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International Engineering Education Journals: Past, Present and Potential Research Directions

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International Engineering Education: Past, Present and Potential Research Directions

Abstract

Past and present experiences have many times proven beneficial for future inquiries as they help us to see the trends in many fields of activities. This manuscript summarizes the evolution of research topics in a well-known international engineering educational journal and offers a condense recollection of research topics for future scientific investigations. The selected journal for text data investigation is the European Journal of Engineering Education spanning from 1978-2012. In order to confirm extracted topics, but also to account for complementary topics, two text mining techniques were applied in five years segments by extracting 6 and 10 topics from the corpus of documents associated with each segment. Latent Semantic Analysis and Latent Dirichlet Allocation are two text mining techniques commonly used for topic extraction over large volumes (corpora) of text documents producing a summary of topics that describe the entire corpus of documents. These topics were then analyzed to determine how the overall engineering education evolved over a period spanning approximately three decades. The results indicate the overall engineering education has evolved from teaching basic engineering and design skills, computers, systems and processes; to creative teaching strategies and didactic curriculums, integrated design technologies and developing technologies; to simulation, quality in higher education, and distance learning; to information communication technology, assessment/accreditation, sustainable technology and project-based training; and to engineering management, women engineering careers, and undergraduate engineering research.

Trends in Engineering Education

The trends in engineering education have been reported over several periods of time by different authors. Meisen[6] mentions that the global trends in engineering education in the 90s were a greater emphasis on experiential programs supported by industry work experience, declining emphasis on laboratory instruction, internationalization of engineering programs, higher emphasis on quality, and higher emphasis on engineering specialization. He also suggested that global quality was to be achieved through the control of engineering education by accreditation systems that allow graduates from accredited engineering programs to demonstrate equivalent competencies. Specialization that existed in the 90s in Canada was demonstrated by the number of types of bachelor engineering degrees that grew from 15 in 1965 to 60 in 1994[6].

Research in the trends in engineering education has been mostly reported through a variety of expert opinions of highly qualified individuals with some of the latest research being centered on how to prepare engineering students for the 21st century. There are authors who suggested that to prepare for the twenty first century, engineering education should be practice oriented, problem-based, and customer oriented; and that the educational organizations for the 21st century must emphasize process orientation, systems thinking, information technology use and the analysis of data for decision making[7]. Other authors have added other perspective on how to best prepare engineering education for the 21st century. Thom[10] believes that a new paradigm for engineering training needs to consider globalization, continuous change in practice and education, increase in new technology, and the effects of technology on the environment. He

also proposes that engineering training should consist of an engineering curriculum that emphasizes environmental sustainable technology, processes and methods; global issues: system oriented approaches; and a higher emphasis on engineering principles rather than on technology that can easily become absolute. The author considers that "the environmental educated engineer needs to have knowledge of systems; appropriate attitudes, skills and knowledge; and exposure to significant issues"[10]. Buchal[3] mentions that the new paradigm for the engineering education training is networked collaborative learning that is supported by the emerging information technologies. Computer-mediated communication (CMC) technologies such as videoconferencing, application-sharing programs, interactive multimedia courseware are facilitating distance education delivery through networks and some rapidly changing fields (e.g. information technology, computer engineering, telecommunications) are making it difficult for professors to stay abreast of current developments. Because of these developments, an environment was created to facilitate the need for networked collaborative learning[3].

Considering the aforementioned engineering educational proposal development direction, a research question arises. How the engineering education has actually evolved over the years? To answer this question, the present research analyses actually cover abstracts from a well established international journal spanning a period of more than three decades through two text analytic methods. This journal was selected on the basis of its longitude of existence as many other relevant journals have disappeared for a variety of reasons. This research differs from traditional articles on engineering education trends is that the reported engineering educations trends were obtained through two well known computerized text-analytical methods used to extract the topics of interest from the analyzed text.

Latent Semantic Analysis (LSA)

Latent Semantic Anaylsis (LSA) and Latent Dirichlet Allocation (LDA) are two computer algorithms designed to extract topics from text. For both methods, a document is represented as a vector of terms (words) in vector space with the assigned values to each term being the frequency of occurrence of that term. A collection of such documents is considered a corpus. The starting point for both algorithms is the corpus which is represented as a term-document matrix. LSA reduces the original term-document matrix into a smaller term-document matrix through a singular value decomposition (SVD) process. Through SVD, the original matrix is decomposed into three matrices: a document eigenvector matrix, an eigenvalue matrix, and a term eigenvector matrix. The SVD of a rectangular matrix $\mathbf{X}$ is given by:

$$\mathbf{X} = \mathbf{U}\boldsymbol{\Sigma}\,\mathbf{V}^T$$

where $\mathbf{U}$ is the $t \times r$ matrix of eigenvectors of the square symmetric matrix of term covariances $\mathbf{X}\mathbf{X}^T$, $\mathbf{V}$ is the $d \times r$ matrix of eigenvectors of the square symmetric matrix of document covariances $\mathbf{X}^T\mathbf{X}$ and $\boldsymbol{\Sigma}$ is an $r \times r$ diagonal matrix containing the square roots of eigenvalues (singular values) of both $\mathbf{X}\mathbf{X}^T$ and $\mathbf{X}^T\mathbf{X}$.

Graphically, the LSA method can be illustrated as follows: The input to the LSA method is the $\mathbf{X}$ matrix that is decomposed through the singular value decomposition method as follows:

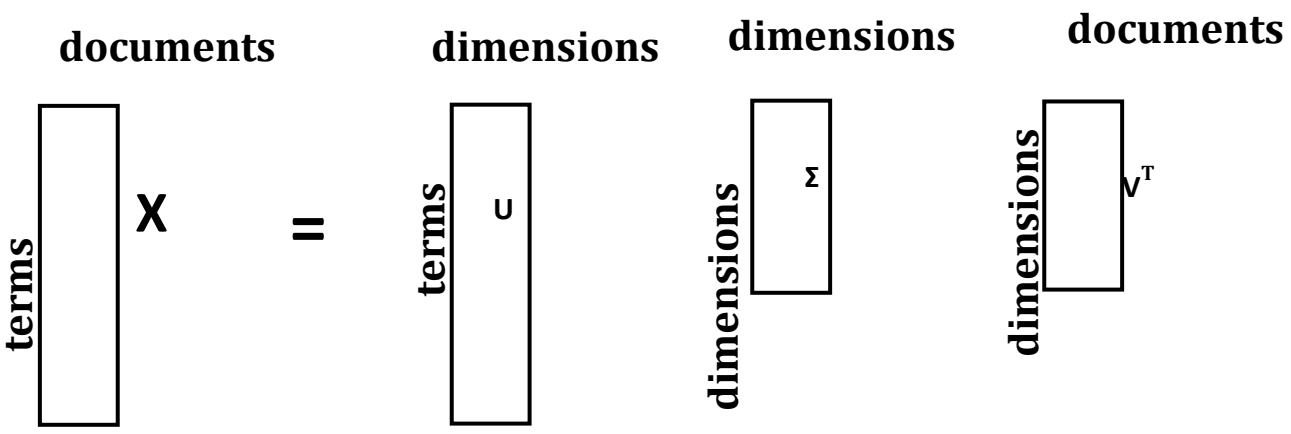


Figure 1: SVD of Original X Matrix.

The output to the LSA method is a truncated **X'** matrix.

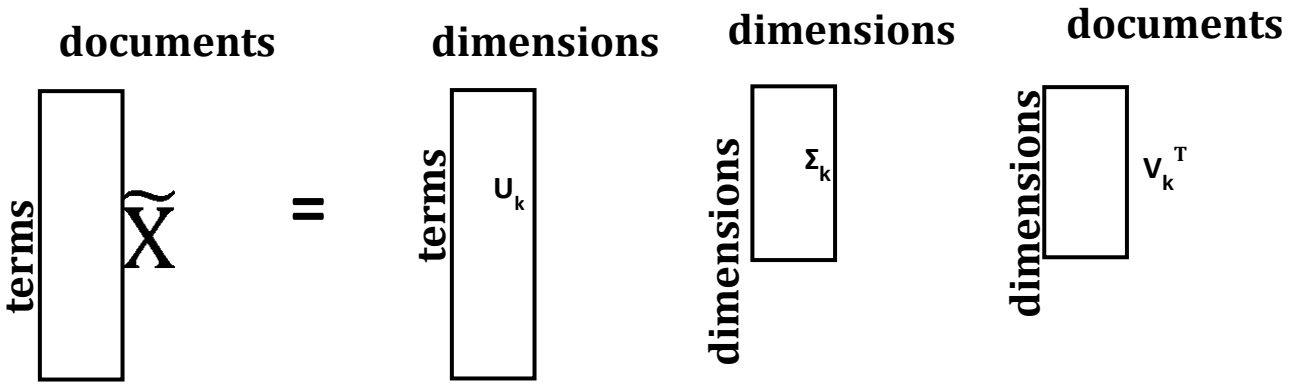


Figure 2: SVD of Truncated $\tilde{X}$ Matrix.

In LSA, the original matrix **X** can be approximated by the truncated matrix $\tilde{X}$ **.** Also, topics can be extracted by using factor loading and matrix rotation by deriving the following L_t matrix.

