AC 2012-4927: KEYWORD, FIELD, AND SOCIAL NETWORK ANALYSIS TRENDS FOR K-12 ENGINEERING EDUCATION RESEARCH

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Keyword, Field, & Social Network Analysis Trends for K-12 Engineering Education Research

Abstract— *This project serves the purpose of defining K-12 engineering education research (K-12 EngER), building a database of publications, tracing analyzing trends, and tracing researchers in this field. This has been achieved in terms of the discipline's methodical publications.* A manually generated list of words relevant in K-12 engineering education research (K-12 EngER) was used to compile a sub-database consisting of bibliometric information from scholarly journals taken from the Web of Science® (WoS) database created by the staff from an institute devoted to engineering education research at a Midwestern university. *These keywords were then used to evaluate current trends of contribution in this research field by year. In addition, the sub-database allowed for a network between authors and the relationships between their productivity and corporations to be analyzed via social network analysis. Furthermore, the databases were used to determine which fields have contributed the most to K-12 EngR. This project contributes to the field of* EngER *in that, it allows for a systematic, organized overview of K-12* EngER *and allows for analysis of this relatively new field.* This study could also guide K-12 EngER researchers to choose their research topics, to look for research collaborators, and to explore niche research areas. *The major findings resulted as follows: (1) K-12 EngER has just began to take shape and grow in the last 10 years, (2) the most popular keywords such as STEM, stud*, teac* and curricul* reveal the topics that have been most researched in the past, (3) Engineering Education (EngE) epistemologies have been the most researched area, (4) high school is the most researched for a K-12 EngE curriculum, (5) elementary education compared to other grade levels is underrepresented in EngER, (6) there is low level of connectivity between researchers in this area, (7) Krause, S. is the "most popular" author according to social network analysis, and (8) the field that has done the most research in this area is "Education, Scientific Disciplines", which indicates that most venues to publish K-12 EngER are educational rather than engineering venues.*

Keywords— *K-12; engineering; education; research; social network analysis*

Introduction

Engineering education (EngE) has strong associations with science, technology and mathematics education and it is concerned with the teaching and learning related to engineering practice. Currently, K-12 EngE is emerging as a new discipline, overcoming that little or no attention has been paid to this sub-discipline, despite its many possible benefits. However, recently the interdisciplinary effort towards research in this area is reaching a high level of academic standard. K-12 EngE could act as a catalyst for youths' interest, increasing the number of children wanting to pursue careers in science, technology, engineering and mathematics (STEM) [1]. Despite, its many possible benefits, there are currently no national K-12 EngE standards in place [2]. According to the National Academy of Engineering and the National Research council, "…K-12 engineering education may improve student learning and achievement in science and mathematics; increase awareness of engineering and the work of engineers; boost youth interest in pursuing engineering as a career; and increase the technological literacy of all students.” Recently, many policy makers and educators have reached the conclusion that K-12 EngE in U.S. classrooms must be improved upon [1].

A cursory look at the literature shows that most K-12 publications specifically focusing on EngE have been published in the past 10 years, indicating that the field of K-12 Engineering Education Research (K-12 EngER) is relatively new. This study therefore aims to look at this field in more detail. A means to discover the emergence and development of this field is significant for researchers deciding the field’s path of evolution. To this end, a bibliometric analysis was done.

This study aimed to create a sub-database using keywords relevant to K-12 EngE in order to filter and collect the bibliographic data from a larger pre-existing database. This pre-existing database was created by the same research group using a validated keyword-based scheme, which produced a parsimonious list of keywords that are salient in EngER to collect bibliographic records from ISI Web of Science® (WoS), a citation index providing access to the world’s leading citation databases and journals. This pre-existing database allows access to all the articles from 1980- Feb. 2010 present in WoS that are relevant to EngE and/or EngER [6]. The keyword based approach offers the benefit of defining K-12 EngER in terms of its vocabulary and offered a universal approach that is currently primarily used for most electronic sources. In this case, “keyword” refers to a combination of words or phrases that is unique to K-12 EngE. The use of keywords allowed for a time appropriate approach for collecting relevant K-12 EngE citation data from a large set of EngER publications. Furthermore, keywords allowed for an analysis of current trends in K-12 EngE. In this study, the keywords used to extract K-12 EngE/EngER relevant data from the pre-existing database to create the sub-database were developed from a literature review.

The bibliometric data gathered using keywords was used to conduct a field analysis and a social network analysis. A social network refers to a bounded and connected social unit and the social network analysis can be applied to various social units such as individuals, group of collaborators, social institutions and nations [8]. The social network analysis in this study focuses on the co-authoring work done among individual members within engineering education research organizations. Although there are many other forms of collaboration among scholars such as conference presentations, peer reviews, informal conversations and non-publication collaboration, the co-authoring of journal articles “may be an objective indicator of intensive, serious, and relatively long-term collaboration among researchers who are highly committed to the relationships” [5]. Carolan and Natriello also suggest that, “[co-authorship] analysis has been proven to be a useful way to identify the small, informal groups that play a major role in dictation how information is exchanged in an academic field” [3].

Furthermore, the specific characteristics of scholarly networks have an effect on how authors construct and write research papers [4]. According to Carolan and Natriello, co-authorship ties are significant influences on the field in which an author will work [3]. In addition to defining the emerging research field of K-12 engineering education, our study also offers an overview of engineering education research to guide researchers to choose research topics they are interested in, to look for research collaborators as well as to explore niche research areas.

The two major research questions of this study are: (1) As an emerging academic field, what had been the research trends in K-12 engineering education research from 1980 - Feb. 2010? (2) What were the collaboration patterns among researchers in K-12 engineering education from 1980- Feb. 2010?

