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Analysis of the influence of the *International Journal of Electrical Engineering Education* on electrical engineering and electrical engineering education

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Abstract This article researches the influence of *IJEEE* on electrical engineering and electrical engineering education as a discipline. For this purpose, the history of this journal has been presented from a citation perspective. To identify leading and evolving research areas within *IJEEE* the authors conducted keyword analysis, which additionally showed how *IJEEE* contains both educational and technical contributions. The authors also studied the temporal evolution and distribution of keywords. Word co-occurrence was analysed to discover the main context in which the keywords have been used. The analysis also revealed the prominent contributors within the community of *IJEEE* based on various authorship and citation criteria. It was observed that the influential authors appear in multiple ways, i.e. most of the authors who were influential by one criterion also made to the top list of other criteria. The authors concluded that the single-author pattern is quite prominent within this community, and very little work has been done between the same co-authors. Therefore, there is a need to encourage *IJEEE* authors to write more collaborative publications so that the authorship/co-authorship network may grow.

Keywords citation analysis; collaboration; engineering education; impact factor; keyword analysis; social network analysis

In this age of information technology, data can be accessed through vast collections of written texts and online resources. The ever-increasing growth of these collections is mirrored by the task of information retrieval.[1] In just one year, 2008, around 1.4 million articles were published.[2] The task of measuring the influence of one source or area on another is considered to be of significant value. Such analysis, for its effectiveness, requires the use of quantitative schemes associated with the necessary theoretical framework. Citation analysis is the best supported method to provide such quantitative measure.[3] According to Moed[4] this analysis relies on building indicators and benchmarks for the 'impact or influence' of scholarly publications using citation and bibliometric data. He further suggests that the use of citation analysis in research assessment of scholars, research groups and organizations is more effective if it is more 'formal, open, scholarly founded, supplemented with expert background knowledge, carried out in clear policy context and enlightening

rather than formulaic'.[4] Citation analysis is thus used for the evaluation of science and for seeing the influence of one venue on another.[5,6] It has been used for measuring impact since Cason and Lubotsky's early study in 1936 and across various fields.[7–10] The current trends in the field of citation analysis are due to the data availability from Science Citation Index (SCI) by the Institute for Scientific Information (ISI).[3] Therefore, the analysis presented in this paper also relies on SCI and on ISI's Web of Science® (WoS) for the retrieval of data.

Introduction to citation analysis and social network analysis

The contribution of an individual to the current knowledge base relies on already established facts and it becomes apparent though citation and referencing.[11] Citation is the appreciation that one article *receives* from another and reference is the acknowledgement that an article *gives* to another.[12] According to Eom[13] the purpose of citation analysis is to find out the most influential individuals, articles or institutions in a particular field of research.[14,15] There has been a noticeable growth in citation analysis.[16] Kostoff defines the uses of citation itself as 'bookmark, intellectual heritage, impact tracker and self serving purposes'.[17]

Citation analysis can be done using citation counts or by conducting co-citation analysis. Citation count of journals is based on impact factor, developed by Garfield.[18–21] According to Smith, from the many available techniques of citation analysis, the easiest is citation count.[16] This is a quantity representing the number of times an article or author has been cited;[14,15] it has no way of linking it to other authors or articles etc.. In contrast, co-citation analysis reveals the intellectual linkage between authors or publications.[22,23] Co-citation analysis may be done using bibliographic coupling, document co-citation analysis, author co-citation analysis and co-word analysis.[24,25]

The aforementioned analyses come under the umbrella of bibliometrics. According to Prichard, bibliometrics is 'the application of mathematics and statistics on written texts and other media of communication'[26] and its purpose is to highlight the life and the course of development of a discipline by analyzing written manuscripts, books and other texts. The limitation of bibliometrics is that it relies on attribute data e.g., data that deals with individual qualities of an actor, such as age, race etc. If the data under analysis is relational e.g., connection between actors etc. then social network analysis (SNA) is the technique to be used.[27,28]

The focus of this article is to utilize the above-mentioned techniques in a way that can not only be replicated but also be learnt and extended for further analysis. Different tools that have been used for such analysis rely on different data sets and a complete description is provided for interested readers to follow. This article aims to illustrate the influence of International Journal of Electrical Engineering Education (*IJEEE*) on other venues and the effect that other venues have on *IJEEE*. Therefore this paper relies, in part, on the citation data and aims to identify leading research areas and new evolving areas within *IJEEE*. It also aims to explore the authorship networks and patterns based on their contributions to *IJEEE*. Using

text mining tools an effort is made to highlight the areas with more potential for research.

Journal history

Dr M. G. Hartley, the longest-serving editor of *IJEEE*, has written about the evolution of *IJEEE* from its foundation in 1948 as the *Bulletin of EEE* (see also his paper in this issue).[29–33] Against this background, our paper aims to look at the history of *IJEEE* from the perspective of citation analysis.

Analysis

In this section, data is presented to illustrate the progress of the journal and to analyse its membership and contributions. Each of the research questions in the next section relies on different data set; therefore, the objective of each question, its corresponding data, analysis and results along with an explanation of the trends is presented separately. Here numerical data is accompanied by a detailed explanation, therefore, the analysis relies on both quantitative and qualitative approaches.[34]

Research questions

The purpose and scope of the present analysis is to determine: What effect has *IJEEE* had on electrical engineering (EE) and electrical engineering education (EEE) as a discipline? An answer to this broader question requires answers to the following sub-questions: Who cites *IJEEE*? What gets cited in *IJEEE*? What is the distribution of *IJEEE* keywords? What is the impact of *IJEEE*? Who are the significant contributors in *IJEEE*? These are considered in detail in the following sections.

Who cites *IJEEE*?

The original objectives of *IJEEE* (the then Bulletin of Electrical Engineering Laboratory Practice) were 'more effective interchange of information on teaching and laboratory practice in engineering'.[29] *IJEEE* objectives are to be 'a forum for the exchange of ideas and innovations in the teaching of electrical engineering and electronics at university level'.[33] These aims match exactly with what Crane has said: in any discipline, the circulation of ideas is what facilitates the formation and propagation of knowledge.[11] The best evidence to prove the effectiveness of *IJEEE* in achieving its desired goals is through citation since the scientific reputation of a journal is determined by the number of citations of its papers over a specific period of time. An expected outcome of the analysis of the number of citations is to identify diverse groups with similar interests to those of the areas covered in *IJEEE*.

Data

The data for finding the records, about the citations made to *IJEEE* has been taken from the Journal Citation Reports (JCR) within the ISI Web of Science (WoS). The

same database is used for finding the records of citations made by the authors publishing in *IJEEE*. The data covered in JCR is only for the years 1998–2009.

Analysis and discussion

Table 1 shows the sources, that have cited *IJEEE* ten or more times. The complete names for these venues are given in Appendix A. From Table 1 it is apparent that the journals with longer history have cited more from *IJEEE*, which itself has the longest history of these journals.

Table 2 allows us to see the trends of the venues citing *IJEEE,* classified into: journals, conference / proceedings and unidentifiable sources. Clearly most of the sources citing from *IJEEE* are journals. It might be due to the reason that self citation is also included in it, which contributes about 17% of the total citing venues. No information was available for the category 'other sources'. It is interesting to note that the contribution of conference / proceedings towards the citation count from *IJEEE* is only 10%. It might be due to the fact that people publishing in journals

TABLE 1 *Citing frequency of venues that cite from the articles published in IJEEE*

Citing Source	Cumulative Count	Percentage	Life Span in Given Form	Actual Span
INT J ELEC ENG EDUC	89	16.888	1963–2010	1948–2010
IEEE T EDUC	32	6.072	1963–2010	1958–2010
IEEE T POWER DELIVER	28	5.313	1986–2010	
INT J ENG EDUC	26	4.934	1984–2010	
COMPUT APPL ENG EDUC	19	3.605	1996–2010	
INT J ELEC POWER	13	2.467	1979–2010	
IEEE T ENERGY CONVER	11	2.087	1986–2010	1952–2010

The cumulative count in Tables 1–3 cover only the years from 1998–2009; since no further data was available from JCR. However, the interested reader/author may do so manually

TABLE 2 *Grouping frequency of venues that cite the articles published in* IJEEE

Citing Source	Source Count	Cumulative Count	Percentage
Journal	115	416	78.94
Conference / Proceedings	27	54	10.25
Unidentifiable	5	6	1.14
Above Sources	**147**	**476**	**90.32**
Other Sources (no info. available)	–	51	9.68
All Sources	–	527	100

For Tables 2 and 3, 'unidentifiable' means: no information found on ISI about the full name or nature of the source. 'no info. available' means nothing provided about the name/nature/count of sources.
No information could be gathered for the following five sources: 'POWER SYST', 'ADV DESIGN CONTROL', 'ASSESS EVAL HIGH EDU', 'DES SOC PUB DS' and 'LEC N EARTH'. Therefore, they have been put in the category 'unidentifiable'.