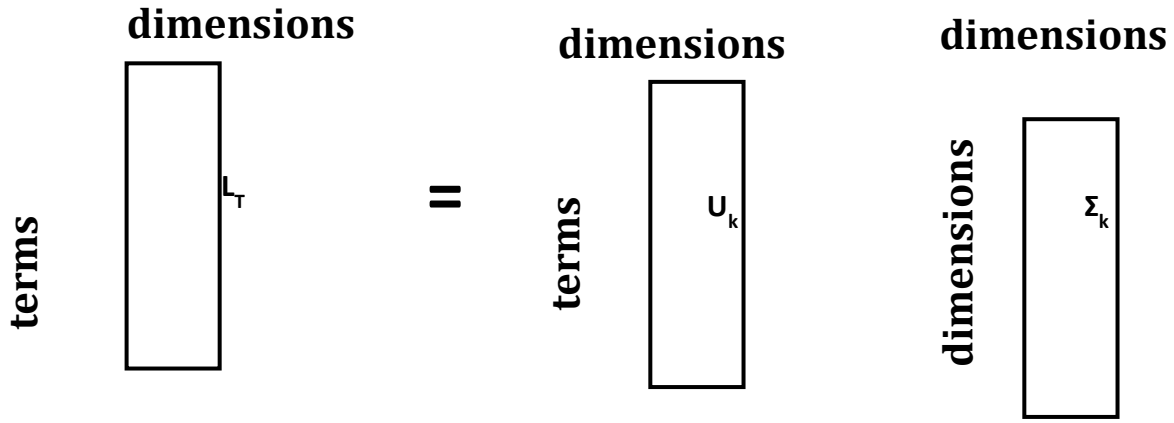


Figure 3: Loading on Words Matrix.

The way the terms load into the dimensions is used to determine what the possible dimensions are. It is desired to apply LSA when three conditions exist: A) documents having the same writing style, B) each document being centered on a single topic and C) a word having a high probability of belonging to one topic but low probability of belonging to other topics[8]. One limitation for LSA is the determination of the dimension factor being a subjective judgment.

Latent Dirichlet Allocation (LDA)

Latent Dirichlet Allocation (LDA) was introduced by Blei and his colleagues[2] as a probabilistic topic model. The LDA algorithm differs from LSA in that it makes different assumptions on what is considered a document. In LDA a document consists of a distribution of z topics and a topic consists of a distribution of words w. The Dirichlet Multinomial Distribution which is given as:

$$Dir(\alpha_1, \ldots . \alpha_T) = \frac{\Gamma \sum_j \alpha_j}{\prod_j \Gamma \alpha_j} \prod_{j=1}^{T} P_j^{\alpha_j - 1}$$

Under the LDA model, the distribution of topics *z* follows the Dirichlet distribution with parameters $\alpha_1, \ldots . \alpha_T$ and the conditional distribution of words given a topic *(w/z)* also follows the Dirichlet distribution with parameters $\beta_1, \ldots . \beta_T$. Using this key probabilities, the probability of finding a word in a document is obtained by:

$$P(w_i) = \sum_{j=1}^{T} P(w_i/z_i = j) P(z_i = j)$$

The probability distribution of words in a document allows for the determination of which words categorize a document better. Blei[2] determined the probability of selecting a word from a document $P(wi/\alpha, \beta)$ using the above Dirichlet distribution for *P(w/z)* and *P(z)* and arrived at the following intractable expression.

$$p(w|\alpha, \beta) = \frac{\Gamma \sum_i \alpha_i}{\prod_i \Gamma \alpha_i} \int \left(\prod_{i=1}^{k} \theta_i^{\alpha_i - 1} \right) \left(\prod_{n=1}^{N} \sum_{i=1}^{k} \prod_{j=1}^{V} (\theta_i \beta_{i,j})^{w_n^j} \right) d\theta$$

Because of intractability, other approaches have been used to implement the LDA model. One of this approaches is the Griffiths and Steyvers [4] Markov Chain Monte Carlo procedure based on a Gibbs Sampling method. Hoggs and his co-authors[5] explain the following Gibbs Sampling method. To start out with, a stream of X_o values are initialized at time $t=t_o$. Then a conditioned random variable Y_i/X_{i-1} is generated from a conditional distribution $f_{y/x}(y/x)$. This conditioned Y_i values are then substituted into another conditional distribution $f_{x/y}(x/Y)$ to generate a new set of conditioned X_i values or $X_i/Y_i \sim fx/y(x/Y)$ and the process repeats itself. Under this method, the new state of the system depends only on the previous state and not on its past history and the movement from one state to another is on a random basis. The details and an application of the Steyvers and Griffiths algorithm can also be found on Anaya and Evangelopoulos[1].

Methodology

Abstracts from the European Journal of Engineering Education were collected and divided into five year segments. The segments were analyzed through the LDA and LSA algorithms for six and then for a ten topic extraction. The segments were analyzed through the two computerized algorithms to achieve a higher level of reliability on the topics extracted and for comparison purposes. Under each method, the six topic extraction allowed for a higher abstract level of topic extraction while the ten topic extraction allowed for a lower abstract level of topic extraction. In all cases, the results revealed that certain key words were part of the extracted topic. From these key words, general topics labeling was performed between the authors by first analyzing these key words separately and then congruently to reach a mutual agreement on the specific topic label that should be assigned to these key words.

Results

1970s. Era

For the period of 1978-1978, the ten topic extraction of LDA and LSA showed emphasis on engineering training. LDA extracted Engineering Curriculum, Engineering Skills, and Engineering Training. LSA extracted Engineering Courses and Teaching Methods. Engineering design also seems to play a role in this period. Both LDA and LSA extracted Design Courses but LSA also extracted Design Field studies and Computer Design. Student work and teaching also seem to play a role in this period. LDA extracted Project Work while LSA extracted Student Work. LDA extracted teaching with Models while LSA extracted Teaching Methods. Computers were also an integral part of this period. LDA extracted Computer Networks while LSA extracted Computer Design. The concept of systems may have also played a part in this period. LSA extracted system processes, university systems and LDA extracted environmental systems. The differences of extraction in the two methods are as follows: Process analysis and Engineering Technology was only observed in LSA as LSA extracted Industrial Processes, System Processes and Engineering Technology while LDA extracted Student Management. The results for this period are illustrated in Figure 4.

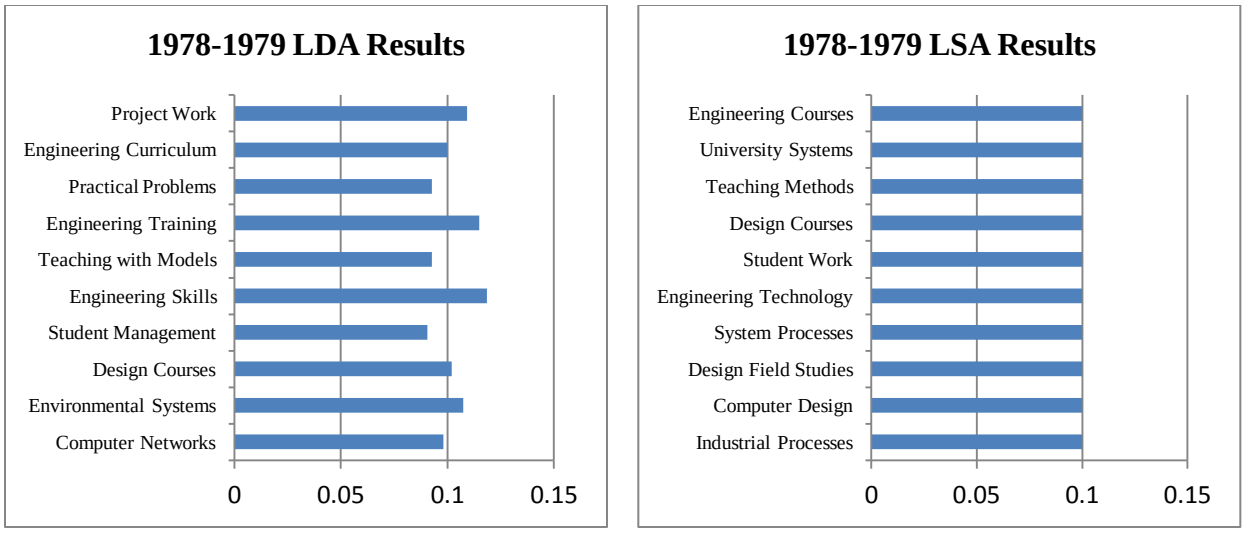


Figure 4: LSA and LDA Ten Topic Extraction for 1978-1979.

For the six topic extraction of the period 1978-1979, the design emphasis on engineering education research was supported as LDA extracted Design Skills and LSA extracted Engineering Design. Practical work experience was also noted as LDA extracted Practical Work and LSA extracted Industrial Engineering Projects. Engineering Training was seen by LDA extracting Engineering Curriculum and LSA extracting Engineering Education. Both LDA and LSA extracted Systems and Processes. One difference is that LDA extracted Computer Networks while LSA extracted Engineering Technology. The results are shown in Figure 5.