Methodology

The K-12 EngE sub-database of this study was created from the aforementioned pre-existing database including all EngER articles from 1980-Feb. 2010. A list of keywords relevant to K-12 EngER was developed in this study to filter the pre-existing database and come up with the sub-database.

Initially 66 keywords were selected from two reports on K-12 engineering education. These two reports were the final products of a two-year study conducted by experts on diverse subjects from the Committee on K-12 Engineering Education and the Committee on Standards for K-12 Engineering Education, which are sponsored by the National Academy of Engineering (NAE) and the National Research Council (NRC) [1] [2].

Upon the realization that the keywords were too general and broad within engineering, a list of narrowing words was then devised to situate the keywords within a K-12 context. These words were specific to K-12 education, such as: K-12, kindergarten, elementary school, middle school, high school, pre-college, children, and P-12. These words also came from the previous two sources.

All keywords were then put into three online databases, Web of Science®, Compendex®, and EbscoHost® for keyword refinement. These keywords were judged based on the results of the searches in these databases. If a keyword produced no results in at least two databases, the keyword was deleted. These searches also allowed for the addition of words such as, advocat*, student engag*, cooperat*, implement*, facult*, etc. A list of 43 selective and effective (meaning on which produces relevant results) keywords was established. It should be noted that as this is an ongoing research, for this study, the refined keywords were only applied to Web of Science®.

To begin creating the sub-database, the narrowing words (K-12, kindergarten, elementary school, middle school, high school, pre-college, children, & P-12) were searched alone via “Sort & Filter” on the “Title” column using the text filter “Contains…” The relevant results were then copied from the original database to a new excel file, the sub-database. The relevant results were highlighted with blue in the original WoS database in order to rule out any repetitions in the sub-database. The filter was then cleared from the “Title” column. This process was used to search all of the narrowing words.

Next, the keywords were used to search the database. First, the keyword was searched via the filter function on the “Title” column using the text filter “Contains...” Once the filtered results were displayed the “Find” command was used to search the “Abstracts” and “Keywords” columns (note that the “Keywords” column contains both author described keywords and the keywords assigned by the search database) were searched for any of the aforementioned narrowing words. If the result was relevant (i.e., contained a keyword in either the “Abstracts” or “Keywords” columns) it was copied and pasted into the sub-database and then highlighted blue. However, if the result was irrelevant, (i.e., did not contain a keyword in neither the “Abstracts” nor the “Keywords” column) it was highlighted red. This system of highlighting results allowed for a quick and efficient method of creating the sub-database, which also eliminated the occurrence of articles being copied over twice.

Looking at the original WoS database, it became evident that not all articles had been considered from filtering by title alone. To address this, the articles were filtered by the “Keywords” section. To do this, the narrowing words aforementioned were searched alone using the “Filter” function with the text filter “Contains…” The relevant results were copied and pasted into the sub-database and highlighted blue. In addition to searching by ‘Title’ and ‘Keywords,’ the ‘Abstracts’ column was filtered by the same means as the ‘Keywords’ column. This methodology resulted in a WoS sub-database containing 671 K-12 relevant results.

In order to check if the previous methodology had worked in extracting all K-12 EngER relevant articles from the original WoS database, spot checks were necessary. First, a random spot check was performed on 50 articles' 'Abstracts,' 'Keywords,' and 'Title' columns. These columns were checked manually (i.e., read through thoroughly) for any K-12 EngE or EngER relevance. No relevant articles were retrieved in this random spot check. Next, a semi-purposeful spot check was performed. This was done via the "Sort & Filter" function in Excel. First, all the citation data in the original WoS database was sorted by year from smallest to largest. Then, the data was sorted by cell color; the cells without any color were filtered—this displayed citation data that had not been collected in the sub-database. Two articles were available to be checked in the 1980s. Neither of the two articles were K-12 EngE relevant. Since the 1990s and 2000s had a large number of articles, the articles chosen to be manually checked from these decades were filtered by the "Fields" column via the "Contains…" function for the keyword "educat*." Then 100 articles were picked at random, five from each individual year. None of the 102 articles that were manually checked contained any K-12 relevance. Using this method, it was assumed that most to all K-12 EngER relevant articles were collected.

The sub-database was organized through the steps illustrated below. It was sorted in ascending order from A to Z based on the first 'Authors' column. Next, any duplicates were eliminated manually. Note that although there were still items that were not highlighted (red or blue) in the Web of Science® database, it is assumed all of the relevant results were obtained in this manner. This is explained in further detail in the "Limitations" (IV) section of this paper.

Results

Keyword Analysis

The analysis of bibliometric data was first done via keyword. An excel file was created with the keywords down the first column and the years broken down into periods of three years from 1980-Feb.2010. In addition to the keywords, the narrowing words, teachers, counselors, and pupils, were added to the keyword column. The WoS sub-database was sorted by year in ascending order. The "Keywords" section of the WoS database was filtered via "Contains…" for each individual keyword along with the narrowing words as mentioned above. The number of times each word occurred per decade was calculated by Excel and manually inputted into the new Excel file in the corresponding keyword and year range cell.