TABLE 3 *Area-wise frequency of venues that cite the articles published in* IJEEE

Citing Source	Source Count	Cumulative Count	Percentage
EE & ECE	105	249	47.25
Other Technical	21	26	4.93
Combined	8	182	34.54
Learning / Education	10	15	2.85
Above Sources	**144**	**472**	**89.56**
Unidentifiable	3	4	.76
Other Sources (no info. available)	–	51	9.68
All Sources	–	527	100

Since no information could be gathered for the following three sources: 'INSIGHT', '2008 P 43 INT UN' and 'DES SOC PUB DS'; so they have been put in the category 'unidentifiable'. Just like the previous case, for the category 'other source' no information is available in JCR.

tend to cite more from journals. Also, the citation patterns depend on the history of that venue as apparent from Table 1.

Table 3 brings out another classification of the citing venues based on the research area of the venues. The categories include:

1. 'Electrical engineering' and 'electrical and computer engineering' (EE & ECE).
2. 'Other technical' includes technical disciplines other than EE & ECE
3. 'Combined' includes engineering or technical disciplines with educational contribution
4. 'Learning / education' (LE) includes venues having purely education related contributions

From Table 1 and Table 3, it can be concluded that a major source of citations to *IJEEE* is self citation; with a count of 89 (about 17%). It is this high count which also raises the contribution of the category 'combined' to 34.54%.

As expected, Table 3 reveals that the highest count of sources that cite from *IJEEE* are EE & ECE followed by engineering education venues. However, *IJEEE* contributes to other communities as well e.g., science, physics, mathematics, education, learning and education technology etc. as seen by the categories 'Other Technical' and 'Learning / Education'. Hence it can be concluded that *IJEEE* is satisfying both needs i.e., bringing out new research in the field of electrical engineering and also improving the field of electrical engineering education (EEE) and engineering education in general.

What gets cited in *IJEEE*?

Analysis and discussion

Table 4 shows the listing of the sources that are cited in *IJEEE* ten or more times. The complete names for these venues are given in Appendix A. It is interesting that the history of *IEEE Transactions on Education* is shorter compared to *IJEEE*, yet it has received the highest citation count in *IJEEE*, highlighting the reputation of the

TABLE 4 *Citation frequency of venues cited in the articles published in* IJEEE

Cited Source	Cumulative count over 1998–2009	Percentage	Life Span in Given Form	Actual Span
IEEE T EDUC	126	3.606	1963–2010	1958–2010
INT J ELEC ENG EDUC	89	2.547	1963–2010	1948–2010
IEEE T POWER SYST	85	2.433	1986–2010	
IEEE T POWER DELIVER	41	1.173	1986–2010	
IEEE T POWER AP SYST	39	1.116	1963–1985	
IEEE T IND APPL	27	0.773	1972–2010	
ELECTR POW SYST RES	21	0.601	1977–2010	
ELECTRON LETT	18	0.515	1965–2010	
IEEE CONTR SYST MAG	17	0.487	1981–2010	
ELECT CIRCUITS	16	0.458		
ENG SCI EDUC J	15	0.429	1992–2010	
P I ELECTR ENG	14	0.401	1873–2010	
BRIT J EDUC PSYCHOL	13	0.372	1931–2010	
IEE P-GENER TRANSM D	10	0.286	1994–2006	1980–2010
INT J ENG EDUC	10	0.286	1984–2010	
IEEE T ENERGY CONVER	10	0.286	1986–2010	1952–2010
IEE P-CIRC DEV SYST	10	0.286	1994–2006	1980–2010
IEEE T IND ELECTRON	10	0.286	1982–2010	1953–2010

The cumulative count in Table 4 covers only the years from 1998–2009 due to the availability of limited data through JCR.

TABLE 5 *Grouping frequency of venues cited in the articles published in IJEEE*

Citing Source	Source Count	Cumulative Count	Percentage
Journal	85	787	22.52
Conference / Proceedings	39	115	3.29
Unidentifiable	111	304	8.7
Above Sources	**235**	**1206**	**34.52**
Other Sources (no info. available)	–	2288	65.48
All Sources	–	3494	100

The cumulative count in Table 5 and Table 6, covers only the years from 1998–2009 due to the availability of limited data through JCR.
For Table 5 and Table 6, 'unidentifiable' means: no information found on ISI including the full name or nature of the source. 'no info. available' means: nothing provided about the name/nature/count of sources.

IEEE Transactions, as well as indicating that the research focus of this journal aligns well with *IJEEE*.

To see the trends of the venues being cited in *IJEEE*, the venues are again subdivided into previously mentioned categories. Again, no information is available for the category 'Other Sources'. Table 5 thus shows the grouping frequency. As expected, the citations made within *IJEEE* are mostly from journals followed by a

TABLE 6 *Area-wise frequency of venues cited in the articles published in* IJEEE

Citing Source	Source Count	Cumulative Count	Percentage
EE & ECE	145	729	20.86
Other Technical	11	23	0.66
Combined	20	284	8.13
Learning / Education (LE)	20	85	2.43
Above Sources	**196**	**1121**	**32.08**
Unidentifiable	38	85	2.43
Other Sources (no info. available)	–	2288	65.48
All Sources	–	3494	100

small proportion of conferences. Again, no information could be gathered for the 111 sources since their full name and nature is not available at the ISI source listing site.

From the data of Table 6, it is observed that the highest count of citations made in *IJEEE* is from the 'EE & ECE' venues followed by 'engineering education'. Therefore, the *IJEEE* community not only gets informed by engineering education but also informs this community. A small percentage of citations are also made to the other technical venues, learning and educational venues. The high count of citations made to EE & ECE (20.86%) along with 'LE' and 'engineering education' (10.56%) shows the closeness of these percentages which justifies *IJEEE*'s objectives.[33]

What is the distribution of *IJEEE* keywords?

This question offers some insight into the area-wise contribution of *IJEEE* towards electrical engineering (EE) and towards electrical engineering education (EEE). Hence the themes and trends being followed in *IJEEE* may guide the reader towards new emerging research areas within electrical engineering education.

Data

The data for this analysis is downloaded from ISI WoS records from 1969 to 2010, (except for a one year gap in 1972). 1491 records were found which includes 1400 articles, 31 editorials, 18 notes, 18 proceeding papers, 14 letters, 3 addenda, 2 software reviews and 1 reprint.

Analysis and discussion

When the keyword field is extracted from these records it is found that out of 1491 total records only 373 records have the keyword field in them. The total count of keyword phrases found in these records is 1556, out of which 1173 are unique so the keyword reuse is 24.614%. Since 75% of the articles did not have keyword field in them, so it cannot be a good representative for predicting the trends of this journal. It was found that almost twice as many articles (620 articles) had the abstract field present, so the authors decided on using this field for further analysis.