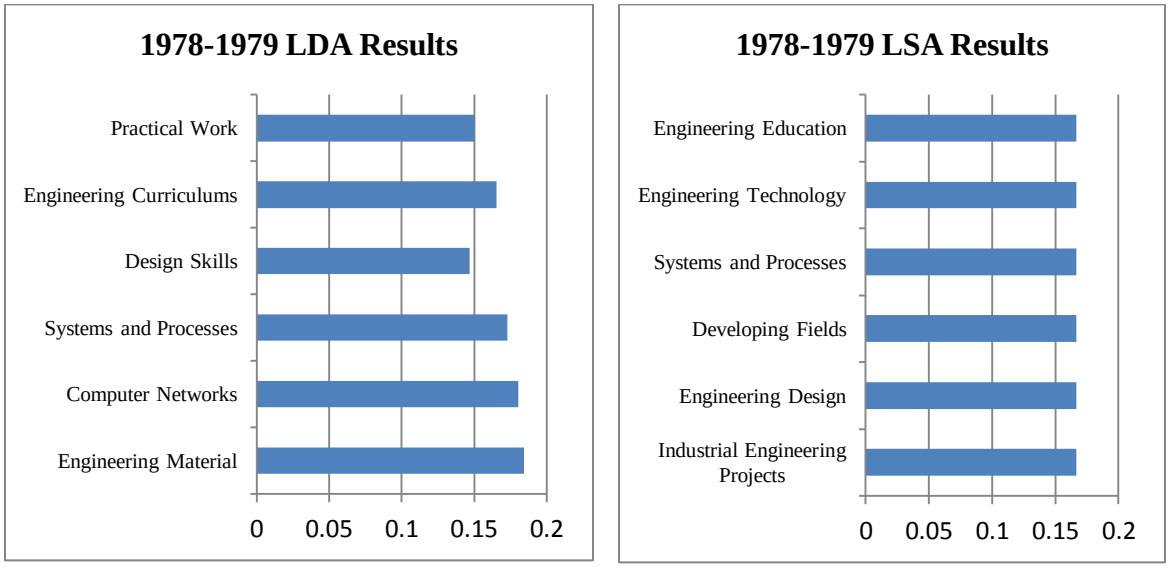


Figure 5: LSA and LDA Six Topic Extraction for 1978-1979.

In summary, engineering training, engineering design, engineering teaching, computers, systems and processes seem to be the field areas where engineering education research engaged in during 1978-1979.

The 1980s Era

For the period of 1980-1984, the ten topics extracted show that engineering training, with a stronger emphasis of using alternative strategies to make it more effective, continued to be an area of engineering education research. LDA extracted Didactic Curriculums, Creative Teaching Methods, Control of Student Groups, while LSA extracted Operational Curriculum, Continuing Education, Course Structure, and Engineering Education Societies. The field of Information seems to also have impacted the area of engineering education research. LDA extracted Telecommunications and Information along with Information, Society Problems. LSA extracted Information Processes along with Information Design Technologies. Computers continued to impact this period but this field seems to have expanded into other areas. LDA extracted Computers and Microelectronics while LSA extracted Information Design Technologies and Computers. For this period, emphasis seems to also be in solving engineering problems using technology. LDA extracted Engineering Problems, Information/Society Problems along with Process Technology while LSA extracted Developing Technologies, Engineering Methods, and Work Results. The results are shown in Figure 6.

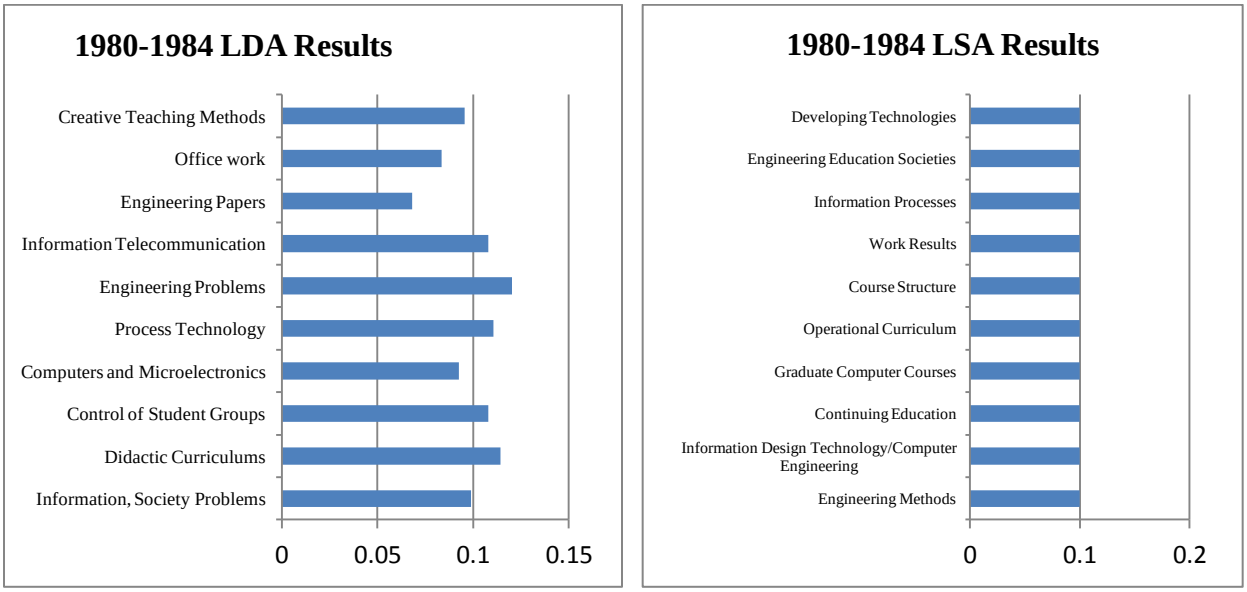
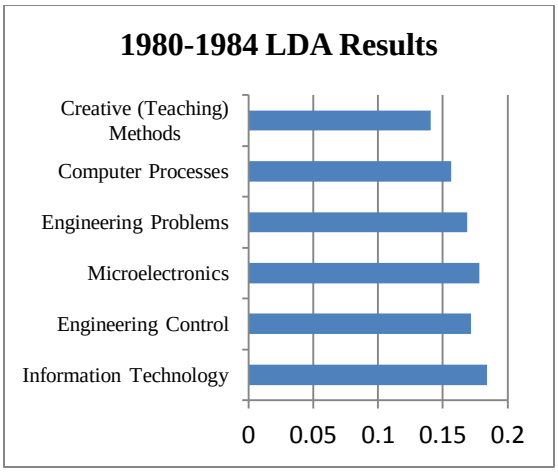


Figure 6: LSA and LDA Ten Topic Extraction for 1980-1984.

For the six topics extracted for the 1980-1984 period, the results indicate that engineering training seems to concentrate on finding better strategies to train students. LDA extracted Creative (Teaching) Methods, LSA extracted Teaching Students and Engineering Course Structures. The information field impacted the engineering education research field. LDA extracted Information Technology while LSA extracted Information Design Technology. Engineering problem solving was also another area of interest as LDA extracted Engineering Problems and Engineering Control while LSA extracted Engineering Methods and Engineering Technology. Emphasis on processes was observed as LDA extracted computer processes while LSA extracted continuous processes. The results are illustrated in Figure 7.



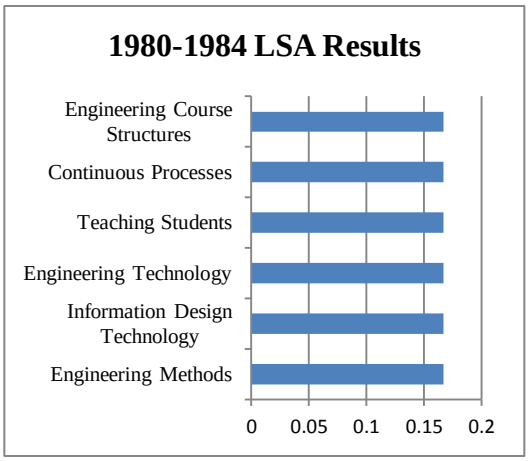
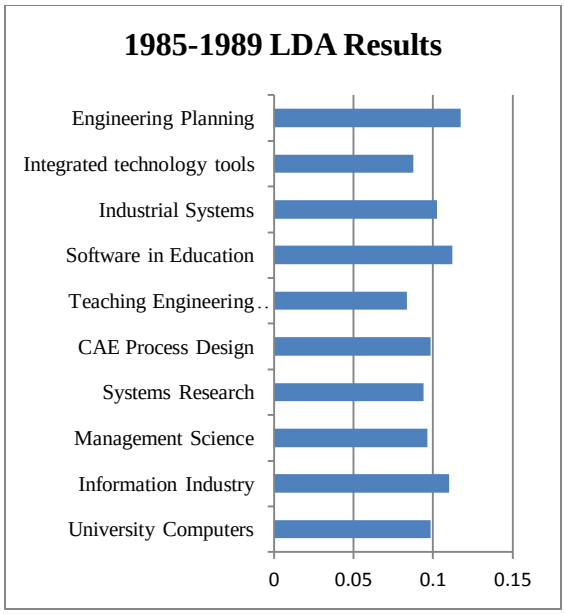


Figure 7: LSA and LDA Six Topic Extraction for 1980-1984.

In summary, for the period of 1980-1984, the topic extractions showed that engineering training, with a stronger emphasis of using alternative strategies to make it more effective, continued to be an area of engineering education research. This included the development of didactic curriculums, creative teaching methods, operational curriculums, continuing education, and improved course structures. The field of Information seems to have impacted the area of engineering education research. This included the field of Telecommunications, Information Design Technologies, and Information processes. Improvements on computers seem to play a part in this area. Microelectronics and Information Design Technologies were topics observed for this period. Lastly, for this period, emphasis seems to also be in solving engineering problems using technology. This includes solving problems for society using process technology, engineering methods, and developing technologies.

For the period of 1985-1989, an emphasis on engineering education research was the design field evolving to include computer aided technologies. LDA extracted CAE Process Design while LSA extracted Computer CAD Design, Engineering Design, and Integrated Design Technologies. The information field continued to impact this research area. LDA extracted Information Industry while LSA extracted Information Technology. During this period, more emphasis was placed on computers and associated software packages in engineering education research. LDA extracted Software in Education, CAE Process Design, University Computers and Integrated Technology Tools , while LSA extracted Integrated Design Technologies, Computer CAD Design, Industrial Software, Computer Programming and Control, Computer Engineering. Engineering training was also part of the engineering education research area. LDA extracted Teaching Engineering Courses and LSA extracted Teaching Engineering and Engineering Programs. Emphasis on the systems concept was noted in this period. LDA extracted Systems Research and Industrial Systems while LSA extracted System Planning. One field that seems to have come into play is the Management Science field, a topic that was extracted by LDA. The results are illustrated in Figure 8.



