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The 100 Most Cited Papers in "Industrial Design": A Bibliometric Analysis

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Abstract

This paper highlights the underlying factors that define the success of industrial design literature which can be measured through citation characteristics. In this regards, the study aims at identifying and analysing the characteristics of top-cited papers published in the Web of Science with the topic of "Industrial Design" from 1980 to 2014. The results showed that the top five papers, received 896 citations which were published between 2002 to 2006 and obtained 278 (31.02%) citations. The top five keywords were extracted from the abstracts of top-cited papers. Besides, the name of top journals was Design Studies, International Journal of Industrial Ergonomics and International Journal of Design. "Industrial Design" is proposed as a new web of science categories.

Keywords: Highly cited, Product Design, evaluation, Industrial Design, interdisciplinary

Introduction

Specific parameters have long been established amongst Industrial designers, these include usability, ergonomics, functionality and aesthetics in designing a product. Industrial design has an integrated approach with art, science and business through ideologies, practices, shapes and patterns. Industrial Design is made up of various categories including product design, interior design, transporter design, environmental design, service design, whereby various methods and strategies within these fields have been established. Industrial designers need to work with various expertise such as engineers, material scientists, sociologists, psychologists, and marketing experts (Tovey, 1997). Industrial design involves the development of products to suit the mass market (Dorst, 1993). There are a series of creative activities that define the official qualities for industries in their production (Black, 1983). Industrial designers interpret and transmit their ideas and visions to environment through their designs (Kazmierczak, 2003).

The term of Bibliometric is defined as the application of mathematical and statistical methods to papers, books and other means of communication which are used in the analysis of science publications (Repanovici, 2010). To recognize the research trends, bibliometric methods are usually used to evaluate scientific manuscripts (Li, Ding, Feng, Wang, & Ho, 2009; Zitt & Bassecoulard, 1994). Bibliometric methods have been used to measure scientific progress in many disciplines of science and engineering, and are a common research instruments for systematic analysis of publications (Ale Ebrahim, Salehi, Embi, Habibi, et al., 2014; Budd, 1988; Cañas-Guerrero, Mazarrón, Calleja-Perucho, & Pou-Merina, 2014; Cañas-Guerrero, Mazarrón, Pou-Merina, Calleja-Perucho,

& Suárez-Tejero, 2013; Jacobs & Ingwersen, 2000). In this research, the bibliometric analysis is employed in the field of "Industrial Design". A peer-based evaluation procedure is implemented in the abstract of top-cited papers.

Every year many publications are released by researchers about "Industrial Design" subjects. Highly cited papers have a greater chance of visibility and thus attract greater attention amongst researchers (Wohlin, 2005). Evaluating the top cited publications content is very useful to get information about the trends of specific fields in perspective of research progress (Fardi, Kodonas, Gogos, & Economides, 2011) How does this sentence add value? It is useful for the reader? It can be revealed for researchers that how they can find the best field or best journal to succeed in their publication- need to be rephrases but not sure what you are trying to say. Although, the citation is not a scientific tool to assess the publication, it is a valuable metric that recognizes research parameters (Shadgan, Roig, HajGhanbari, & Reid, 2010). Citation index as a type of bibliometric method shows that the number of times an article has been used by other papers (Fooladi et al., 2013). Citation analysis helps researchers to get a preliminary idea of the articles and research that make an impact in a field of interest (Ale Ebrahim, Salehi, Embi, Bakhtiyari, et al., 2014). Nevertheless, there is no citation and bibliometric analysis published on "Industrial Design" literature. The influence and contribution of publication needs to be evaluated to display the research trends in a specific research area.

The evaluation of reviewed papers and obtained information like keywords, categories and research areas can help institutions to find suitable area for funding research. The collaboration amongst researchers have allowed for prominent themes within "Industrial Design" to establish itself and influence the future of "Industrial Design". Therefore, this research aimed to identify and analyse bibliometric data of top-cited papers that were published in the Web of Science from 1980 to 2014 with the topic of "Industrial Design".

1. Methodology

This study evaluates "Industrial Design" research that was published in the Institutes for Scientific Information (ISI). Among examining publication distribution and other information that will be discussed, the statistical characteristics of "Industrial Design" research will be defined. In addition, the pattern of publication such as the author's country, author's institute, web of science categories and research areas that are used will be analysed. Finally, it will evaluate information associated with the author's keywords, abstract analysis, and trends in "Industrial Design" during 1980 – 2014. The purpose of this research is to highlight the key information that is used amongst researchers as a grounding when gaining insight into Industrial Design literature.

