publications and citations [14].

Along with the excellent publication record, Cleland-Huang has received many prestigious awards and honors which include the following [15]:

- The ACM SIGSOFT Distinguished Paper Award at the International Conference on Software Engineering (2010 and 2011) [15].
- Workshop Chair and Program Board Member for the 16th IEEE International Requirements Engineering Conference (2009) [15].
- The Manfred Paul TC2 Manfred Paul Award for Excellence in Software: Theory and Practice (2006) [15].

A unique contribution of Cleland-Huang is her active involvement in women in engineering. She is a member of IEEE Women in Engineering, the largest international professional organization dedicated to promoting women engineers and scientists. She has been a supervisor for many young women pursuing engineering degrees and careers. For example, Xuchang Zhou is a recent woman Ph.D. graduate from Cleland-Huang’s group, and Yonghee Shin is a women Postdoc fellow seeking to advance her career under Cleland-Huang’s supervision. In summary, Cleland-Huang has an enormous role as a woman in RE and is continuously influencing the community and many young women by serving as an Associate Professor at DePaul University in the College of Computing and Digital Media.

## DISCUSSION AND CONCLUSIONS

In this work, we used purposeful sampling to identify three women researchers and studied their roles in RE. Like many exploratory studies, our work is not subject to statistical generalization but theoretical generalization. Even though our sample size is small, we believe our selected subjects are representative among the leading women “role models” in the field of RE. To the best of our knowledge, our study is the first to provide in-depth, qualitative analysis of the roles the subjects play in RE. The questions answered in our research can be refined and extended to examine more women scientists, engineers, and educators.

In this exploratory study, our goal is to uncover successful stories about women in engineering, and use the stories to attract young men and women into the software requirements and other engineering fields. Table 1 summarizes our key findings. The results confirm that RE is an interdisciplinary field and contributions can be made by researchers (especially women researchers) with diverse background and expertise.

Table 1. Summary of Results

	Background	Expertise	Writing Style
<b>Ann Hickey</b>	Mathematics and Management Information Systems	<ul style="list-style-type: none"> <li>Elicitation</li> <li>Modeling</li> </ul>	Soft-side, human-centered approach
<b>Betty Cheng</b>	Computer Science	<ul style="list-style-type: none"> <li>Formal methods</li> <li>Object-oriented analysis</li> <li>Embedded systems</li> </ul>	Formal, mathematical approach
<b>Jane Cleland-Huang</b>	Computer Science	<ul style="list-style-type: none"> <li>Machine learning</li> <li>Trace retrieval</li> <li>Data mining</li> </ul>	Technical, practitioner-oriented approach

It is important to point out that the “role models” resulted from our exploratory study is one of the methods to improve the status of women in engineering. In addition to exposing girls to successful females in math and science, the following activities are also recommended in order to increase women in engineering [10]:

- Teach girls that intellectual skills, including math and science skills, grow over time.
- Help girls recognize their career-relevant skills.
- Perform outreach to high schools and encourage high school girls to take calculus, physics, chemistry, computer science, and engineering classes when available.
- Encourage current college women to join organizations such as SWE and WIE.
- Attract and retain female members because they are a great contribution in helping recruit and retain female students and students from other underrepresented groups.

Despite the variety of activities listed above, we feel that the role models identified in our work can serve as a stepping stone for more research in the roles that women play in engineering. We are now in the process of incorporating our key findings to the training materials for recruiting girls in computing and in engineering in general. We look forward to reporting our recruiting experience in the near future.

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