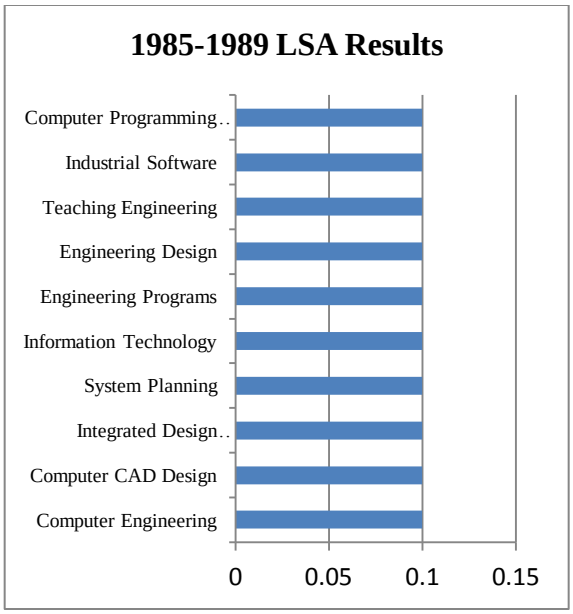
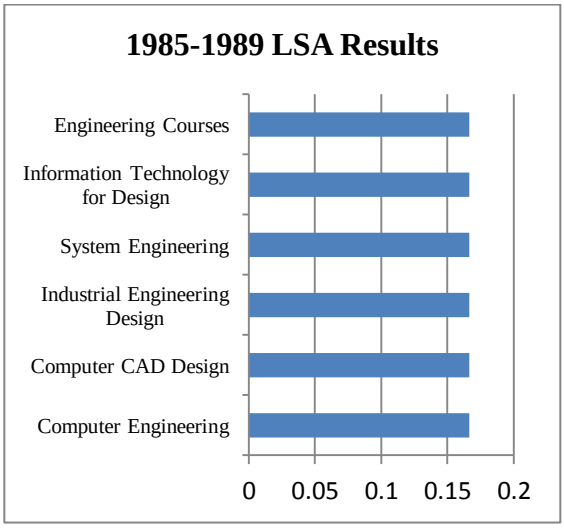


Figure 8: LSA and LDA Ten Topic Extraction for 1985-1989.

For the six topic extraction, the results for the 1985-1989 period reveal that engineering training was a part of this period as was noted by both methods extracting Engineering Courses and LDA extracting Curriculum Development. Engineering design was also part of this engineering education research area. LSA extracted Industrial Engineering Design, Computer CAD Design while LDA extracted Computer Design and Engineering. The information field continued to affect this research area. LSA extracted Information Technology for Design while LDA extracted Information Management Systems. One difference in extraction was that Integrated Technologies was extracted by LDA while System Engineering was extracted by LSA. The results are illustrated in Figure 9.



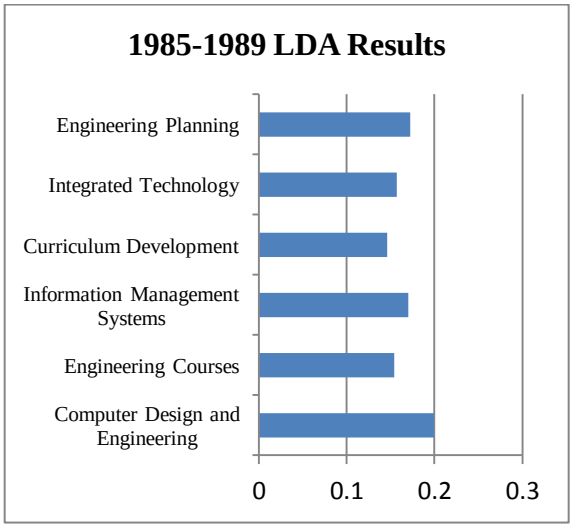


Figure 9: LSA and LDA Six Topic Extraction for 1985-1989.

In summary, for the period of 1985-1989, a stronger emphasis on computers and associated engineering design software was observed. This included emphasis on CAE software, CAD software, integrated design technologies, and computer programming and engineering. The information field continued to impact this period to include information technology, information management systems and its impact on industry. Basic engineering training continued to be was also part of the engineering education research area and this included teaching engineering and developing engineering programs. More emphasis on systems was observed as noted by a LDA extracting Systems Research and LSA extracting Systems Engineering.

The 1990s Era

For the 1990-1994 period, the ten topics extracted indicate that the construction field plays a role in engineering education research. LDA extracted Information and Construction Studies, Industry Research, and Civil Engineering Drawings while LSA extracted Civil Engineering Curriculum and Information and Construction Industry. Simulation of processes and products seems to also play a role in engineering education research. LDA extracted Simulation with Industrial Software, Simulation-based Design of Processes and Products, Computer Programs and LSA extracted Simulation Methods with Software, Computer-based Simulation Design, Simulation of Construction Systems and Simulation Methods/Statistics. Engineering training continues to be part of the engineering education research. LDA extracted Teaching Engineering and LSA extracted Engineering Education courses. In this period, an emphasis in Quality and Statistics is noted. LDA extracted Systems Engineering/Statistics and Quality in Higher Education, while LSA extracted Quality in Higher Education and Simulation Methods/Statistics. The period also shows emphasis on Systems Engineering as LDA extracted Systems Engineering/Statistics and LSA extracted Systems Engineering Models. Two new topics come into play and they are: Expert Systems Education and International Management Research. The results are illustrated in Figure 10.

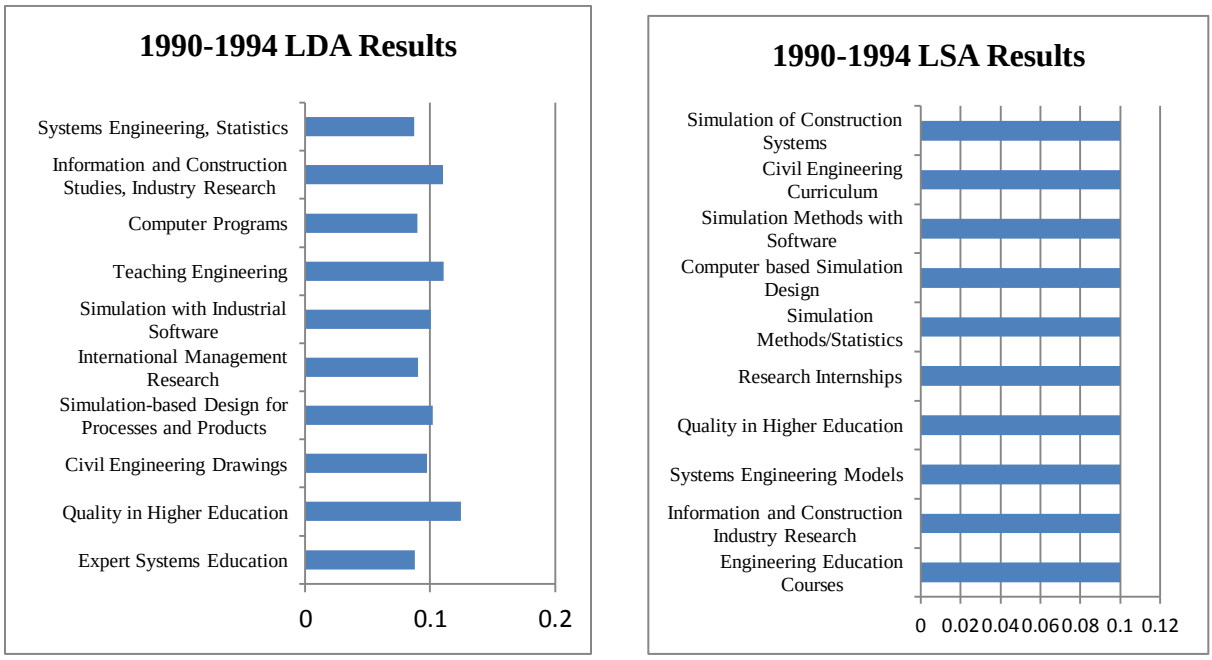


Figure 10: LSA and LDA Ten Topic Extraction for 1990-1994.

For the six topic extraction of the 1990-1994 period, the results indicate that the construction field plays a role in engineering education research. LDA extracted Information and Construction Research and Civil Engineering while LSA extracted Information and Construction in Industry and Civil Engineering. Quality in higher education also plays a role in this period. LDA extracted Quality in Higher Education while LSA extracted Qualitative Methods in Higher Education. Simulation plays a stronger role in this period for engineering education research. LDA extracted Simulation-based Design for Processes and Products and Simulation in Industry while LSA extracted Computer-based Simulation Design and the Simulation of Experiments. Two different topics showed up in this extraction. LDA extracted Teaching Engineering while LSA extracted Research Internships. The results are illustrated in Figure 11.