Year Range	Number of Keyword Relevant Results
1980s	0
1990s	25
2000s	736

Table 1. Number of Keyword Relevant Results per Year

EngER has developed within the past 20 years. Furthermore, over the past 10 years the field of EngER has really began to bud tremendously by both increasing the amount of research and the scope of research

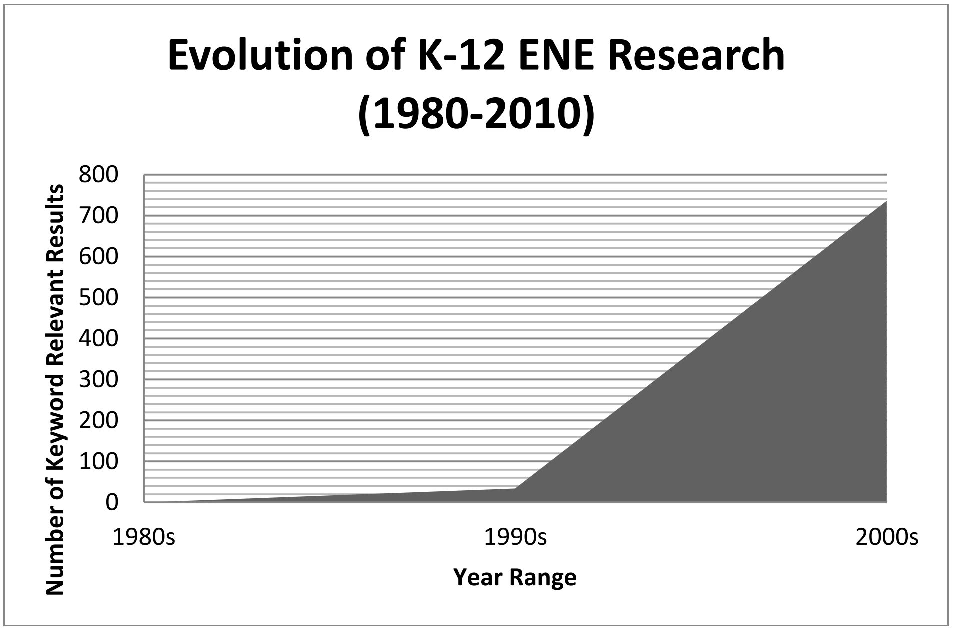

Figure 1. Number of Keyword Relevant Results vs. Decade

This is a graphical representation of Table 1. It gives us further visualization how K-12 EngER has developed over time to encompass a larger scope of research in the past two decades (i.e. more keyword relevant results in the 1990s and 2000s). Furthermore, this indicates that the field of EngER is reaching a higher level of academic standard.

The top 10 keywords are shown along with their frequencies in Figure 2.

Figure 4 contains the ten most frequently occurring keywords contained within the compiled database. This tells us what terms have been researched and published most within the period from 1980 to 2010. Furthermore, this figure can be used to indicate where more research needs to be done.

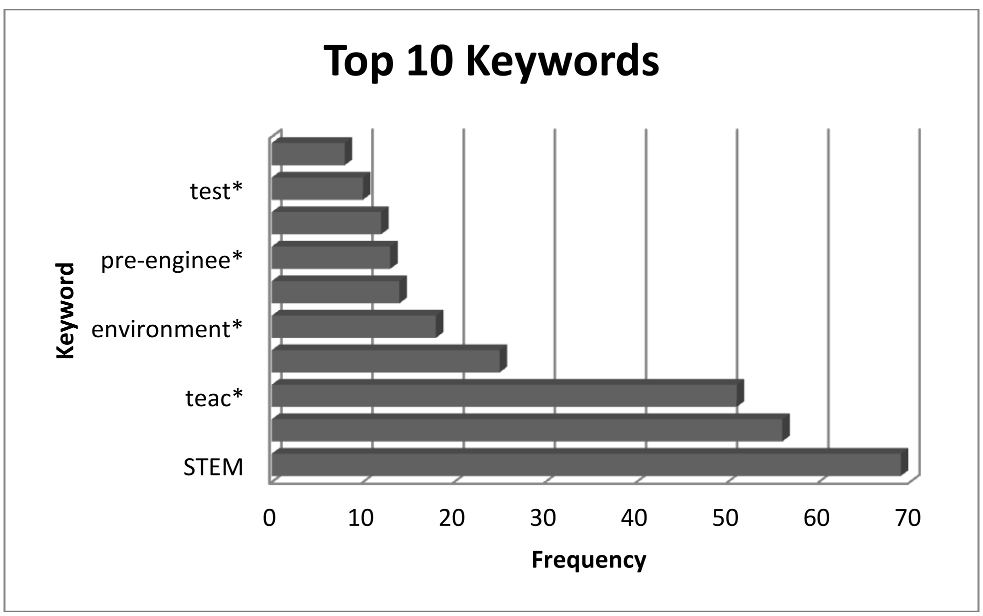

Figure 2. Top 10 Keywords

This study also classified the 43 keywords into seven areas of educational research [6] [7]. Table 2 contains the criterion that was used to classify each keyword. Note that keywords may fit into more than one category. For example, the keyword “grade*” belongs in both categories three and seven (refer to Table 2), because it is the organizational aspect of education and is also used for assessments.