The first and most frequently used way of predicting the journal trends is through tag crowd.[35] A tag crowd based on the abstract field of the articles is presented in Fig. 1. For tag generation: the whole abstract field was converted into keywords and processed to ignore 137 common English words e.g., *and*, *another*, *because*, *use*, *very*, *to, etc*. The remaining 4835 unique keywords were then manually refined to exclude obvious entries such as *student(s)*, *engineer(ing)*, *educat(ion)al*, *electric(al)*, and *electronics, etc*. The final refined list contained not only technical keywords such as *circuit*, *current*, *computer*, *voltage*, but also had education-related keywords such as *learning*, *university*, and *study etc*. Since Fig. 1 is a pictorial illustration of the top keywords for the entire period 1991–2010 (no abstract was available in ISI WoS prior to 1991); it is thus, a representative of the overall research trends followed in *IJEEE* during this time frame. In order to map how the research themes have evolved within *IJEEE*, it is necessary to see the temporal usage of keywords and their distribution over time. Figure 2 shows the frequency based distribution of the top 30 keywords, per five year span, taken from the abstracts of the articles for 1991–2010. (It should be noted that while the authors conducted this analysis, 18 additional documents were added to the *IJEEE* dataset in ISI for 1991–2010). In the following

Fig. 1 *Tag crowd for the top 50* IJEEE *keywords based on abstract.*

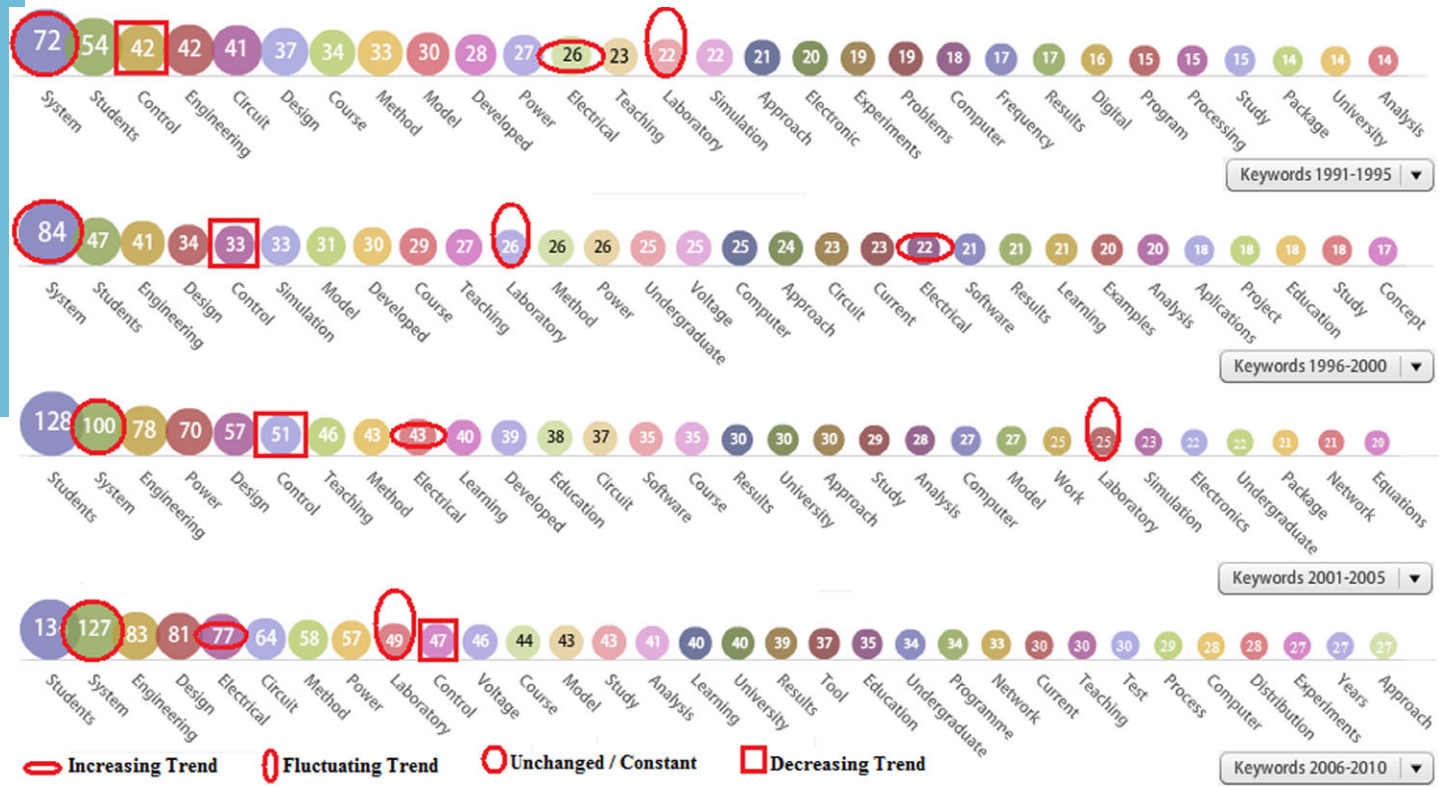

Fig. 2 *Yearly distribution of top keywords of abstracts.*

analysis, absolute keyword counts are not considered; rather their relative ranks are observed. Given the trend of ever-increasing publications,[1] absolute count is not justified. From this figure it is found that over the given period 1991–2010: the relative distribution of keywords *system(s)*, *student(s)*, *engineer(ing)*, *design,* and *method*, remains the same; that of keywords *control*, *teach(ing)*, *approach*, and *experiment(s)*, decreases; and that of keywords *electric(al)*, *power*, *laboratory*, *study* and *university*, increases. The usage of the following keywords started in 1996 and has been found to increase since then: *education*, *learning*, and *undergraduate*. The following keywords are absent from the top 30 list of the year 2006–2010: *simulation*, *developed*, *experiment*, *electronics*, *digital*, *frequency*, and *problems*. Some keywords absent in the 1990s but found in the top 30 list for 2000–2010 are: *network*, *tool*, *test*, *years*, and *distribution*. For *IJEEE* the utility of this analysis is: trend observation for electrical and computer engineering (ECE) and trend observation in education.

A further investigation into the research themes can be made by conducting a word co-occurrence analysis.[1] This analysis has many possible applications including browsing, summarization, comparison of document distribution, trend analysis and association discovery etc.[36,37] The authors used the Sci^2 tool[38] to perform this analysis for the time span 1991–2010. Again, for this analysis, the abstracts of the articles were used to find the co-occurring words. There was a pre-existing stop word list in the Sci^2 tool which omits some of the common English words. Also, in this step the abstracts were processed to tokenize the phrases into words and then join plurals of the same word. Later, the top edges were extracted based on their weights (an edge connects two words based on their co-occurrence in the text. The edge weight is the frequency of co-occurrence of two words. An edge with the highest edge weight is regarded as the top edge) The top nodes (words) could also be extracted, but since we are interested in co-occurrence, only top edges were extracted. The isolated articles were then removed which are the articles whose words did not match with other words or the articles that did not have the abstract field in them. After this, using the GUESS visualization of the Sci^2 tool, the top 1000 co-occurring words were mapped as shown in Fig. 3. Due to space limitation, the authors decided to conduct the word co-occurrence analysis for the entire time span of 1991–2010 (rather than conducting it in 5 year spans as in Fig. 2). Interested readers may also perform temporal analysis for the word co-occurrence. It should be noted that Fig. 3 still contains some of the generic and broader keywords, which will later be eliminated for doing further analysis.

Now the top keywords are available through Fig. 2 and the top co-occurring word list is available through the Sci^2 tool. The results of these two were then used together to see how in 1991–2010 the top keywords within *IJEEE* have been defined and utilized. (At this stage the generic and broader terms were excluded manually.)

