Embracing Complexity in Engineering Education at Southeastern Universities

James Russell[1], Michelle Maher [2], Nadia Craig[1], Wally Peters[1]

Abstract

The authors systematically examined programs of mechanical engineering located in the southeastern United States. The examination was conducted as if high school students were searching for a college. Information available on the web was reviewed to identify the occurrence and frequency of language and concepts associated with complex systems (e.g., complexity, complex systems, and emergent properties). Several results and conclusions can be drawn from this study. A significant level of activity in complexity is present at the university level, but not at the engineering college and mechanical engineering department level. It was also found that there is not a strong correlation between the results of complexity found by means of search engines and those found by "surfing" the websites. At most universities, a search engine is available at the university level, but not generally available at the college and department level. Finally, an examination of curriculum, the fundamental indicator of mechanical engineering students' education, showed that slightly less than 28 percent of the sample embraced complexity.

Introduction

As powerfully stated by William Wulf, president of National Academy of Engineers, "Many of the students who make it to graduation enter the workforce ill-equipped for the complex interactions, across many disciplines, of real-world engineered systems" [Wulf, 4]. Wulf suggests that mechanical engineers are increasingly required to solve problems involving complex physical, biological and social systems. As educators, we must recognize the needs of undergraduate mechanical engineering students to both master an ever-increasing amount of content knowledge within these systems and develop an ability to think critically and holistically across these systems. The need for our undergraduates to do both is critical and urgent, and calls for a reexamination of the content of current undergraduate mechanical engineering programs. Specifically we would like to examine how well current programs equip their students to practice at the intersection of these complex systems. We will create a broad "portrait" to reveal the extent to which programs of mechanical engineering in the Southeast are responding to Wulf's call to equip students to enter the workforce prepared for the complexity inherent in the real world of engineering.

Unfortunately, the traditional engineering curriculum is a series of courses that teach simple systems. There is no emphasis on the true complexity of these systems and how they interact with other systems. "Engineers normally will not spend their lifetimes solving purely technical problems. Most engineering problems span a wide range of both technical and non-technical areas. The non-technical include environmental, political, economic, social, regulatory and corporate factors that are usually interrelated in a complex fashion" [Splitt, 3]. There is a need to engage students in a new way of thinking about the problems that they will encounter in their careers. For those interested in introducing complexity into their curriculum, we have discussed creating a complex learning experience for freshmen in a prior paper [Craig, 2]. Before educators attempt to change the way that courses are

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[1] Department of Mechanical Engineering, University of South Carolina.

[2] Department of Educational Leadership and Policies, University of South Carolina.

taught, it is appropriate to evaluate the extent to which complexity has been embraced by engineering educators in southeastern universities. The study presented herein will determine the progress that is being made toward incorporating complexity into the undergraduate engineering experience. We will accomplish this by examining not only the vision and mission statements of the engineering college and the mechanical engineering department, but also by examining curriculum, a fundamental indicator of mechanical engineering students' education.

We will conduct this study through the eyes of "Susan and Sam Student," high school seniors, who are searching for a mechanical engineering educational experience that embraces complexity. They have an interest in attending universities in the Southeast. As typical students, they first turn to the internet for information. Initially they use search engines available on the university web pages. They extend their information gathering by "surfing" the websites to find information about complexity in the college of engineering, department of mechanical engineering, and more specifically in the curriculum.

Methodology

In this study, the authors put themselves in the shoes of postmodern high school seniors residing in the southeastern United States who want an education in mechanical engineering stressing complex systems in addition to the typical simple systems that are traditionally taught. Using the information gathering technique most familiar to high school students today, the authors turn to the internet to systematically collect relevant information. All web based information used for this study was collected in November and December of 2003.

Sample

All college and universities that responded to ASEE's 2002 Engineering and Engineering Technology College Profiles in the southeastern region and offer an Accreditation Board for Engineering and Technology accredited bachelors degree in mechanical engineering were included in the study sample. This sample consists of 43 institutions.

Web Search Criteria

To provide a broad view of the institutional culture, the first author utilized the sample websites search engines to identify the occurrence (number of "hits") of the terms "complexity," "complex systems," and "emergent properties." The university main web page search engine was queried first. Next, the college level search engine was queried. Last, the department level search engine was queried.

The remaining authors divided the sample to conduct a systematic analysis to assess the extent to which the college, department, and curricula embraced the concepts of complexity. Each institution's websites were reviewed according to the following procedures:

•Access college of engineering web page and review, when available, the vision or mission statement and Dean's welcome message. Search for terms and phrases that indicate that the concepts of complexity are being woven into the educational experience.

•Access department of mechanical engineering web page and review, when available, department's educational objectives, educational outcomes, and Chair's welcome message. Search for terms and phrases that indicate that the concepts of complexity are being woven into the educational experience.