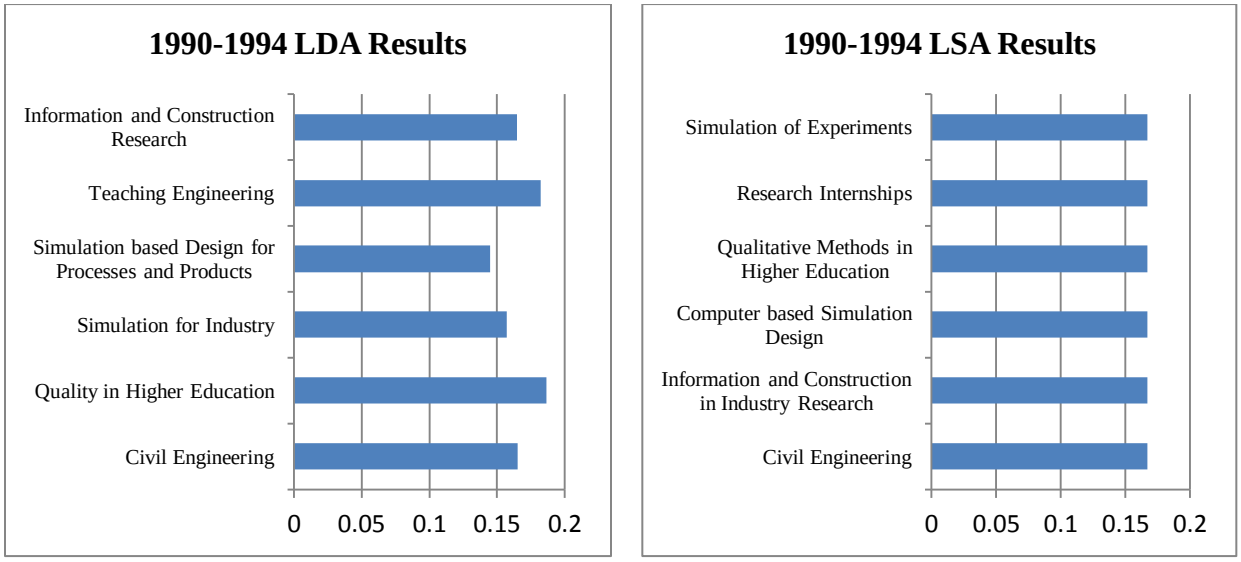


Figure 11: LSA and LDA Six Topic Extraction for 1990-1994.

In summary, for the 1990-1994 period, engineering education research evolved around simulation. This includes simulation with industrial software, simulation-based design of products and processes, simulations methods, and associated simulation software. Along with simulation, statistics played a role as statistics is generally applied to the output of several simulation runs. The Quality movement of the 1980s was extended to the education field. Quality in the Engineering Field and associated statistics as applied in the quality field showed up through both extraction methods. The construction field played a strong role in the engineering education research field during this period. This was shown by the methods extracting civil engineering curriculum, construction studies, and construction industry. This period also showed an emphasis on systems engineering as well as other newer fields showed up: expert systems and International Management.

For the 1995-1999 period, the ten topic extraction indicates that the technology programs play a significant role in engineering education along with distance learning. LDA extracted Technology Distance Education Models while LSA extracted Teaching Techniques in Technology Programs, Distance Technology and Distance Learning Models. Project-based

Design is also a topic that seemed to be of interest in this period. LDA extracted Projects for Technology Students while LSA extracted Project-based Technologies and Creative Studies/Assessment of Design Project Courses. In this period, traditional engineering topics were also observed. LDA extracted Creative Engineering Programs/Accreditation, Undergraduate Courses, Engineering Courses and LSA extracted Teaching Techniques in Technology Programs, Creative Studies/Assessment of Design Project courses. But other interesting topics were observed. They are total reliability engineering, quality management, engineering management, accreditation/assessment, and training with emphasis on the environment. The results are listed in Figure 12.

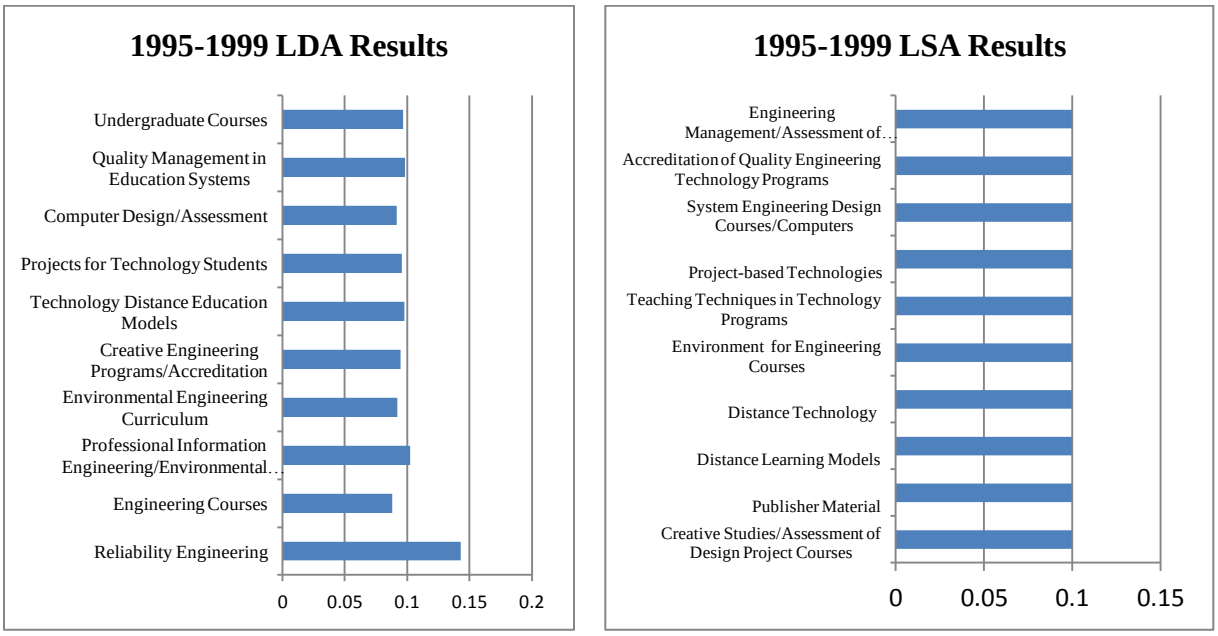


Figure 12: LSA and LDA Ten Topic Extraction for 1995-1999.

The six topic extraction for the 1995-1999 also show distance learning and information technology to play a role in this period. LDA extracted Distance Project Courses while LSA extracted Distance Technologies. Both methods extracted project based design as LDA extracted Distance Project Courses and LSA extracted Project Design/Computers. Traditional engineering training was demonstrated by LDA extracting Design Courses/Assessment while LSA extracting University Courses, Teaching Techniques, Technologies/Environment. Other topics of interest observed were Reliability Engineering, emphasis on environment consideration, and ethics. The results are illustrated in Figure 13.

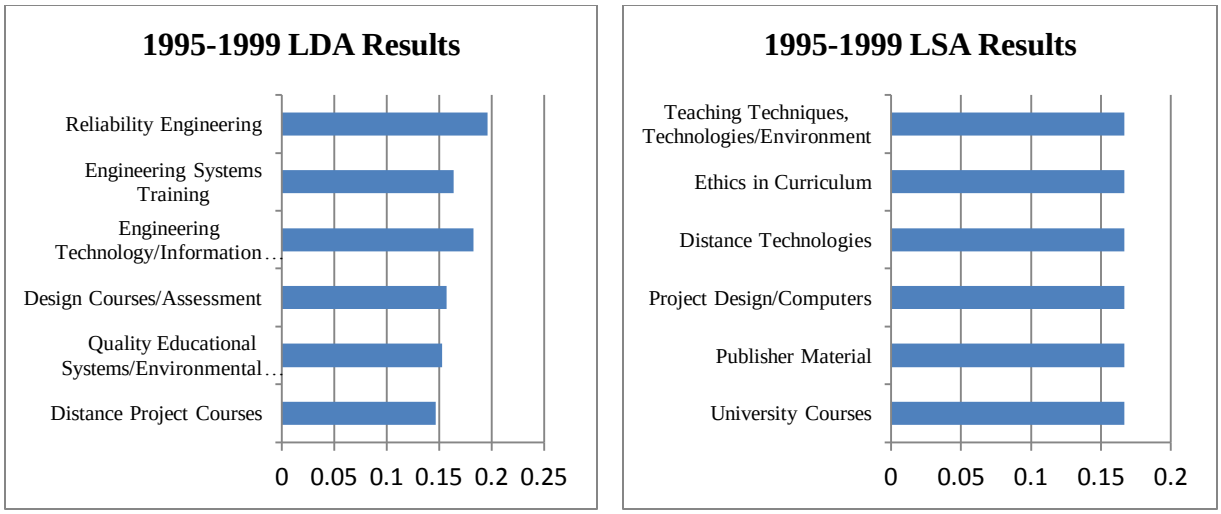


Figure 13: LSA and LDA Six Topic Extraction for 1995-1999

In summary, the 1995-1999 indicated that distance learning, information technology, concern for the environment in engineering design, total quality management, accreditation/assessment and project-based design were topics of interest for engineering education research for this period. Engineering ethics and reliability engineering were issues that showed up for the first time in this period.

The 2000s Era

For the 2000-2004 period, the ten topic extraction indicates engineering research comes into focus. LDA extracted Professional Research in Curriculum while LSA extracted Engineering Design and Research. Assessment is also an important area of consideration. LDA extracted Student Assessment Methods while LSA extracted Assessment and Accredited Engineering Programs along with Assessment of Project-based Methods. Information Communication Technology (ICT) also play a role as LDA extracted Information Communication Technology while LSA extracted Information Communication Technology (ICT) Engineering. Project-based training is considered important as LDA extracted Design Projects for Processes and LSA extracted Project-based Courses and Assessment of Project-based Methods. Other traditional engineering topics continue to exist as LDA extracted Teaching Experiences/Environment, Technical Knowledge Skills, while LSA extracted Engineering Design and Engineering. Other topics of interest are programming skills and mathematics, ethics, and quality in higher education. The results are illustrated in Figure 14.