Some of the top keywords of Fig. 2 that have consistently maintained their rank over the years are: '*student*', '*system*' and '*design*'. When their top ten co-occurring words from 1991–2010 are extracted and plotted we get Fig. 4. It is apparent from this figure that some of the keywords such as: '*design*', '*student*', '*develop*', '*course*' and '*engineer*' are common in all of them. However, some keywords such as

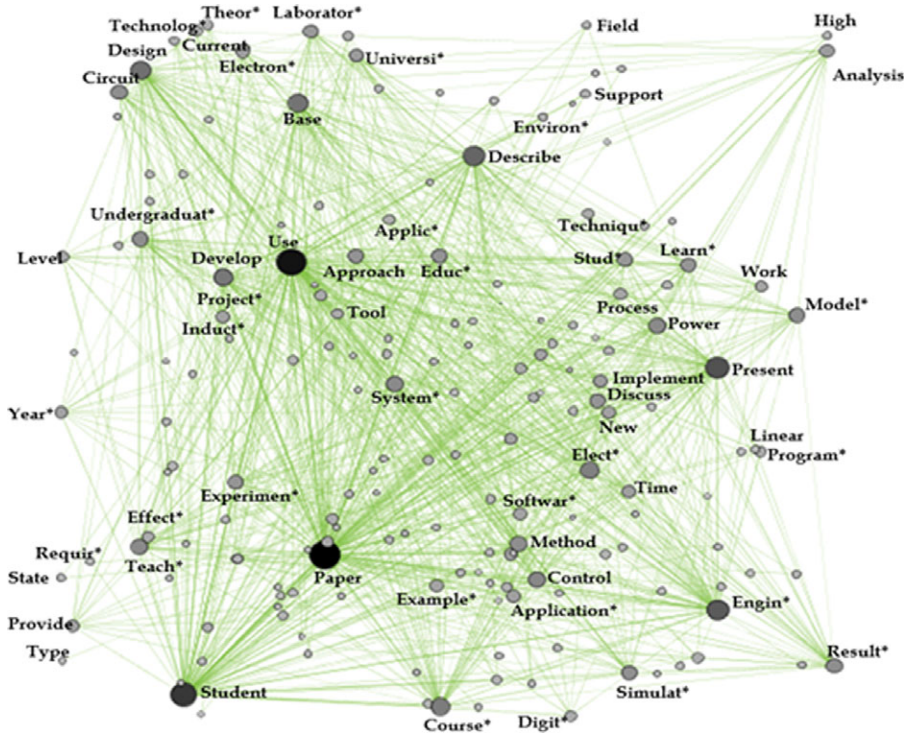

Fig. 3 *GUESS Visualization of 1991–2010 top 1000 co-occurring words.*

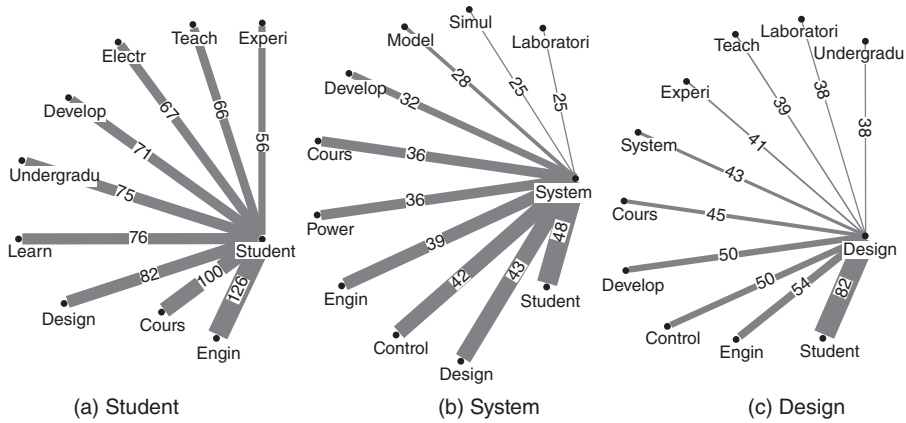

Fig. 4 *Network diagram for the word co-occurrence analysis.*

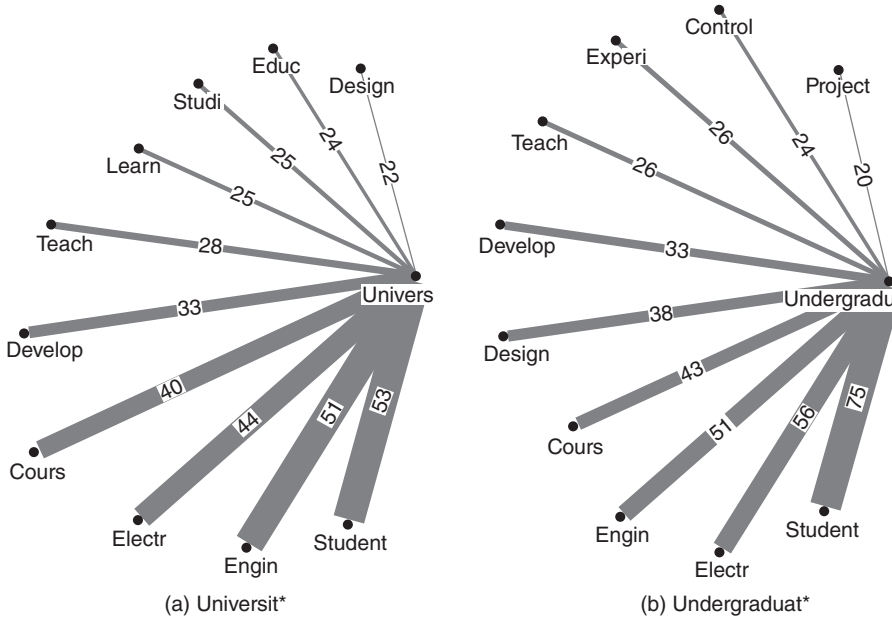

Fig. 5 *Network diagram for the word co-occurrence analysis of universit* and undergraduat*.*

'*simulat**', '*model**' and '*power*' appear only in the top ten list of the keyword '*system*'. Similarly, '*electr**' and '*learn**' appear only with the keyword '*student*'. However, there are no words that are unique in the top ten list of the keyword '*design*'.

The authors next drew the network diagrams of the keywords '*universit**' and '*undergraduat**', as presented in Fig. 5. Both the keywords have almost the same usage i.e., design, development, student learning and teaching, university studies and education, undergraduate project and experimentation etc. A temporal network diagram could also be plotted.

What is the impact of *IJEEE*?

Various measures are used to see the impact or significance of a journal. The chosen method here is impact factor (IF) (see Appendix B).[39] The use of IF is often criticized.[40,41] Alternatives include PageRank (which measures the hyperlinks to the published source or journal on the net), eigenfactor scores (which is a measure of importance), and article Influence score (which is a measure of prestige).[42,43] These new indicators produce information that is different from the JCR's IF. However, they correlate very well with the WoS IF and among each other.[44] Also, the disadvantages associated with IF are linked to inappropriate usage; rather than a defect in this bibliographic parameter.[41] A comparison of the critique against IF was made and it was concluded that 'impact factor can decide 'the success or failure of a

journal'.[45] So in this study, IF will be used. Moreover, following Garfield's guideline (Appendix B) a 2-year span was used to calculate the journal IF.

Data

The data for finding the journal impact factor has also been taken from JCR for 1998–2009. For the IF analysis, only the data for those venues similar in scope to *IJEEE* have been included. These venues were chosen based on ISI subject category 'Education, science disciplines' and then only the venues related to education research, engineering education, technology education etc. were extracted. Some venues, such as J SCI EDUC TECHNOL, STUD SCI EDUC, had no information about IF (during 1998–2009) and thus are not included in the following table. Similarly, for INT J ENG EDUC, the data is available only for 2003–2008. Appendix A lists the complete names of all of these venues.

Analysis and discussion

Table 7 shows an overall increase in IF over the years (as evident from 'combined average'). All these venues have similar scope, so we can say that research is increasing in areas such as education research, engineering education, technology education. As Haghighi suggests: 'engineering education research is the most effective avenue through which we can address over arching and grand questions'.[46] There is a need of collaboration between engineering faculty and social scientists so that EER may contribute to learning theory and not only be informed by it.[47]

Who are the significant contributors in *IJEEE*?

The answer to this question is two-fold; firstly it can be explained by the co-authorship network and secondly by the citation counts. Citation may be used by an author, to refer to another person's ideas while developing the author's own understanding or to help others to locate related work.[48]. It relates the document being cited with the citing document. The act of citation gives significance to the material being cited.[19,20] Citation count therefore reassures the scientific activity, utility, and influence of scientific work.[49]

Authorship / Co-authorship data

The data for this analysis is downloaded from ISI WoS records from 1969 to 2010 (excluding a one year gap in 1972). Of 1491 records, 31 editorials were excluded, since the editor is already known as an influential person and the aim is to bring out the most contributing authors of research publications. This left 1400 articles, 18 notes, 18 proceeding papers, 14 letters, 3 addenda, 2 software reviews and 1 reprint.