	Classification	**Criteria**
1	learning mechanisms, learning processes/learner's attributes, & engineering learning mechanisms	Keywords in this area directly relate to how students learn and development. Furthermore, this area covers students' characteristics and learning tools or devices. For example, the keyword 'mathematical model*’ is a learning tool and is used to help students learn and develop and therefore belongs in this category.
2	instructional culture/theories/epistemologies/education research, & engineering epistemologies	Keywords contained in this area have a direct relationship with the principles and foundations of teaching. The philosophy of education and engineering are also within the realm of the category. For example, 'innovat*' is associated with the building blocks of what it means to be an engineer.
3	institutional/organizational structure/infrastructure/technologies, & engineering learning systems	Keywords in this category have to do with the framework of the education system. This is how education is organized. For example, 'grade*' is not only associated with the assignment of grades but also the organizational structure of the different grades in K-12.
4	educator's practices/curriculum	Keywords in this area have direct correlation to the current practices of educators and the set of courses required by students. For example, to develop a ‘teach* strateg*' is a current practice of educators.
5	diversity & engineering diversity and inclusiveness	Keywords in this classification category have to do with the inclusiveness of all races and sexes. Furthermore, keywords in this category help to break down the uniformity in most curricula. For example, 'minorit*' belongs to this category.
6	competence	Keywords contained in this area have to do with a pupil's ability to learn and recall information. Benchmarks within education and engineering are also included here. For example, 'techn* literacy' belongs in this category as it means to be well-educated in the area of technology.
7	assessment / evaluation	Keywords in this category are directly related to measuring a student’s abilities and competence. Furthermore, assigning a level of competence relative to other students. For example, a 'test*' is a way of doing this.

Table 2. Criteria for Keyword Classification

The keywords and the years they occur in Table 3 in hint at what has been researched and how the field of EngER has evolved over time, beginning with basics and exploding to contain more complex and specific terms. This may indicate the field is moving towards implementation of standards and curriculum. It should be noted that there were no relevant publications from the 1980s in our sub-database.

Years	**Keywords (No. Occurred)**
1980s	No relevant publications
1990s	adapt* (1); caree* (1); cooperat* (1); curricul* (2); environment* (1); experiment* (3); facilitat* (1); pupil* (1); STEM (1); structur* (3); stud* (1); teac* (2);
2000s	academi* (6); achiev* (11); adapt* (6); caree* (15); classroo* (3); collaborat* (13); communicat* (9); cooperat* (2); curricul* (25); enginee* communit* (1); environment* (22); experiment* (11); facult*(4); grade* (2); hands-on (6); initiative* (4); innovat* (6); integrat* (9); interdisciplin* (4); lesson* (2); mathematical model* (3); minorit* (7); outreac* activit*(2); partnership*(6); PBL (problem based learning) (4); pedag* (7); pre-enginee* (13); prepar* (4); problem solv* (4); prototyp* (1); pupil* (1); self effi* (1); STEM (157); structur* (12); stud* (65); teac* (46); teac* strateg* (2); teamwork (2); techn* literacy (3); test* (13); tuto* (3)

Table 3. Keyword Occurred per Year Range

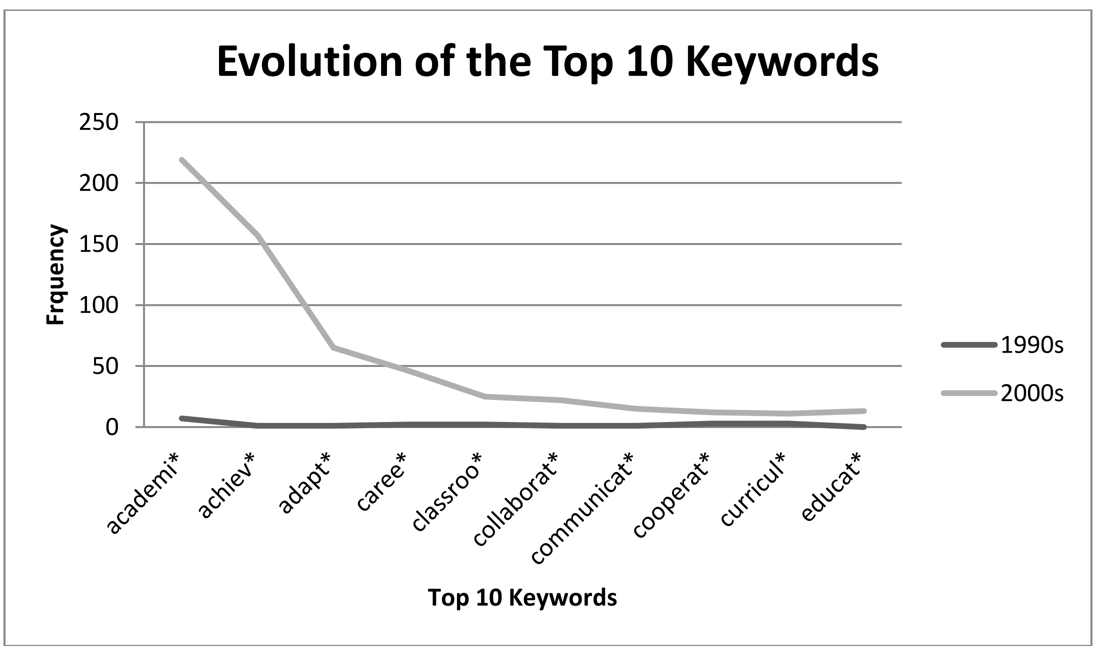

Figure 3. Top 10 Keywords Evolution

Figure 3 shows how the field of EngER has evolved over time increasing in the amount of research overall and per keyword.

The frequency of each keyword was split into three columns based on decades. These keywords were also divided based on the classification defined earlier; as a result Figure 4 was obtained.