•Access mechanical engineering curricula and descriptions of courses. Search for courses with complexity content—those that address the intersection of technology and non-technical issues including but not limited to environmental, political, economic, social, regulatory, and corporate factors.

Results

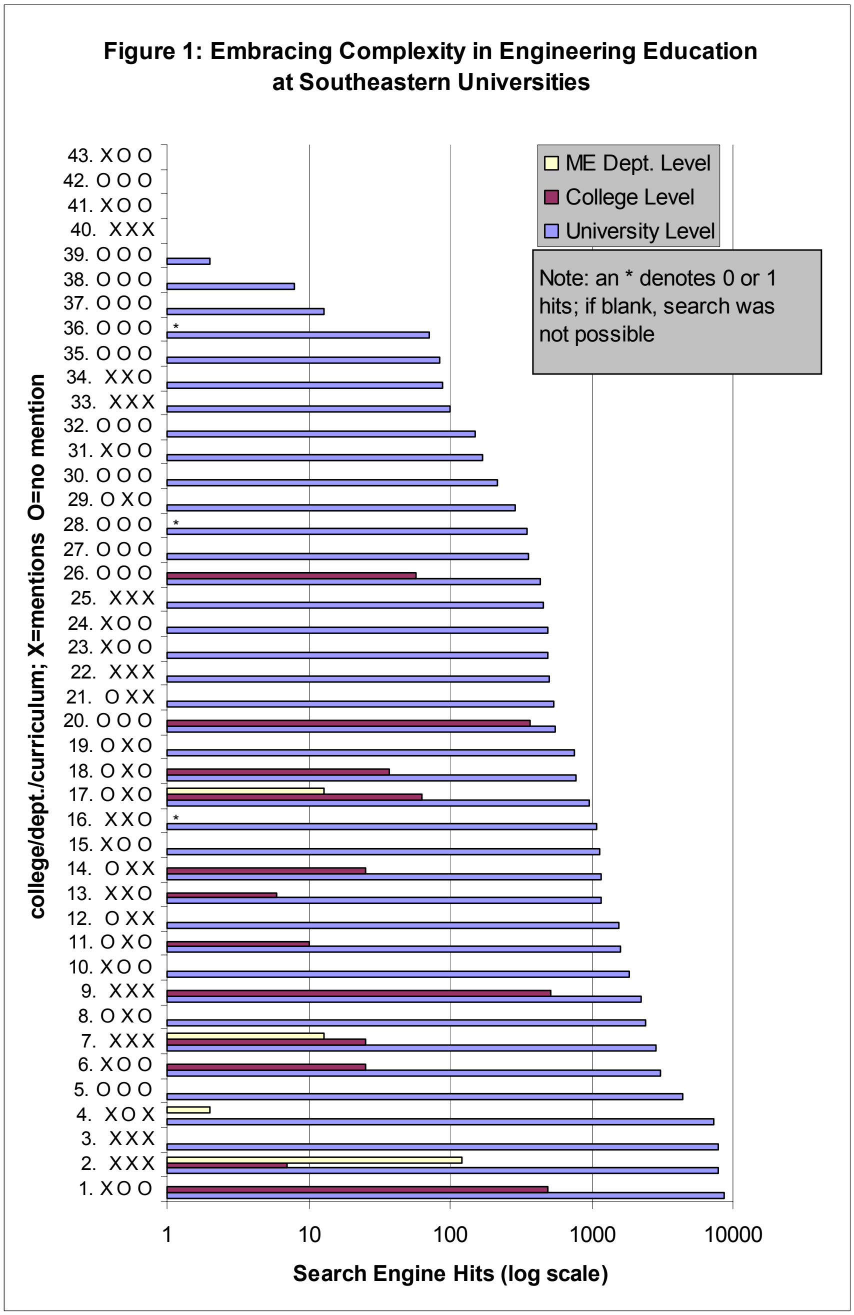
For clarity of understanding we present the results from the systematic review of university web pages for the concepts of complexity and then we combine these results with the search engine query results.

Table 1 below presents the results of a systematic review of the websites for each of the universities with a department of mechanical engineering who responded to ASEE's 2002 Engineering and Engineering Technology College Profiles in the southeastern region. The college of engineering websites, the department of mechanical engineering websites, and the department of mechanical engineering curricula for each university were examined for terms and concepts representative of the concepts of complexity. The table identifies each university with a unique number. An "X" denotes that concepts of complexity are addressed. An "O" denotes that there is no mention of complexity.