Analysis and discussion

The author field was extracted from ISI and analysed. The resulting Fig. 6 is a pictorial illustration of authorship patterns within *IJEEE*. The loops in the graph are indicators of single author articles. The darker this loop becomes the higher is the count of single author publication. The thick black circles around the boundary are vertices; their diameter is an indicator of the combined degree (in-degree and

TABLE 7 *Impact factor overview between the periods of 1998–2009*

Source	Period											
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
IEEE T EDUC	0.226	0.313	0.303	0.214	0.454	0.426	0.526	0.644	0.362	0.815	1.4	0.822
INT J ELEC ENG EDUC	0.052	0.103	0.065	0.075	0.031	0.098	0.089	0.069	0.047	0.125	0.118	0.106
J PROF ISS ENG ED PR	0.031	0.061	0.333	0.210	0.254	0.134	0.094	0.202	0.090	0.181	0.161	0.133
COMPUT APPL ENG EDUC	–	0.138	0.104	0.167	0.14	0.395	0.205	0.094	0.218	0.31	0.388	0.203
INT J TECHNOL DES ED	–	–	–	–	0.300	0.533	0.276	0.062	0.235	0.281	0.429	0.286
INT J ENG EDUC	–	–	–	–	–	0.244	0.228	0.304	0.355	0.356	0.552	–
J ENG EDUC	–	–	–	–	–	–	–	–	1.515	3.000	1.093	2.317
Combined Average	**0.309**	**0.615**	**0.805**	**0.537**	**1.179**	**1.828**	**1.418**	**1.375**	**3.057**	**5.068**	**4.141**	**3.867**

Empty columns indicate unavailability of data for that year.

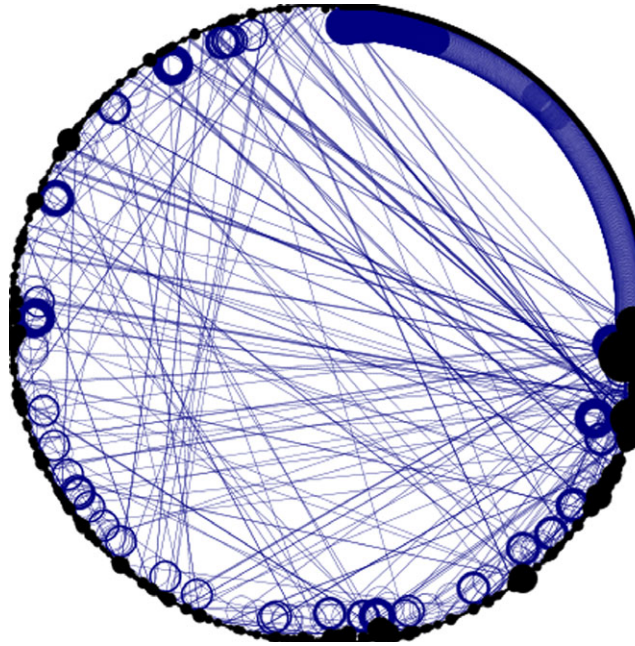

Fig. 6 *Authorship and co-authorship trends within* IJEEE.

out-degree) of that vertex. The straight lines joining vertices are edges and just like the loops: the darker these edges become the higher is the count of articles between these authors/vertices.

Since most of the edges are loops, single author articles dominate the trend. In the figure if a vertex is greater in size than other vertices it shows the scholarly pursuit of an author by being involved in more publications. The above figure brings out the fact that there has not been much work done in *IJEEE* between the same co-authors. An alternative way to look at this is through comparing the graphical distribution of authors for the single- and multi-author articles (Fig. 7).

As expected, some of the authors of the single author network also do collaborate with each other, the count of these collaborating authors within this network is found to be 344. Similarly, 119 of the authors of the multi-author network also have single author publications. The comparison of Figs 7(a) and 7(b) brings out the distribution which happens to be widely spread and with more nodes in the multi-author network than the single author network. From the node widths it can be brought out that most of the authors of the single-author network have more publications per author in contrast to the multi-author network.

When a further analysis into authorship patterns of *IJEEE* is made it is found that out of the total 1859 authors, 795 authors (about 42.76%) have single author publications. The top 10 authors and their corresponding count of single author publications are presented in Table 8.

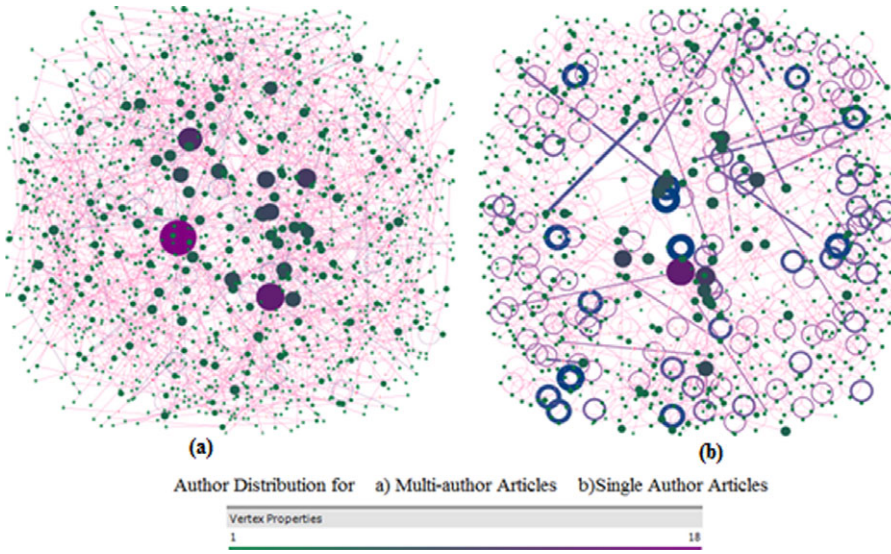

Fig. 7 *Authorship pattern for single and multi author articles.*

TABLE 8 *Top 10 contributing authors to* IJEEE *(based on single author article trends)*

Author name	Article count
Indulkar, CS	7
Chan, TF	7
Watson, DB	7
Okelly, D	6
Cheung, WN	6
Rajaraman, KC	6
Hartley, MG	6
Ho, CF	5
Hart, BL	5
Walker, AJ	5
Asamoah, F	5
Hobson, GS	5
Wilson, B	5

Next a similar analysis for the co-authorship patterns in *IJEEE* is made. It is found that out of 1859 authors, 1410 have co-authored articles. The counts of the maximum collaborative work for the top 10 authors range from 3–6 articles. The top authors, their corresponding co-authors and combined publication count are presented in Table 9.