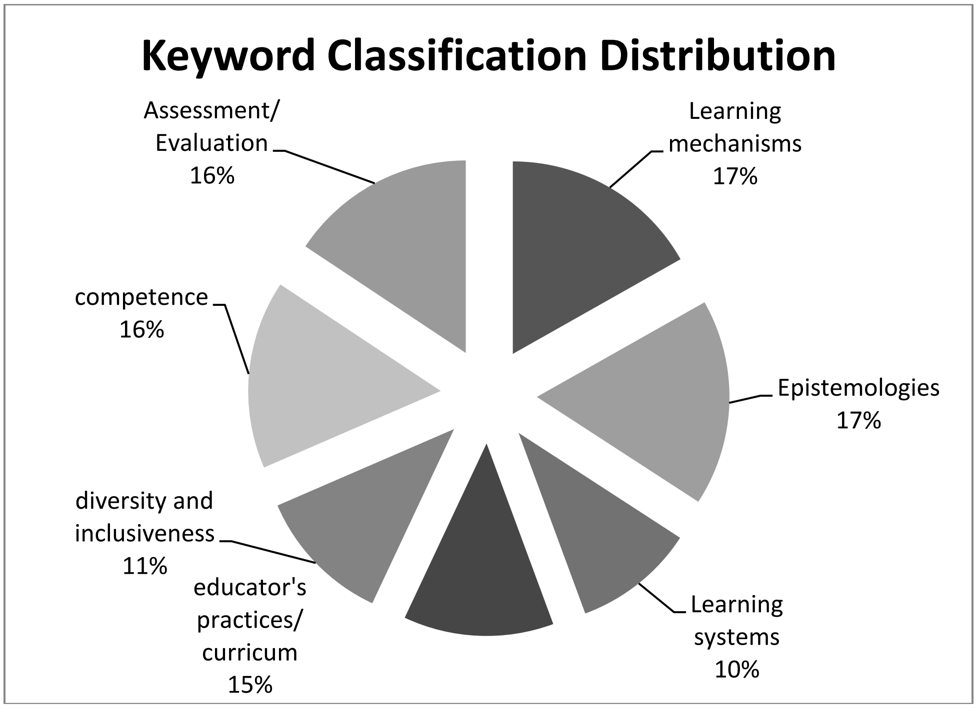

Figure 4. Keyword Classification Distribution

Figure 4 shows the cumulative distribution of keywords into the aforementioned categories for the entire duration of 1980-Feb.2010. This poses an alternate view of quantifying what research has been done and what areas need more attention. Furthermore, this supports the theory that K-12 EngER is moving towards implementation of curriculum because learning systems (10%), educator's practice/curriculum (15%), and diversity and inclusiveness (11%) have had the least amount of research. For this reason, it can be expected that in order for progress to be made more research in the aforementioned areas will increase in the next decade. . Figure 4 also shows that there has been close to equal amounts of research in epistemologies (17%), competence (16%), assessment/evaluation (16%), and learning mechanisms (17%). Due to the increased research activity in these areas, it can be expected there will be an increase of research in the less popular areas. This may indicate a push to expand the field to include more women in order to increase levels of equality in engineering, which is a predominately male field. This may also indicate a push for minorities to become more involved in STEM fields. This also tells us that the groundwork has been laid for the implementation of curriculum, indicating that national implementation may be the major next step in research.

In terms of demographic analysis in the WoS K-12 sub-database, the words kindergarten, elementary, middle, and high were filtered via the text filter "Contains…" in the "Title," "Abstracts," and "Keywords" columns. The columns were filtered respectively. For the first filter, the results were highlighted and counted. For the second filter, the results were counted and if any results were highlighted, they were subtracted before adding to the previous total for the word. Then the results were all highlighted for the last filtering, which was done in the same manner as the second filter. Finally, all highlights were cleared and the next word was searched. This data allowed for the creation of Figure 5.

Figure 5 indicates that as compared to high school level, relatively much less research work has been done in kindergarten, elementary, and middle school levels as a whole.

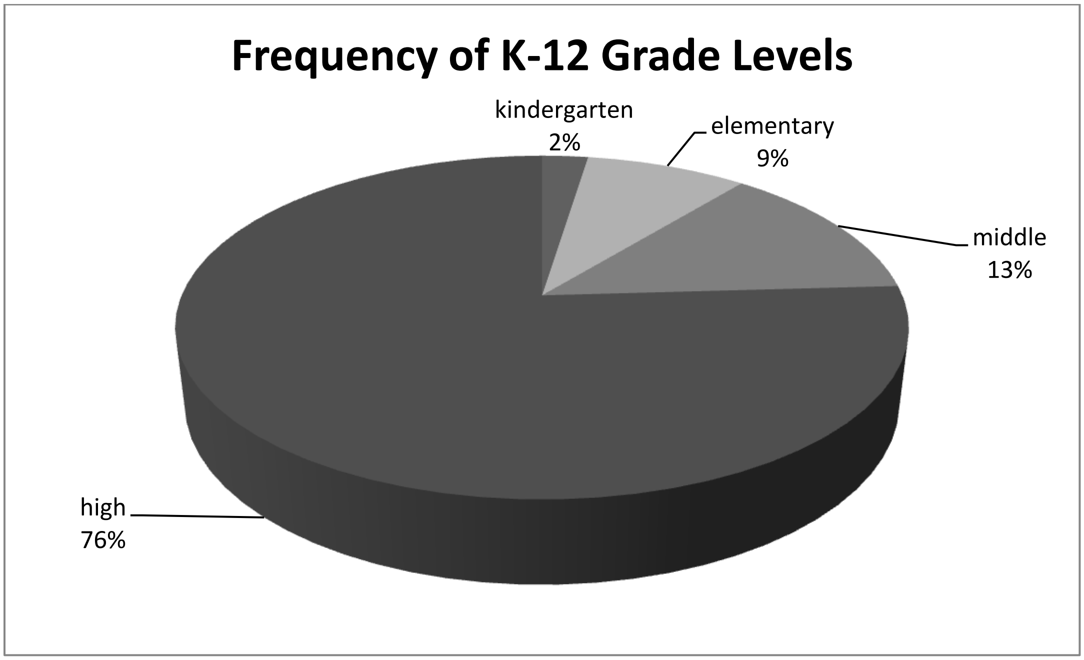

Figure 5. Frequency of Grade Levels

The classification and demographic analysis show that high school is the most researched for a K-12 EngE curriculum. This may be because researchers feel the greatest benefit of EngE may come from high school level students.