Table 1: Systematic Review of University WebPages for the Concepts of Complexity

University Identification Number	College Embraces Complexity	Department Embraces Complexity	Curriculum Embraces Complexity
1	X	O	O
2	X	X	X
3	X	X	X
4	X	O	O
5	O	O	O
6	X	O	O
7	X	X	X
8	O	X	O
9	X	X	X
10	X	O	O
11	O	X	O
12	O	X	X
13	X	X	O
14	O	X	X
15	X	O	O
16	X	X	O
17	O	X	O
18	O	X	O
19	O	X	O
20	O	O	O
21	O	X	X
22	X	X	X
23	X	O	O
24	X	O	O
25	X	X	X
26	O	O	O
27	O	O	O
28	O	O	O
29	O	X	O
30	O	O	O
31	X	O	O
32	O	O	O
33	X	X	X
34	X	X	O
35	O	O	O
36	O	O	O
37	O	O	O
38	O	O	O
39	O	O	O
40	X	X	X
41	X	O	O
42	O	O	O
43	X	O	O

In addition to the information presented above, search engine queries were carried out for each university. Search engine queries for the following words or phrases were carried out; "complexity," "complex systems," and "emergent properties." Queries were carried out using the university search engines and where applicable using the college and department level search engines. Hits for the three words or phases were summed to produce a total score for the university, college, and department levels. These total hit scores are presented in figure 1 below in conjunction with the data from the table above. Search engine hits for the university, college, and department levels are represented by the bars in the graph and grouped by university using the unique university identification number. If a bar is absent, then it was not possible to carry out a search at that level. Note that the number of hits is listed using a log scale. Three universities returned search results of zero or 1 for the college level search. These universities; numbers 16, 28, and 36; have asterisks placed in lieu of bars due to the limitations of presenting that data using a log scale.



Discussion

There are several conclusions and recommendations that can be drawn from this study.

The results obtained via search engines illustrate that the ability to search is uniformly available at the university level and much less available at the college and department level. These results also suggest a significant level of activity in complexity at the university level and less activity at the college and department levels; however, due to a lack of search engines at the college and department level this interpretation may be skewed.

The web search carried out by the “surfing” method indicates that there is a notable interest in complexity at the college and department level.

Viewing the search engine and “surfing” data concurrently shows that interest at the university level does not guarantee interest at the college and department level. The absence of search engine capabilities or hits for college and department levels are not a reliable indication of the actual implementation of complexity as found from web “surfing.”

Overall, opportunities exist in mechanical engineering departments, colleges of engineering, and universities in the southeast for students to receive an engineering education that has complexity as a fundamental emphasis and experience.

Many departments of mechanical engineering, colleges of engineering and universities in the southeast are embracing complexity; therefore, those who would like to expand their educational programs to also embrace complexity can look inside their own institutions (colleges and universities) or interact with their nearby neighbors.

Search engine results do not positively correlate with web “surfing” results and vice-versa. Our strong recommendation to “Susan and Sam Student” who have an interest in exploring complexity would be to use all means to gather information about educational opportunities available in various departments, colleges and universities. For example, web searches and web “surfing” should be augmented by personal contact both by phone and campus visits.

Finally, an examination of curriculum, the fundamental indicator of mechanical engineering students’ education, showed that slightly less than 28 percent of the sample embraced complexity.

Conclusions

Desmond Hudson, President of Northern Telcom Inc., said that, “My concern is for the students who come out of school suitably versed in mathematics, physics, and the sciences, but lacking an appreciation for literature, history, and philosophy. The view they have is that modern technology is a collection of components rather than an integral part of our society, our culture, our business environment” [Splitt, 3]. There is a need for a change in the current engineering curriculum. The Accreditation Board for Engineering and Technology addresses this need in the current accreditation method, Criteria 2000. It states that the graduates must possess the broad education necessary to understand the impact of engineering solutions in a global and societal context [ABET, 1].

We would like to suggest that a true measure of the extent to which engineering educators have embraced complexity is its inclusion in curriculum and courses. Although few mechanical engineering programs currently meet this measure, the widespread interest in complexity demonstrated in the sample supports the creation of synergistic partnerships to embrace and implement complexity into the curriculum.

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Bibliographic Information

James Russell

James Russell is a post-doctoral researcher and teacher in the Laboratory for Sustainable Solutions. His research interests include environmental management systems, industrial ecology, sustainable design, and complex systems science. His dissertation "Evaluating the Sustainability of an Ecomimetic Energy System: An Energy Flow Assessment of South Carolina" involved modeling energy flows in both human and natural systems.

Michelle Maher

Michelle Maher is Assistant Professor of Higher Education Administration. Her research interests include undergraduate student development, the use of technology in educational settings, and educational research methodology.

Nadia Craig

Nadia Craig is currently conducting research in the Laboratory for Sustainable Solutions while completing her Ph.D. in mechanical engineering. She is a recipient of the National Science Foundation's Graduate Research Fellowship. Last year she also taught in a 3rd grade science and mathematics class through the National Science Foundation's GK-12 fellowship program.

Wally Peters

Wally Peters is Professor of Mechanical Engineering, Director of the Laboratory for Sustainable Solutions, and Faculty Associate in the School of the Environment. His research interests include sustainable design, industrial ecology, complex systems, and environmental/earth ethics.