To gain further insight of the top contributing authors the authorship pattern of top ten authors from Tables 8 and 9 is plotted in Fig. 8. Information in the figure

TABLE 9 *Top collaborating authors in* IJEEE

First Author Names	Co-Authors	Count
Chatzarakis, GE	Tortoreli, MD/Cottis, PG	6/4
Terrell, TJ	Simpson, RJ	4
Mullineu. N	Reed, JR	4
Mukerji, SK	Goel, SK	4
Carter, G	Lee, LS	4
Arlett, PL	Vasudeva, KS	3
Martinez, PA	Pollan, T	3
Perahia, J	Nayar, CV	3
Jahmeerbacus, MI	Soyjaudah, KMS	3
Indulkar, CS	Ramalingam, K	3
James, C	Hub, DR	3
Mukerji, SK	Basu, KP	3
Walczowski, LT	Waller, WAJ	3
Ipson,SS	Booth, W	3
Warner, G	Anderson, R	3
Moreno, L	Sanchez, JL / Acosta, L	3/3

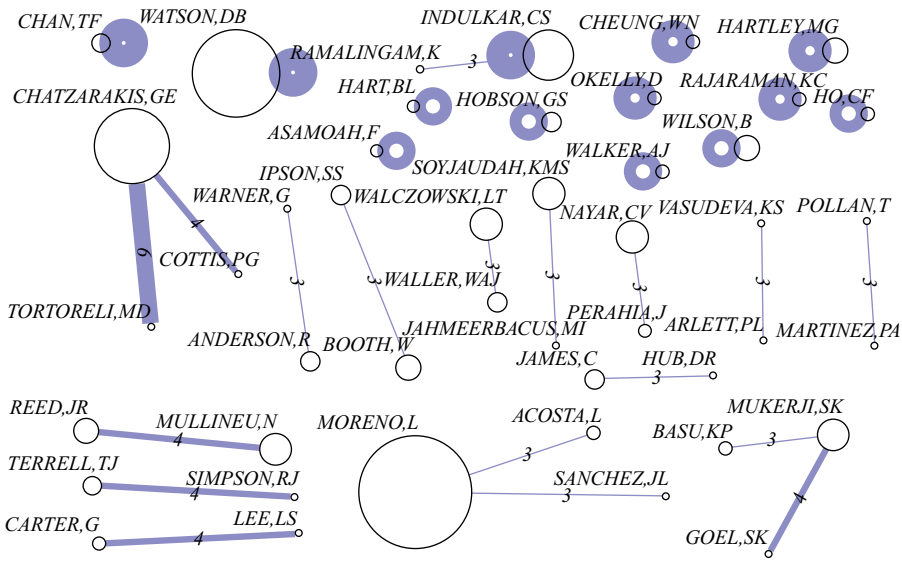

Fig. 8 *Authorship pattern for top authors of single- and multi-author articles.*

can be explained by: 1) the thick/wider blue circles that are representatives of the single author articles. The thicker the circle gets the higher is the count of such single authored articles. 2) the thin black circles of varying diameter, these are representatives of the degree of a vertex (author). Remember that, in this context degree of an author represents the count of collaboration with distinct researchers. The diameter

of this circle increases with the count of such collaborating persons. 3) the straight line (edges) which carries a weight is representative of the count of articles between two authors. They also have a varying widths based on this count.

The authors of single-author articles are shown at the top of Fig. 8. Only Indulkar out of the top ten authors of single-author articles is making a collaboration with an author from the top ten multi-author articles. For the multi-author articles, it is apparent that in the top ten list, 87.5% of the time, authors collaborate with just one other author. Out of the combined top ten list Moreno,Watson, and Chatzarakis have the highest degress respectively; which is an indicator that these authors not only have a good count of articles but also they bring a diverse group of researchers. The number on the edges is an indicator of articles between two authors. The highest count of publication is found between Chatzarakis and Tortoreli, which is in agreement with Table 9. From Fig. 8 we can also say that there is need to encourage the publishing authors of *IJEEE* for more publications so that the authorship and co-authorship network may grow. Similarly, efforts need to be made so that the existing co-authorship network grows stronger.

Citation count data

The same data was used as for the authorship data, again excluding 31 editorials.

Analysis and discussion

Figure 9 represents the citation patterns made to articles in *IJEEE*. Since 70.5% of all articles (other than editorials) published in *IJEEE* did not receive any citation, it raises the question of the stability of the journal. But since some of the articles have been cited ten or more times and some have not been cited at all; it makes sense to compute the weighted average for citations per article. This average turns out to be 0.635 citations per article (i.e., 927/1460) which is fairly reasonable and justifies

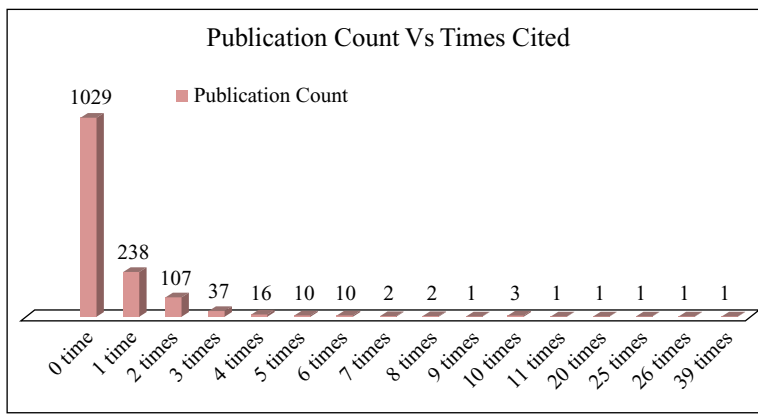

Fig. 9 *Citation pattern based on publication counts.*

TABLE 10 *Highly cited articles of* IJEEE

Title	Authors	Times cited
Numerical laplace transformation and inversion	Wilcox, DJ	39
Application of fast fourier-transform to electrical transient phenomena	Ametani, A	26
Filling the gap between the bilinear and the backward-difference transforms: An interactive design approach	AlAlaoui, MA	25
A single-phase self-excited induction generator for lighting loads in remote areas	Singh, B; Saxena, RB; Murthy, SS; Singh, BP	20
Autonomous and parallel operation of self-excited induction generators	Watson, DB; Milner, IP	11
The role of laboratory work in engineering education: student and staff perceptions	Edward, NS	10
New undergraduate laboratory experiments on induction generators	Banerjee, S	10
Application-oriented ray theory	Censor, D	10
Analog current mode circuits	Wilson, B	9
Experiments on a dc-motor based system for a digital-control course	Moreno, L; Acosta, L; Mendez, JA; Hamilton, A; Pineiro, J; Merino, JJ; Sanchez, JL; Aguilar, RM	8
Investigation of electrical breakdown in air using an image-processing technique	Watson, DB; Barber, MI; Samuels, KA	8

this journal maintaining its good rank. However, necessary measures are needed to encourage the readership. It is also interesting to note that the articles that did not receive any citation, span from the year 1969 to 2010. In earlier publications i.e., in the first six years of the journal, all of its articles have been cited. From Fig. 9 the top ten articles are those that have been cited eight or more times. These are listed in Table 10.

Interestingly, five authors with highly cited articles are also found in common with the previous top ten author lists (which includes single-author as well as multi-author articles). These authors are Watson, Wilson, Moreno, Acosta and Sanchez. Two articles by Watson have been highly cited. Wilson is among the top ten authors for single author articles and also his single author publication is among the top ten articles. Similarly, Moreno, Acosta and Sanchez are among the top ten multi-author articles (based on their collaboration counts) and they also have co-authored articles in the top ten highly cited articles.

Publication count data

The same data was used as for the authorship data, again excluding 31 editorials.

Analysis and discussion

Table 11 presents the top ten author list based on absolute count of publications. It is apparent that some of the authors from top ten list of single-author publication,

TABLE 11 *Authors with highest publication counts*

Authors	Publication count
WATSON DB	15
INDULKAR CS	14
CHATZARAKIS GE	9
HOBSON L	9
HARTLEY MG	8
CHAN TF	8
WILSON B	7
MORENO E	7
MORENO L	7
NAYAR CV	7
REED JR	7

multi-author publication and highly cited article lists are found in this table. It highlights an interesting fact about *IJEEE* that influential authors keep appearing in one form or another. These analyses will help the journal to encourage influential authors for more publications. Collaboration among influential authors based on their interests would increase the productivity of the journal.

Conclusions and limitations

This article has introduced the reader to *IJEEE* and tried to answer various questions pertaining to the citation pattern of this journal. Keyword distribution and the journal impact factor have been studied and an effort has also been made to see the authorship pattern and the authors contributing most. This article is the first attempt at such an analysis of *IJEEE* and not all the analysis could be included due to space limitations.