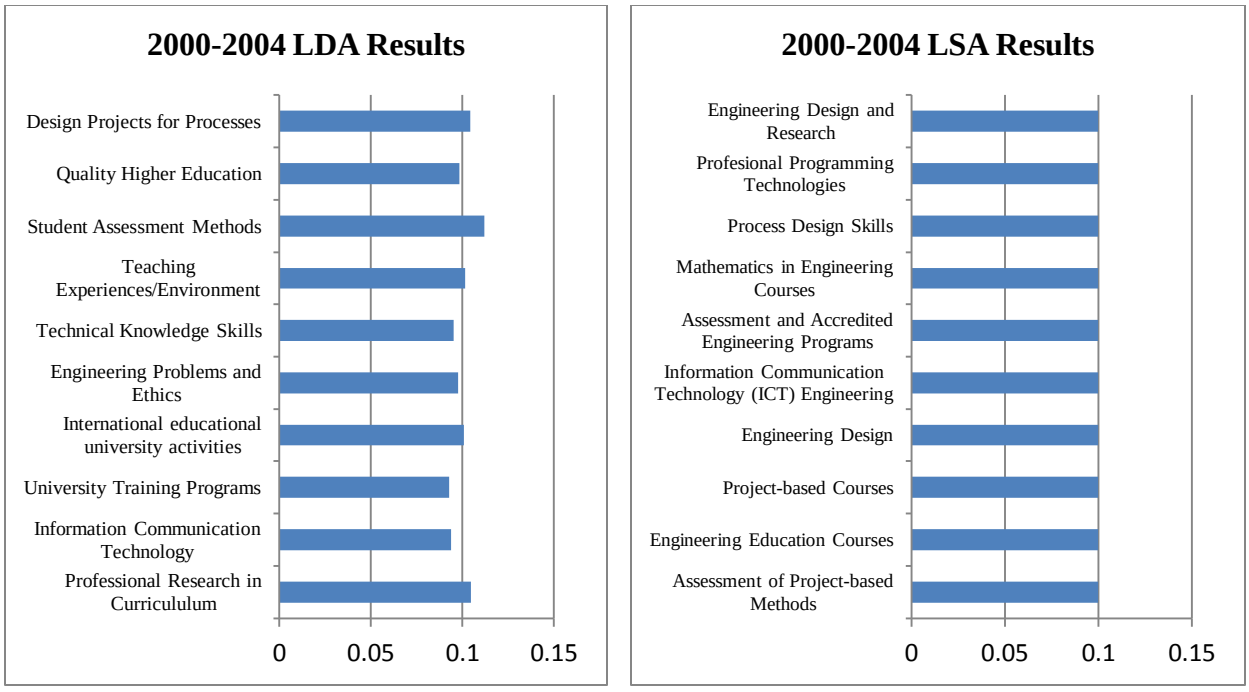


Figure 14: LSA and LDA Ten Topic Extraction for 2000-2004

The six topic extraction for the 2000-2004 period show that project-based training is considered to be important as LDA extracted Student Projects/Assessment and LSA extracted Project-based design/Experiantial Teaching, Projects for Student Research and Assessment/Practical Projects. Design skills are also important as LDA extracted Process Design Work and LSA extracted Professional Design Skills Courses. Other topics of interest are Information Communication Technology, System Training, and Quality in Engineering Education. The results are illustrated in Figure 15.

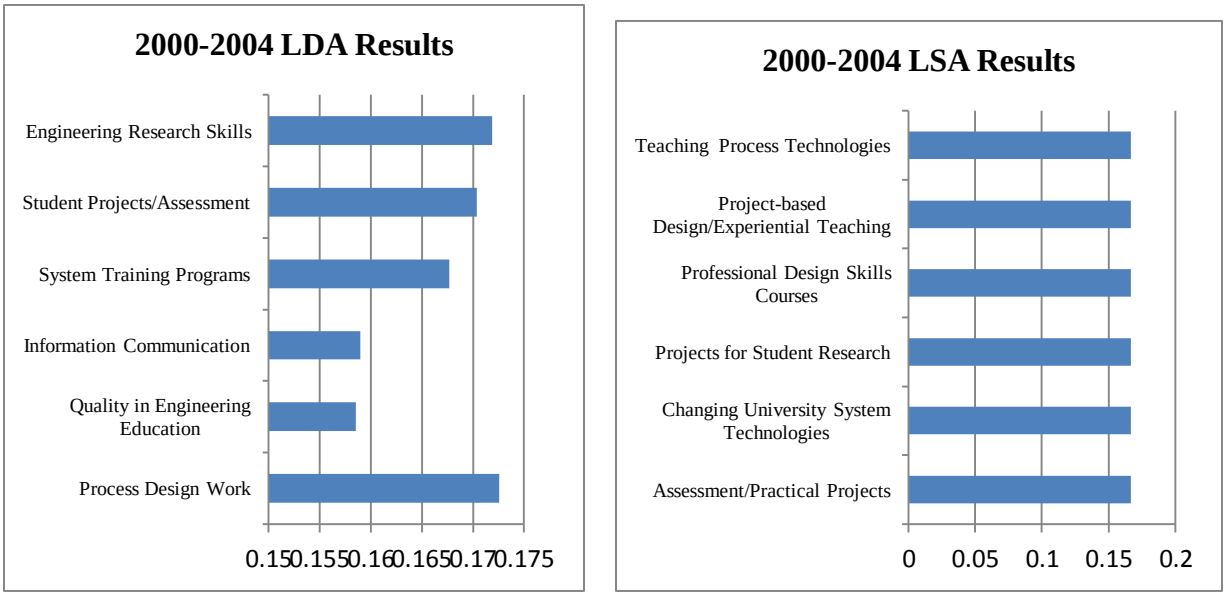


Figure 15: LSA and LDA Six Topic Extraction for 2000-2004

In summary, for the 2000-2004 period, the results indicate that for this period, project-based training, engineering research, assessment and accreditation, information communication technology (ICT), programming skills, mathematics knowledge, and engineering design were considered to be important research areas for engineering education. Ethics and quality in higher education came into focus for this period.

For the 2005-2009 period, the ten topic extraction indicates concern for the environment comes into play in the form of sustainability technology. LDA extracted Sustainable Development courses while LSA extracted Practical Sustainability Technology Processes and Sustainability Technology. This period also shows more emphasis on working with industry as LDA extracted Training in Industrial Skills while LSA extracted Project-based Industrial Design/Research, Industrial Research, and Practical Industrial Skills. Project-based education seems to continue to be the focus for this period as LDA extracted Project-based Learning Activities while LSA extracted Projects and Processes, Project-based Industrial Design/Research, Project-based Design/Assessment. Emphasis on engineering research was also observed as LDA extracted Research-based Teaching while LDA extracted Project-based Industrial Design/Research and Industrial Research. Traditional engineering training was observed as LDA extracted Student Work Issues, Higher Education Programs and Models while LSA extracting Issues in Engineering Education and Engineering Skills Competency. Assessment and more emphasis on science were also observed topics for this period. Other topics of interest were social science, engineering management, and women issues. The results are illustrated in Figure 16.

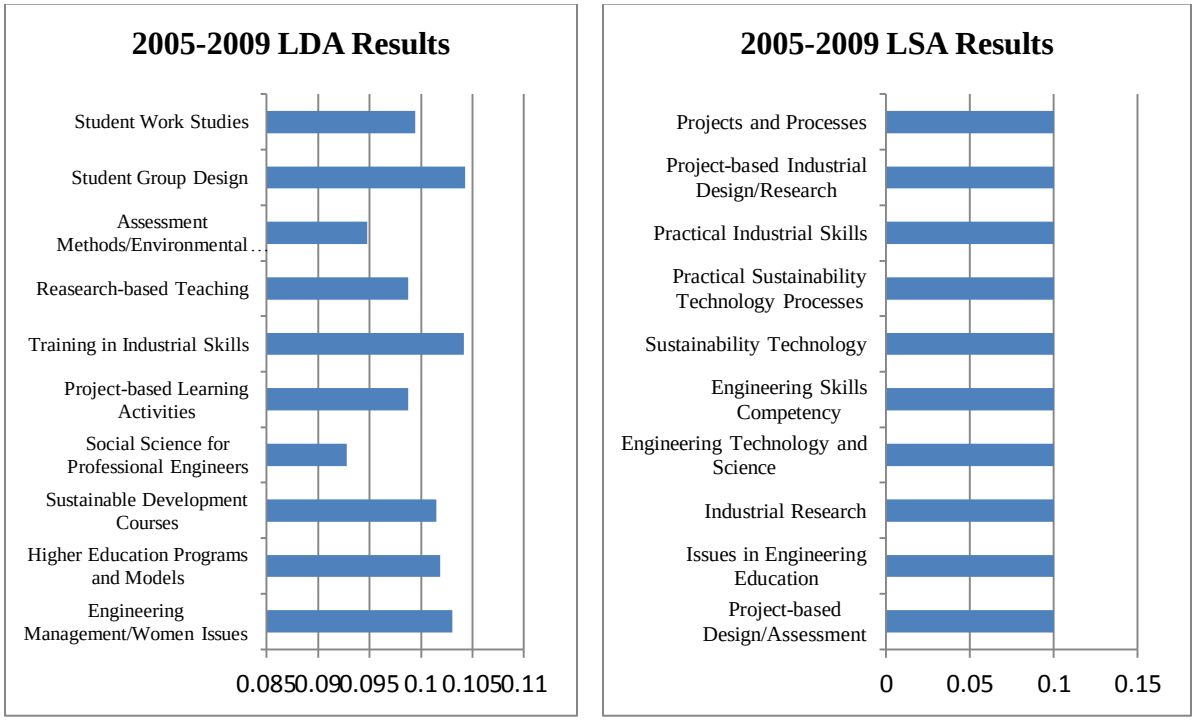


Figure 16: LSA and LDA Ten Topic Extraction for 2005-2009

The six topic extraction for the 2005-2009 period show that sustainability technology is an area of interest along with project-based design. LDA extracted Sustainable Development Research, Project-based Technology while LSA extracted here Sustainable Industrial Technology/Research, and Project-based Design Courses and Student Engineering Papers/Project Design Work. An emphasis on design was also observed. LDA extracted Design Methods for Processes while LSA extracted Student Engineering Papers/Project Design Work and Project-based Design Courses. More focus is observed in engineering research being extended to include student research. LSA extracted Engineering Student Research Papers, Student Engineering Papers/Project Design Work. The other topics of interest relevant to related to engineering articles and books, and women issues. The results are illustrated in Figure 17.