"Field" Analysis

To begin the field analysis, the "Field" column was copied from the WoS database and into a new Excel file. The fields were then put into separate columns by using "Text to Columns" function. It was separated by the semicolon deliminator in the field cells separating fields. The fields were copied from their separate columns into one column. Any extra spaces were then deleted between the fields. The fields were sorted via the "Sort & Filter" function in ascending order from A to Z. Then a duplicate file was saved. Within this duplicate file, all repetitive fields were deleted in order to get a list of all the various fields to filter—this file will be referred to as "Field_List." The original file of all fields with their duplicates included was filtered via the "Sort & Filter" function with the text filter "Equals..." and the resulting number of fields in each filter was recorded in the "Field_List" file next to the corresponding field in the "Fields" column. In the "Field_List" file, a custom sort was used to see which fields were the top ten fields contributing to K-12 EngER based on the values collected. This information was used to create Table 4 and Figure 6.

No. of Relevant Publications	Field of Journal in which Article is Published
1	Agriculture, Multidisciplinary; Architecture; Biochemical Research Methods; Biology; Communication; Construction & Building Technology;

	Demography; Dermatology; Education, Special; Emergency Medicine; Endocrinology & Metabolism; Engineering, Chemical; Engineering, Geological; Engineering, Ocean; Entomology; Environmental Studies; Ethnic Studies; Family Studies; Geochemistry & Geophysics; Geography, Physical; Geology; Geriatrics & Gerontology; Health Policy & Services; Humanities, Multidisciplinary; Integrative & Complementary Medicine; Marine & Freshwater Biology; Materials Science, Biomaterials; Materials Science, Characterization & Testing; Materials Science, Composites; Mathematics, Applied; Microscopy; Mining & Mineral Processing; Multidisciplinary Sciences; Nuclear Science & Technology; Obstetrics & Gynecology; Parasitology; Pharmacology & Pharmacy; Physiology; Plant Sciences; Political Science; Polymer Science; Psychology; Psychology, Biological; Psychology, Clinical; Psychology, Experimental; Remote Sensing; Reproductive Biology; Social Sciences, Mathematical Methods; Statistics & Probability; Transportation; Tropical Medicine; Water Resources
2	Acoustics; Anthropology; Biophysics; Clinical Neurology; Ecology; Engineering, Aerospace; Genetics & Heredity; Hematology; History Of Social Sciences; Imaging Science & Photographic Technology; Industrial Relations & Labor; Infectious Diseases; Linguistics; Materials Science, Ceramics; Medical Ethics; Metallurgy & Metallurgical Engineering; Nanoscience & Nanotechnology; Nutrition & Dietetics; Physics, Applied; Physics, Multidisciplinary; Public Administration; Social Issues; Virology; Women's Studies
3	Allergy; Astronomy & Astrophysics; Biochemistry & Molecular Biology; Economics; Geosciences, Multidisciplinary; Materials Science, Multidisciplinary; Medical Informatics; Microbiology; Nursing; Operations Research & Management Science; Philosophy; Psychiatry; Psychology, Social; Social Work; Sociology; Sport Sciences; Toxicology; Transplantation; Transportation Science & Technology
4	Behavioral Sciences; Cell Biology; Critical Care Medicine; Energy & Fuels; Health Care Sciences & Services; Information Science & Library Science; Instruments & Instrumentation; Oncology; Respiratory System
5	Business; Engineering, Manufacturing; History & Philosophy Of Science; Management; Otorhinolaryngology; Psychology, Multidisciplinary; Social Sciences, Interdisciplinary
6	Engineering, Environmental; Ergonomics; Medicine, General & Internal; Medicine, Research & Experimental; Psychology, Educational; Telecommunications
7	Cardiac & Cardiovascular Systems; Computer Science, Hardware & Architecture; Engineering, Industrial; Psychology, Applied; Social Sciences, Biomedical
8	Psychology, Developmental; Robotics
9	Automation & Control Systems; Computer Science, Software Engineering; Immunology; Optics; Radiology, Nuclear Medicine & Medical Imaging; Rehabilitation; Surgery
10	Biotechnology & Applied Microbiology

11	Computer Science, Cybernetics; Engineering, Civil; Ethics
13	Engineering, Mechanical; Neurosciences
14	Environmental Sciences
20	Public, Environmental & Occupational Health

Table 4. No. of Relevant Publications by Field

Table 4 summarizes what field is most involved in the research of EngE excluding the top ten fields. This also may tell us what field is looking to gain most from the implementation of K-12 EngE. Figure 6 below summarizes the top ten fields involved in EngER.