Analysis of the citation patterns of the venues citing from *IJEEE* indicates that a major source of citations to *IJEEE* is self citation, with a count of 89 (about 17%). Later, the citing venues were classified into research areas such as 'EE & ECE', 'other technical', 'combined technical/education' etc. The citation patterns based on such classification helped to reveal the influence of *IJEEE* on various communities. It can be concluded that *IJEEE* is both bringing out new research in the field of electrical engineering and also improving the field of electrical engineering education (EEE) and engineering education in general.[29,33] Analysis of the venues being cited in *IJEEE* articles indicated that the highest citations are from within IEEE T EDUC followed by *IJEEE* itself. It was also found that the authors publishing in *IJEEE* mostly cite from other journals and only a small percentage refer to conferences etc. The most frequently cited research area within *IJEEE* is 'EE & ECE' followed by 'engineering education'. Based on the citations made to *IJEEE* and citations made within *IJEEE*, it can be concluded that the *IJEEE* community not only gets informed by engineering education but also informs this community; which is one of the motivations needed to drive the field of engineering education.[50,51]

Furthermore, it was found that the count of citations made to EE & ECE (20.86%) along with 'LE' and 'engineering education' (10.56%) shows a closeness in these percentages, justifying *IJEEE*'s objective to be: 'a forum for the exchange of ideas and innovations in the teaching of electrical engineering and electronics at university level'.[33]

Keyword analysis was conducted to see the trends and themes being followed. The tag cloud based on the abstracts of the articles reveals that *IJEEE* has educational as well as technical contributions. Temporal evolution and distribution of keywords indicated that some keywords – control, teaching, experiments – were decreasing in their usage, while others – power, laboratory, study, university – increased. Some keywords – students, design, system – have retained their rank over years. An analysis of word co-occurrence for some of the top keywords suggested that the main context in which the keywords 'university' and 'undergraduate' have been used was nearly the same i.e., design, development, student learning and teaching, university studies and education, undergraduate project and experimentation etc. Other such interpretations could also be made.

Based on authorship and citation pattern criteria, it was found that the single author pattern is quite prominent within this community, amounting to 42.17% of the total authorship. Also, there has not been much work between the same co-authors. Only one author pair has appeared in six articles together and the remaining author pairs have four or fewer co-authored articles. When the single author community within *IJEEE* was compared with the multi-author community, it was found that the node (author) count was higher in the multi-author community. As expected, it was found that some authors of the single-author community also do collaborate with each other and vice-versa for multi-author community.

When the IF of *IJEEE* was compared against other such venues, it was found that the overall IF was increasing, possibly due to a more general expansion in engineering education research (EER). Although 70% of *IJEEE* articles have not been cited, on average there have been 0.635 citations per article made within this journal. Based on the collaboration patterns within *IJEEE*, the authors concluded that there is a need to encourage the contributing authors of *IJEEE* for more publications so that the authorship/co-authorship network may grow. Similarly, efforts are needed to strengthen the existing co-authorship network. An interesting fact was observed when the main contributors based on various authorship criteria were compared against each other: the influential authors keep appearing in one form or another. Influential authors thus could establish collaborations since they share nearly the same interests. Furthermore, this analysis will help the journal to further encourage the main contributors.

Like other studies, this study has some caveats. First, the current trends in the field of citation analysis are due to the data availability from Science Citation Index (SCI) by the Institute for Scientific Information (ISI).[3] It is one of the limitations of SCI that although it is the biggest database it does not cover all the scientific and technical venues.[19] The un-indexed venues are mentioned cumulatively in SCI under the heading 'All Others' and no information even to the names or counts of these venues was thus accessible. Secondly, some 5–10% of citations appear to be

erroneous.[52,53] Thirdly, the high citation of an article could be due to various reasons, some substantive but others dubious. So citation count can only provide approximate proxy for scientific quality.[10] Fourthly, data taken from Journal Citation Reports (JCR), only covers the periods from 1998–2009. Lastly, while doing the keyword analysis, not all articles had the abstract or the keyword field in them. Therefore, the results may be skewed to some extent.

Tools

The analysis tools that have been used in the article include Hermetic Word Frequency Counter, Tag Crowd and IBM's Many Eyes for the keyword analysis. NodeXL was used for the authorship and co-authorship network. Sci^2 tool was used to conduct the word co-occurrence analysis.

Future work and implications

The interested reader may explore questions such as: What are the factors controlling the co-authorship network? How does this network change over years? Can research themes be associated with authorship/co-authorship? How does the temporal analysis of keyword co-occurrence help in predicting the journal themes and trends?

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References

1 M. A. Andrade and A. Valencia, 'Automatic extraction of keywords from scientific text: application to the knowledge domain of protein families', *Bioinformatics,* **14** (1998), 7.
2 'The rise of retractions in science – more misconduct or stiffer scrutiny?' (2009), available at http://www.timeshighereducation.co.uk/story.asp?storycode=407826, last accessed November 2010.
3 G. Pinski and F. Narin, 'Citation influence for journal aggregates of scientific publications: Theory, with application to the literature of physics', *Information Processing & Management,* **12** (1976), 297–312.
4 H. F. Moed, 'New developments in the use of citation analysis in research evaluation', *Archivum immunologiae et therapiae experimentalis,* **57** (2009), 13–18.
5 E. Garfield, 'The use of journal impact factors and citation analysis for evaluation of science', 41st Annual Meeting of the Council of Biology Editors, Salt Lake City, UT. 1998.
6 E. Garfield, 'Citation analysis as a tool in journal evaluation', American Association for the Advancement of Science, 1972.
7 H. Cason and M. Lubotsky, 'The influence and dependence of psychological journals on each other', *Psychol. Bull.,* **33** (1936), 95–103.
8 Institute for Scientific Information, 'The application of citation indexing to journals management' (1994), available at http://thomsonreuters.com/products_services/science/free/essays/application_of_citation_indexing/, last accessed June 30, 2012.

9 M. E. D. Koenig, 'Citation analysis for the Arts and Humanities as a collection management tool', *Collection Management,* **2** (1978), 247–264.
10 S. Redner, 'Citation statistics from 110 years of Physical Review', *Physics Today,* 58 (2005), 49–54.
11 D. Crane, *Invisible Colleges: Diffusion of knowledge in scientific communities* (University of Chicago Press, Chicago, 1972).
12 F. Narin, *Evaluative bibliometrics: The use of publication and citation analysis in the evaluation of scientific activity* (Computer Horizons, Washington, DC, 1976).
13 S. Eom, *Author cocitation analysis: quantitative methods for mapping the intellectual structure of an academic discipline*, Information Science Reference-Imprint of: IGI Publishing, 2008.
14 S. B. Eom, 'Ranking institutional contributions to decision support systems research: a citation analysis', *Database,* **25** (1994), 35–42.
15 S. B. Eom and S. M. Lee, 'Leading universities and most influential contributors in DSS research: a citation analysis', *Decision Support Syst.,* **9** (1993), 237–244.
16 L. C. Smith, 'Citation analysis', *Library Trends,* **30** (1981), 83–106.
17 R. N. Kostoff, 'The use and misuse of citation analysis in research evaluation', *Scientometrics,* **43**(1998), 27–43.
18 E. Garfield, 'Citation indexes for science: a new dimension in documentation through association of ideas', *Science,* **122** (1955), 108–111.
19 E. Garfield, 'Citation analysis as a tool in journal evaluation', *Science*, **178** (1972), 471–479.
20 E. Garfield, 'Journal citation studies.33. Botany Journals, Part 1: What they cite and what cite them', *Current Content,* **31** (1980), 5–12.
21 E. Garfield, 'The history and meaning of the journal Impact Factor', *J. Amer. Med. Assoc.,* **295** (2006), 90–93, January 4, 2006.
22 K. E. Rosengren, *Sociological aspects of the literary system*, *Natur och kultur*, **4** (1968).
23 K. E. Rosengren, 'Who carries the field? Communications between literary scholars and critics', in C. L. Borgman (Ed.) *Scholarly Communication and Bibliometrics*, (Sage, Newbury Park, CA, 1990), pp.107–128.
24 D. R. Baker, 'Citation analysis: A methodological review', *Social Work Research and Abstracts,* **26** (1990), 29–55.
25 H. F. Moed, *Citation Analysis in Research Evaluation*, Vol. 9 (Kluwer, Amsterdam, 2005).
26 A. Prichard, 'Statistical bibliography or bibliometrics?', *J. Documentation,* **25** (1969), 348–349.
27 C. J. Wilson *et al.*, (2009) 'Using social network analysis to advance traditional qualitative methods in evaluation and program design' Opinion Dynamics Corporation, available at: http://comm.eval.org/snaTIG/TIGResources/References, last accessed 22 April 2013.
28 R. A. Hanneman and M. Riddle, *Introduction to Social Network Methods* (University of California, Riverside, CA, 2005).
29 M. G. Hartley, 'A publication celebrates it half century 1948–1998: A brief account of 50 years of the Bulletin of Electrical Engineering Education Laboratory Practice and the International Journal of Electrical Engineering Education', *Int. J. Elect. Enging Educ.,* **35**(4) (1998), 293–302.
30 M. G. Hartley, 'The International Journal of Electrical Engineering Education celebrates its quarter century', *Int. J. Elect. Enging Educ*., **25**(3) (1988), 197–208.
31 E. Bradshaw, 'Electrical engineering laboratory practice', *J. Vocational Education & Training,* **1** (1948), 92.
32 K. L. Johnson, 'A bulletin of mechanical engineering education', *J. Vocational Education & Training,* **3** (1951), 173–174.
33 Available at http://www.manchesteruniversitypress.co.uk/journals/journal.asp?id=11, last accessed 22 January 2011.
34 J. Neill, Qualitative versus quantitative research: key points in a classic debate (2007). Available at http://wilderdom.com/research/QualitativeVersusQuantitativeResearch.html (last accessed 6 April 2011).
35 Tag cloud. *Wikipedia*. Available at http://en.wikipedia.org/wiki/Tag_cloud (last accessed 11 July 2012).
36 I. Dagan, *et al.*, 'Keyword-based browsing and analysis of large document sets', Proceedings of the symposium on document analysis and information retrieval (SDAIR-96), Las Vegas, Nevada, (1996).