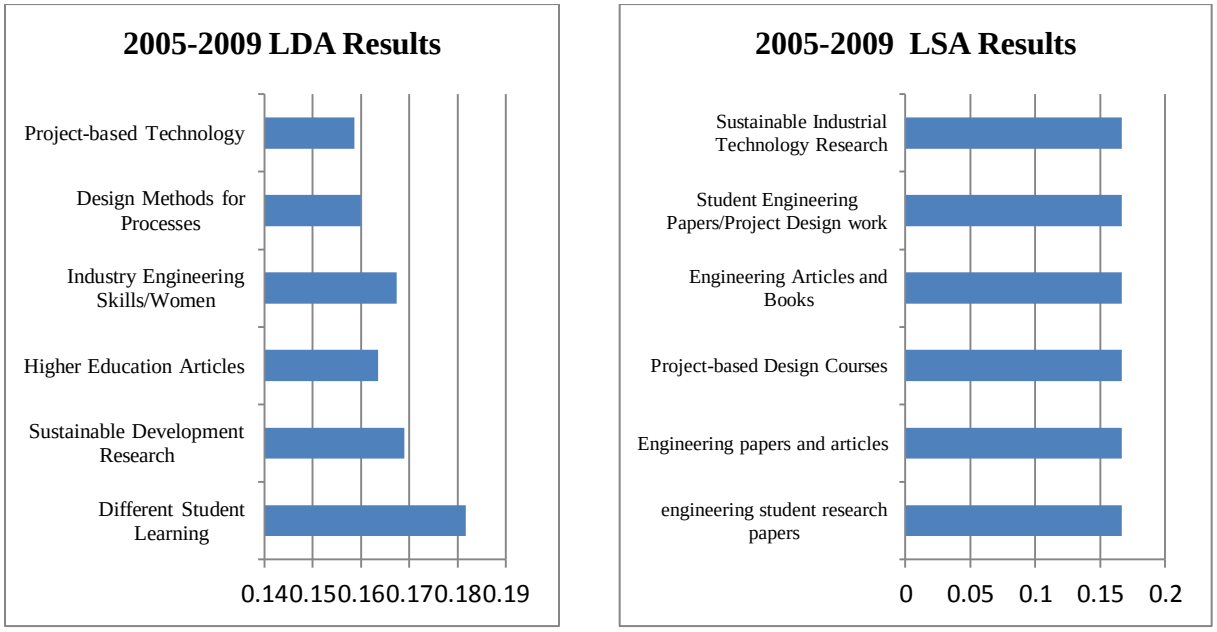


Figure 17: LSA and LDA Six Topic Extraction for 2005-2009

In summary, for the 2005-2009 period, engineering education research seems to encompass research in sustainability technology, more focus on research performed by students, project-based design, industrial oriented research, processes, assessment/accreditation and more emphasis on science to include social science. The emphasis on science may be due to the recognition that technology can readily become obsolete and engineering training in technology may not be useful in future years. Other topics of interest were engineering management and women issues.

2012s Era

For the 2010-2012 period, the ten topic extraction indicates more focus on engaging students to participate in engineering research. LDA extracted Educational Student Research while LSA extracted Design, Experiments and Research, Design of Experiments/Institutional Research, and Practical Research Papers. Project-based engineering education is still being encouraged as LDA extracted Final year Project Courses and LSA extracted Programming Skills in

Curriculum/Project Design Assessment, Project-based Learning and Design, Project-based Learning Approaches and Engineering Project Papers. Assessment, quality improvement and more focus on female oriented programs are observed. The results are illustrated in Figure 18.

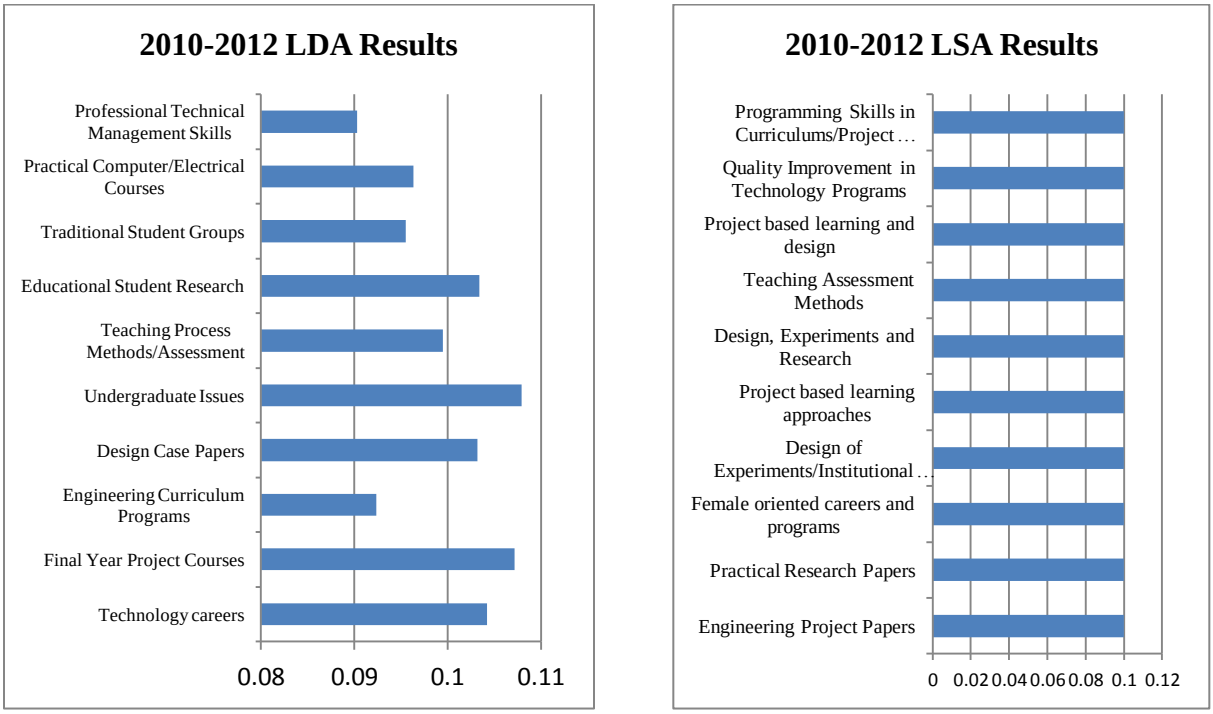


Figure 18: LSA and LDA Ten Topic Extraction for 2010-2012.

The six topic extraction for the 2010-2012 period show that project-based learning continues to be a focus for this period. LDA extracted Project Work Skills while LSA extracted Project-based Technologies/Design, Project-based Learning and Programming, and Project-based Learning/Assessment. More focus on engineering research training is observed. LDA extracted Engineering Research Programs while LSA extracted Student Research Papers. More focus on the female engineering student is observed as LSA extracted Experiments/Female Careers. More focus on students being engaging in research is observed as LSAS extracted Student Research Papers and Experiments/Female Careers. Other topics of interest are electrical courses, assessment, and programming. The results are illustrated in Figure 19.

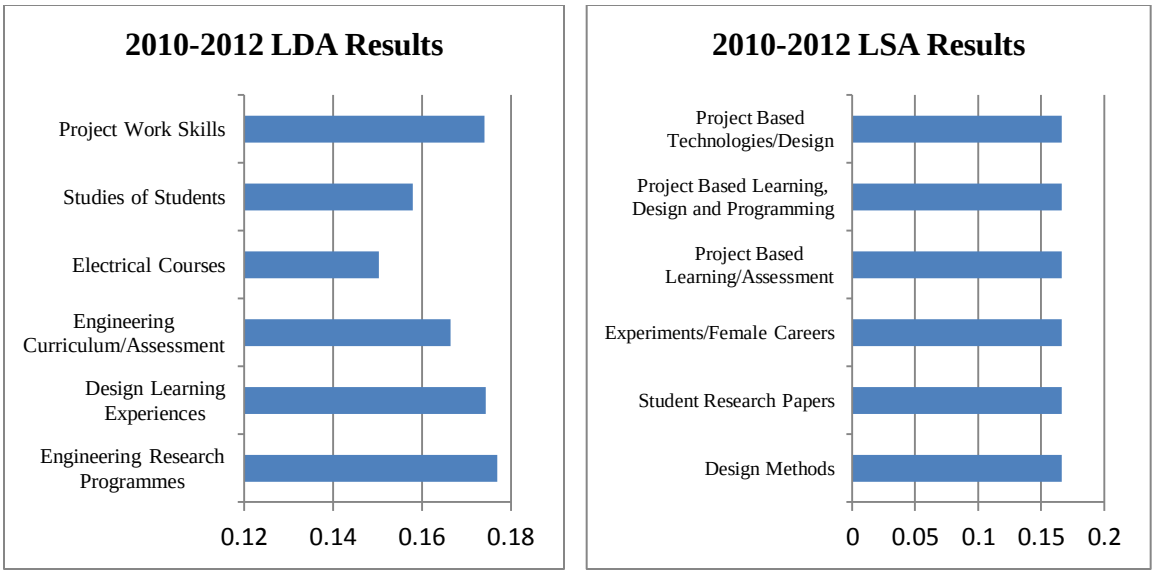


Figure 19: LSA and LDA Ten Six Extraction for 2010-2012.