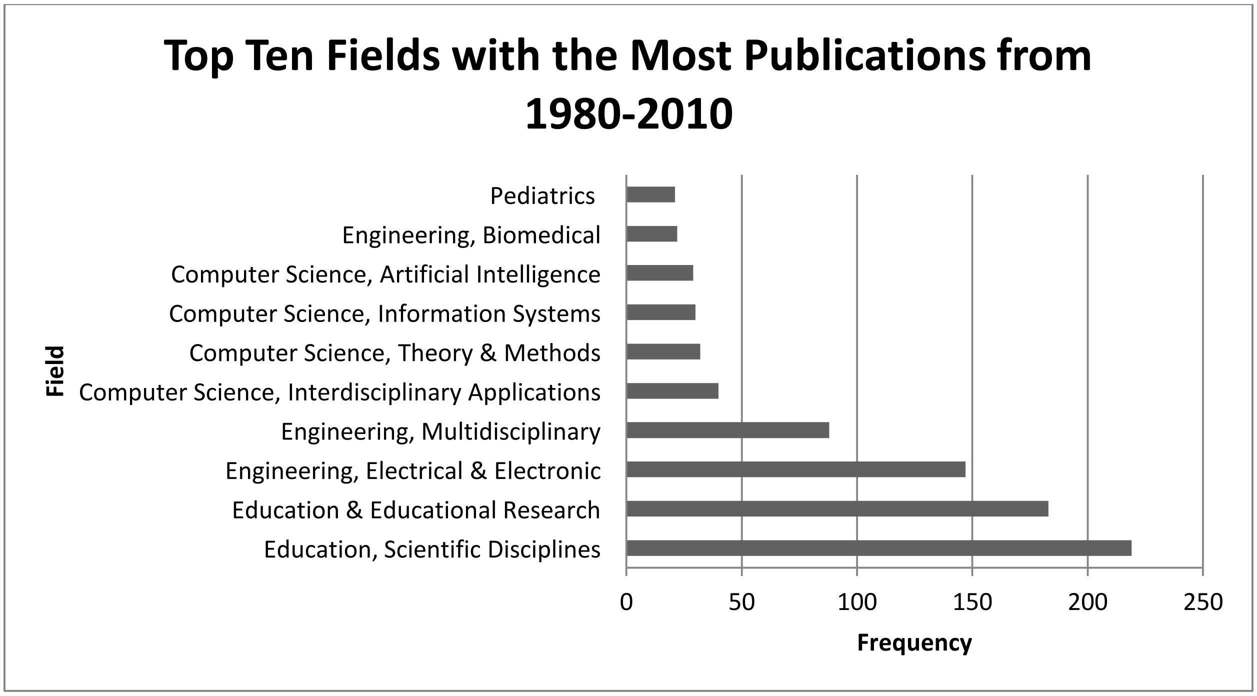

Figure 6. Ten Fields with the Most Publications from 1980-Feb.2010

Social Network Analysis

NodeXL was used for the analysis of author contributions. All co-author relationships were mapped manually. For example, John, Jane, and Grace are co-authors. The relationships would be as follows: (1) John-Jane, (2) John-Grace, and (3) Grace-Jane. Single authors were mapped as self-loops (i.e., Bob-Bob). The co-author relationships were inputted into NodeXL®. The data was then mapped and the overall metrics were calculated. Due to the density of the map, it was necessary to choose the top ranked 50 authors based on their degree of connection to other authors (i.e., the authors that had the highest degree were used). The map was condensed to these authors by using the "Dynamic Filter" tool in NodeXL® to choose the degree minimum and maximum (11-23). The data was then analyzed manually.

The NodeXL® social network map of co-author relationships resulted in Figure 7.

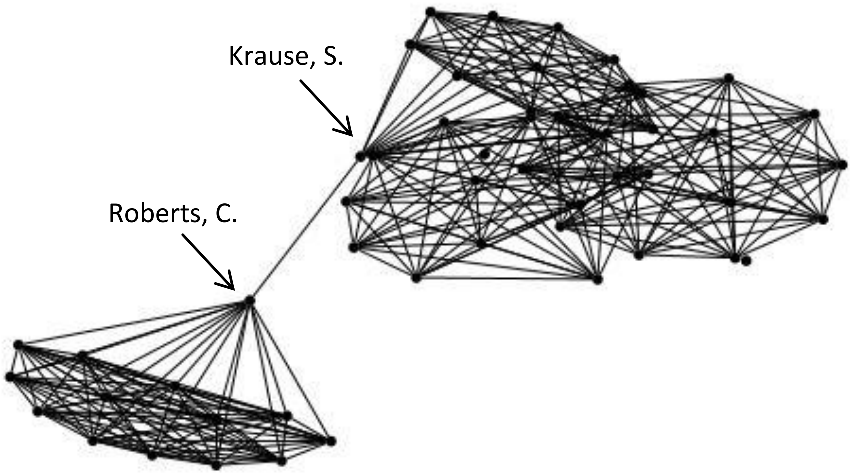

Figure 7. Social Network Map of K-12 EngER

The above Figure shows the social network map generated by NodeXL. Its overall structure is highly dense and connected and since the network is well connected, it is deduced that the connections are not random. Furthermore, the "most popular" researcher in the sense of collaboration is Krause, S. with a degree of 23, meaning he/she is directly connected to 23 other authors. Krause, S. also had the highest betweenness centrality indicating his position as a bridge allowing for communication to flow through to many authors. Roberts, C. received the second highest betweenness centrality also showing that he/she is an important factor for the flow of communication. Looking at the map, Krause, S. and Roberts, C. are connected along an edge. Their relationship is significant for the current communication between researchers. Table 5 below shows the top collaborating group of authors in the sub-database, which includes Baker, D., Krause, S. and Roberts, C.