37 T. D. Gedeon and L. T. Koczy, 'Hierarchical co-occurence relations', *in Proc. IEEE International Conference on System Man and Cybernetics (SMC'98), session: Data Analysis & Information Science,* San Diego, 1998, Vol. 3(IEEE, Piscataway, NJ, 1998), pp.2750–2755.
38 Sci2 Team. (2009), Science of Science (Sci2) Tool. Available at http://sci2.cns.iu.edu
39 'The Thomson Reuters Impact Factor', Available at: http://thomsonreuters.com/products_services/science/free/essays/impact_factor/ (last accessed 17 January 2011).
40 P. O. Seglen, 'Why the impact factor of journals should not be used for evaluating research', *British Medical J.,* **314** (1997), 498–502.
41 A. D., 'The counting house', *Nature,* **415** (2002), 726–729.
42 C.-L. Chang *et al.* 'Journal Impact Factor Versus Eigenfactor and Article Influence' (2010). Available at http://publishing.eur.nl/ir/repub/asset/21725/EI2010-67.pdf (last accessed 17 January 2011).
43 J. Bollen *et al.*, *Scientometrics,* **69** (2006), 669–687.
44 R. Rousseau and the Stimulate 8 Group, 'On the relation between the WoS impact factor, the Eigenfactor, the SCImago Journal Rank, the Article Influence Score and the journal h-index', 2009, available at: http://eprints.rclis.org/13304/1/Rousseau_Nanjing_conference_contribution.pdf.
45 G. Semenzato *et al.*, 'Impact Factor as measure of scientific quality', *Amer. J. Respiratory Critical Care Med.,* **169** (2004), 1070–1071.
46 K. Haghighi, 'Quiet no longer: birth of a new discipline', *J. Eng. Educ.,* **94** (2005), 351–353.
47 R. A. Streveler and K. A. Smith, 'Guest editorial: conducting rigorous research in engineering education', *J. Eng. Educ.,* **95** (2006), 3.
48 J. Martin *et al.*, 'Who listens to whom? A citation analysis of recent papers on engineering design education', in *Proc. of the American Society of Engineering Education 2002, Annual Conference*, Montreal, Canada, Session 2325, 2002, pp. 1737–1745.
49 P. N. Mishra*, et al.*, 'Citation analysis and research impact of National Metallurgical Laboratory, India during 1972–2007: a case study', *Malaysian Journal of Library & Information Science,* **15** (2010), 91–113.
50 Special Report, 'The research agenda for the new discipline of engineering education', *J. Eng. Educ.,* **95** (2006), 259–261.
51 R. A. Streveler and K. A. Smith, 'Conducting rigorous research in engineering education', *J. Eng. Educ.,* **95** (2006), 103–105.
52 H. F. Moed, 'Towards a critical, informative, accurate and policy relevant bibliometrics', *Nature,* **415** (2002), 731–732.
53 S. Redner, available at http://arxiv.org/abs/phy8ics/0407137vl, last accessed 22 January 2011.

Appendix A

Journal abbreviations

BRIT J EDUC PSYCHOL	BRITISH JOURNAL OF EDUCATIONAL PSYCHOLOGY
COMPUT APPL ENG EDUC	COMPUTER APPLICATIONS IN ENGINEERING EDUCATION
ENG SCI EDUC J	ENGINEERING SCIENCE AND EDUCATION JOURNAL
ELECTR POW SYST RES	ELECTRIC POWER SYSTEMS RESEARCH
ELECTRON LETT	ELECTRONICS LETTERS
IEE P-GENER TRANSM D	IEE PROCEEDINGS-GENERATION TRANSMISSION AND DISTRIBUTION
IEE P-CIRC DEV SYST	IEE PROCEEDINGS-CIRCUITS DEVICES AND SYSTEMS
IEEE CONTR SYST MAG	IEEE CONTROL SYSTEMS MAGAZINE
IEEE T EDUC	IEEE TRANSACTIONS ON EDUCATION
IEEE T POWER SYST	IEEE TRANSACTIONS ON POWER SYSTEMS
IEEE T POWER DELIVER	IEEE TRANSACTIONS ON POWER DELIVERY
IEEE T POWER AP SYST	IEEE TRANSACTIONS ON POWER APPARATUS AND SYSTEMS
IEEE T IND APPL	IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS
IEEE T ENERGY CONVER	IEEE TRANSACTIONS ON ENERGY CONVERSION

IEEE T IND ELECTRON	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS
INT J ENG EDUC	INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION
INT J ELEC POWER	INTERNATIONAL JOURNAL OF ELECTRICAL POWER & ENERGY SYSTEMS
INT J ELEC ENG EDUC	INTERNATIONAL JOURNAL OF ELECTRICAL ENGINEERING EDUCATION
INT J TECHNOL DES ED	INTERNATIONAL JOURNAL OF TECHNOLOGY AND DESIGN EDUCATION
J SCI EDUC TECHNOL	JOURNAL OF ECIENCE EDUCATION AND TECHNOLOGY
J PROF ISS ENG ED PR	JOURNAL OF PROFESSIONAL ISSUES IN ENGINEERING EDUCATION AND PRACTICE
J ENG EDUC	JOURNAL OF ENGINEERING EDUCATION
P I ELECTR ENG	PROCEEDINGS OF THE INSTITUTION OF ELECTRICAL ENGINEERS-LONDON
STUD SCI EDUC	STUDIES IN SCIENCE EDUCATION

Appendix B

Impact factor

Garfield first came up with the idea of an impact factor in 1955.[18] According to Garfield[21] the idea of impact factor (IF) allows the smaller journals (i.e., the journals with lesser publication count) to be included in the list of significant journals; the smaller journals would never have been selected if publication count was the only factor considered to see the importance of a journal. The IF of a journal is an indicator of the frequency with which average article in a journal gets cited in a given year.[39] A journal's IF depends on two factors:

Numerator = No. of citations in current year to items published in the previous 2 years
Denominator = No. of articles published in the same 2 years e.g.

$$2011\ \text{IF} = \frac{(\text{total citations in 2011 to the articles published in 2009 and 2010})}{(\text{total articles published in 2009 and 2010})}$$

According to Garfield[21] the IF could be taken for longer periods of time but taking them over a 2 year span allows more weight to the rapidly changing fields. Similarly, IF could solely be based on previous year's articles, it would give even higher weight to rapidly changing fields than the two years IF.