In summary, the recent period of 2010-2012 shows that the engineering education research focus is on project-based design, engaging the female engineering student, engaging students to perform research, assessment, quality improvement and programming skills. There seems to be a push to engage everyone, including the students, in engineering research and the curriculums are being redesigned to include courses research oriented courses such as design of experiments. A continuing focus on serving the female engineering student continues for this period as more emphasis on female careers/issues is observed.

Discussion

A comparison of the two methods for extraction yielded Figure 20 and Figure 21. The results indicate that a 10 topic extraction tend to yield clearer results than the six topic extraction. The number of topics selected can affect the interpretability of the results and different approaches have been used to determine the appropriate number of topics to select.[9] But overall, the results indicate that the main focus in engineering education research changed from one period to another for both extraction methods. In the 1970s, the focus under both extraction methods, was primarily on basic engineering training. This included topics in engineering teaching and engineering design. The new areas that seem to be emerging involved computers. This included computer networks and computer design.

In the early 1980s, a stronger emphasis seemed to be placed on teaching strategies to make engineering education more effective. This included didactic curriculums, creative teaching methods, operational curriculums, continuing education, and improved course structures. Under LDA, the focus seem to be on creative teaching while under LSA, the focus was on continuing education. New areas that emerged in this period seem to deal with the Information age. LDA extracted information telecommunication, computers and micro-electronics while LSA extracted information processes. In the late 1980s, a large emphasis was placed on teaching engineering using software. This included using process technology, design software (CAE, CAD),

integrated design technologies and computer program. The new areas that emerged during this period were systems research, information technology, and computer engineering.

In the beginning of the 1990s era, engineering education research seems to evolve around simulation and civil/engineering training. Simulation emphasis was seen by LDA extracting simulation of product and processes while LSA extracted simulation methods. Both extraction methods extracted civil/engineering training. Speculations exist as the cause of the civil/construction engineering research topic appearing with such prominence in the period 1990-1994 in a global journal. Why would this type of research appeared during this period is difficult to answer. One possibility may be that this period of 1990-1994 is considered a global recession period that engulfed European countries such as France, United Kingdom, Sweden, Italy, Greece, etc; the United States and Japan and somehow this recession affected the construction industry.[12] Further research to determine the exact cause will need to be done and this is beyond the scope of this article. Other areas that emerged during this period appeared to have been due to the quality movement of the 1980s. LDA extracted quality in higher education and statistics while LSA extracted quality in higher education. Other emerging areas seem to be expert systems and systems engineering.

Toward the later part of the 1990s era, the main focus under both extraction methods were distance learning and assessment/accreditation. Emphasis on environmental consideration in engineering education research was also observed. New areas that emerged in this period are reliability engineering, environmental engineering, systems engineering and engineering management.

In the early part of the 2000s era, the focus in engineering education research continued to be assessment and accreditation, and quality in higher education, but a newer emphasis on engineering research emerged. The new areas that also emerged were information communication technology (ITC) and ethics. Toward the later part of the 2000s ear, focus was on research based teaching, project based learning and industrial research. The new areas emerging in engineering education research were women's issues, sustainability technology and engineering management. Toward the later part of the 2000s era, engineering education research seems to focus more on the environment by covering sustainability technology.

In the latest recent period, 2010-2012, engineering education research focus on project based learning, technology careers, undergraduate issues and primarily on student research. The new areas emerging are female oriented careers and technical management. Engineering research seems to be the "buzz word" currently and everyone, including the undergraduate students, are being asked to jump into this research focused wagon. Undergraduate curriculum are now being redesigned to include previously seen only graduate level research oriented courses such as design of experiments, probability and statistics.[11]

MAIN FOCUS OF PERIODS									
	6 Topic Extraction	10 Topic Extraction				6 Topic Extraction	10 Topic Extraction		
LDA	X	X	1978-1979	Engineering Training	LSA	X	X	1978-1979	Engineering Training
	X	X	1980-1984	Creative Teaching			X	1980-1984	Continuing Education
						X			Engineering Methods
	X	X	1985-1989	Teaching Engineering (Design) with Software		X	X	1985-1989	Teaching Engineering with Software
	X	X	1990-1994	Simulation of Processes and Products		X	X	1990-1994	Simulation Methods
	X	X		Civil/Construction Engineering Training		X	X		Civil/Construction Engineering Training
	X	X	1995-1999	Accreditation and Assessment			X	1995-1999	Accreditation/Assessment
	X	X		Distance Education Engineering Training		X	X		Distance Learning Training
	X			**Systems Training**					
		X		Environmental Focus					
		X	2000-2004	University Training Programs		X	X	2000-2004	Engineering Research
	X	X		Assessment/Accreditation		X	X		Assessment and Accreditation
	X	X		Quality in Higher Education		X	X		Engineering Design
	X	X		Research in Curriculum		X	X		Project Based Methods
		X		Technical Knowledge Skills					
		X	2005-2009	Research-based Teaching		X	X	2005-2009	Industrial Research
	X	X		Project-based Learning		X	X		Project based Learning
	X	X		Sustainable Development Training		X	X		Sustainability Technology
	X	X	2010-2012	Student Research		X	X	2010-2012	Project-based Learning
	X	X		Undergraduate Issues		X	X		Student Research
		X		Technology Careers			X		Design of Experiments

Figure 20: Main Engineering Education Research Focus Over Time.

EMERGING AREAS									
LDA	6 Topic Extraction	10 Topic Extraction			LSA	6 Topic Extraction	10 Topic Extraction		
	X	X	1978-1979	Computer Networks			X	1978-1979	Computer Design
	X	X		Materials Engineering			X		Process Systems
						X			Industrial Engineering Projects
	X	X	1980-1984	Information Telecommunication			X	1980-1984	Computer Engineering
	X	X		Computers and Micro-Electronics		X	X		Information Technology Processes
		X		Process Technology					
	X	X	1985-1989	Systems Engineering Research		X	X	1985-1989	Information Management Technology
		X		Information Industry		X	X		Computer Engineering
	X	X		Industrial Systems					
	X	X		Information Technology					
		X	1990-1994	Expert Systems			X	1990-1994	System Engineering
	X	X		Quality in Higher Education		X	X		Quality in Higher Education
		X		Statistics					
	X	X	1995-1999	Reliability Engineering			X	1995-1999	Systems Engineering
	X	X		Environmental Engineering			X		Engineering Management
	X			Information Technology		X			Ethics
	X	X	2000-2004	Information Communication Technology (ITC)			X	2000-2004	Information Communication Technology (ITC)
		X		Ethics		X			University System Technologies
		X	2005-2009	Engineering Management		X	X	2005-2009	Sustainability Technology
		X		Women Issues					
	X			Sustainability Technology					
		X	2010-2012	Technical Management		X	X	2010-2012	Female Oriented Careers
	X			Engineering Research Programs					

Figure 21: Emerging Areas in Engineering Education Research Over Time.

Conclusion

In summary, analyzes of the abstracts gathered revealed that the focus of engineering education research changes over time. Basic engineering education research has evolved over time and a large portion of this evolution appears to be attributed to the evolution of computers. As computers and information technology have become predominant factors in society, engineering education research has evolved from computer networks, to teaching with software, to simulation oriented research, to distance learning and to information communication technology. Engineering education research also seems to be affected by the general societal movements that have existed during certain periods. The 1980's quality movement seem to have impacted engineering education research as determined by the quality oriented topics (quality in higher education and statistics) extracted by both methods in the early 1990s. Somehow the 1990-1994s global recession seems to have impacted the housing market and the prominence of civil/construction research in engineering education research.

Possible inference about the results arising from the analysis of these abstracts is that these results can be extrapolated to the analysis of the actual articles published. Moreover, engineering education research is often a reflection of what our educational education institutions are doing in the engineering fields. Thus, one possible inference that can be deduced from this research is that knowing the direction of where engineering education research is going is important to educational institutions as these institutions tend to place resources (human, equipment, etc.) in research areas of interest to remain competitive with other national and global institutions.

Lastly, the contribution of this research allows researchers to explore and perhaps revisit the topics in engineering education research that have existed over time to explore possible future directions. For example, future research could be steered toward simulation oriented research that was predominant in the 1990s but not recently. Other past predominant areas to reconsider are expert systems and sustainability technology. Since the mid-2000s, it is also observed that more emphasis in engineering education research has been centered on female student issues. Perhaps this is an indication that the engineering field is beginning to put more value in the success of the female student for engineering fields that have been traditionally male oriented.

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