Top Collaborating Pairs of Authors		Co-authorship Article Count
Baker, D	Krause, S	3
Baker, D	Roberts, C	3
Krause, S	Roberts, C	3
Harding, TS	Carpenter, DD	2
Harding, TS	Finelli, CJ	2
Carpenter, DD	Finelli, CJ	2
Baker, D	Yasar, S	2
Baker, D	Robinson-Kurpius, S	2
Yasar, S	Robinson-Kurpius, S	2
Yasar, S	Krause, S	2
Yasar, S	Roberts, C	2
Robinson-Kurpius, S	Krause, S	2
Robinson-Kurpius, S	Roberts, C	2
Tran, NA	Nathan, MJ	2

Table 5. Top Collaborating Pairs of Authors

Discussion & Conclusion

The bibliometric analyses show that engineering education research began in the last 10 years and has developed to cover a greater number and variety of keywords in the more recent years, which indicates how the field has reached a higher level of academic visibility. K-12 engineering education research began with research that had a very narrow perspective. In fact, in 1980s little or no research had been done in the area of K-12 engineering education. Then, in the 1990s, research began to cover 13 keywords. The research rose dramatically to encompass 42 keywords in the 2000s. Furthermore, there were only 25 keyword occurrences in publications in the 1990s on K-12 EngER in WoS. In the 2000s, this number expanded to 736 keywords occurrences (refer to Table 1). This indicates a spike in interest in this topic. From Figure 2, we learn that the keywords STEM, stud*, teach*, and curricul* were considered among the most significant keywords in the K-12 publications in the WoS sub-database indicating that researchers have a high interest in these topics. The keywords and the decades they occurred in (Table 3) have the potential to reveal current trends in K-12 EngER.

Classification analysis reveals that the most research in K-12 EngER has been done on "epistemologies". The areas of "learning systems" and "educator's practice/curriculum" have gained relatively less attention from researchers, which would imply the current state of K-12 engineering education: as a subject, fewer K-12 schools or teachers implementations are reported in the research literature [1]. Furthermore, more research has been done about epistemologies, competence, assessment/evaluation, and learning mechanisms revealing researchers main interests from 1980-Feb 2010.

The demographic analysis exposes that most research has been done about engineering education in high school. This also tells us, that many believe the greatest benefit would be using EngE in high schools to encourage and spark students' interest in pursuing STEM careers. Furthermore, it tells us that EngER in elementary school needs more attention (see Figure 5). On the other hand, it should be noted that upon realizing the significance of implementing engineering education in K-12 classrooms, a number of programs or projects have already been established in recent years to promote engineering-based curriculum across a variety of K-12 grades, for example: Engineering is Elementary (elementary level), LEGO engineering (elementary level); Project Lead The Way (middle and high school level), The Infinity Project (high school level), The Vanderbilt Instruction in Biomedical Engineering for Secondary Science (middle and high school level); The Institute for P-12 Engineering Research and Learning (P-12 level) [9] [10].

Using field analysis, the major finding was the fields, which have contributed most to K-12 engineering education research in the past 15 years. From Figure 6, the top ten contributing fields are revealed along with how many results were found for each field. The field that had the most K-12 relevant articles (219) was Education, Scientific Disciplines. Runners up include Education & Educational Research (183), Engineering, Electrical & Electronic (147), Engineering, Multidisciplinary (88), Computer Science, Interdisciplinary Applications (40), Computer Science, Theory & Methods (32), Computer Science, Information Systems (30), Computer Science, Artificial Intelligence (29), Engineering, Biomedical (22), and Pediatrics (21). This can be cautiously interpreted that the field of Education, Scientific Disciplines is contributing most to the growth of K-12 EngER. This field might also be mostly impacted due to the large amount of researchers in this field. This may also indicate a need for more research to be done in the less researched fields on the benefits of K-12 EngER. Table 4 contains the full list of fields and the numbers of relevant publications for each. This is information is important and relevant in order to see what fields are most interested and important in K-12 engineering education research. It also shows which fields are looking to benefit most from the implementation of K-

12 engineering education research. Furthermore, from this it can also be inferred that K-12 engineering curriculum might include lesson plans with pertinent information from these top fields.

The social network analysis results reveal that there is a high trend of collaboration between authors in the K-12 EngER community. Krause, S. was found to be the most collaborative author— who also had a significant position as a bridge for communication for other authors in this field in addition to Roberts, C. The fact that the two most collaborative authors are connected is a good sign; however, more collaboration could greatly improve the field as a whole. Overall, more work needs to be done in this field in order to make deeper sense of the data.

In summary, this research methodology functions as a means to quantify and track the progress of the field of EngER. This reveals what has been researched most and what still has yet to be researched. This research could be used a means for the progression of EngER as a whole.

Limitations

Limitations in this specific research project include that only one database, the Web of Science database, was used. This is an ongoing research project and more databases will be analyzed later. Also a large limitation is the possibility that 43 keywords did not capture all K-12 EngE relevant articles from the pre-existing database. However, to cover more articles a larger list of keywords with greater variety would be needed. This could be done by using a greater variety of literature to develop the keywords. An alternate solution would require checking a very large amount of publications (at least thousands) manually for any correlation. This solution was not time effective for the timeline of this project. So it was assumed that the keywords did capture all relevant articles from the pre-existing database. In addition to this, for the demographic analysis a total of 494 articles were captured in acquiring the data. However, it is assumed that this analysis is still accurate, because the other articles could be general to K-12 Engineering Education Research as a whole.

Recommendations for future work

As this is an ongoing research project, the suggested methodology summarized in this article can be repeated for other databases such as EBSCOhost® and Compendex®. Based on the upcoming articles in this area, more keywords from a greater variety of literature should be added to the keyword list to ensure that all relevant articles are taken from the original databases. In addition, any outcomes from further research should be combined with the outcomes of this research project in order to come up with results that are accurate and general to K-12 Engineering Education Research.

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