The information obtained from the online platform of Thomson Reuters Web of Science on 20th July 2014 was used in this article. To recognize "Industrial Design" related research, documents were found using the keyword "Industrial Design" in the topic (it means that at least one of the titles, abstract, author keywords found should contain the

phrase "Industrial Design"). As "industrial Design" doesn't have a specific category within the ISI subject area, this means that searching for specific "Industrial Design' articles can be a timely process for end users and they will have to filter through an extensive number of articles that are dispersed amongst several categories. Hence, the user interface of ISI is not tailored for those authors attempting to gain specific content related to "Industrial Design" only. It was found that in many cases the articles analysed within the field of "Industrial Design" could be found in unrelated fields such as computer science, material science and even within social sciences such as cultural, business and marketing related topics. In the first step of the methodology, "Industrial Design" was searched in the online database of web of knowledge. In this step, 1899 publications were revelled, thus highlighting that the search engine needed to be refined. By refining the web of science categories and excluding unrelated research areas 833 publications were explored by searching "Industrial Design" through the "Topic" search tool (Figure 1).


Figure 1: Methodology

All the information reported from web of science that contains the author's name, author's address, publication's title, publication year, journal's name, author's keywords, number of citations, web of science categories and research areas were downloaded into a Microsoft Excel format file. A key metric used when assessing the popularity of an article is reflected with the Impact Factor (IF). The IF assesses the average number of citations received per article, allowing a measure from low to high popularity to be calculated from this measure (Dong, Loh, & Mondry, 2005). Also from the 2014 Journal Citation Report (JCR), an analysis of the impact factor (IF) related to each journal. At first, by the records that were obtained from the downloaded report of the search, all the publications were sorted by number of citations per year and top 100 publications were selected through this method. For the selected 100 top cited articles, it was necessary that these were all related to "Industrial Design" with the abstract. Publications include both single type authors and collaborated type authors whereby several authors work together to produce an article. In the publication, the first author is someone who involved preparing and writing the document more than the other authors (Gaeta, 1999). Each publication also displays the different countries where an author is from and would be categorised as an international collaborative publication (Chiu & Ho, 2005).

2. Results

In total, 833 publications were published between 1980 and 2014 about "Industrial Design". The number of articles fluctuated between 1 to 15 from 1989 to 2013 in which there is an increase in the number of articles published per year (Figure 2). The most frequent type of publication involves Articles with 81%, it's followed by Proceeding Paper with 16% then Book, Book Chapter and Editorial Material comes with 1%.
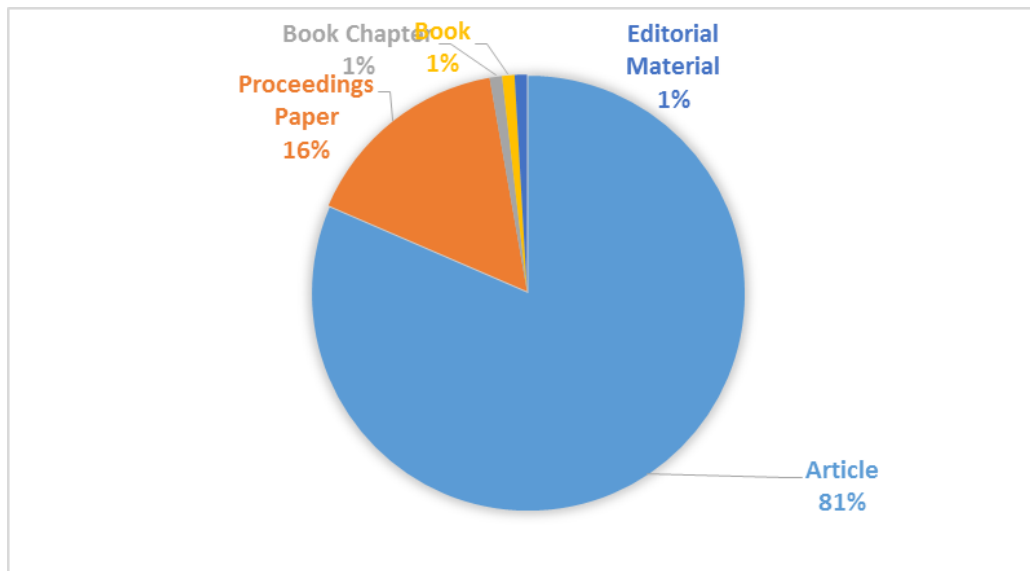
Figure 2: Publications type

The number of publications in the last 34 years are shown in Figure 3 which highlights the 100 top cited articles. The number of documents increased from one document in 1989 to 15 in 2011. However, it shows a reduction in 2008 (8 publications) and 2009 (7 publications). It also shows the total distribution of citations in a year. This amount fluctuated between 2 citations in 2013 and 214 citations in 2004. The total citation in 2004 belongs to 7 publications in which 3 of them are in the 100 top 10 cited. Additionally, the first two highly cited publications received a total of 73 and 68 citations during 2004 (Table 1).
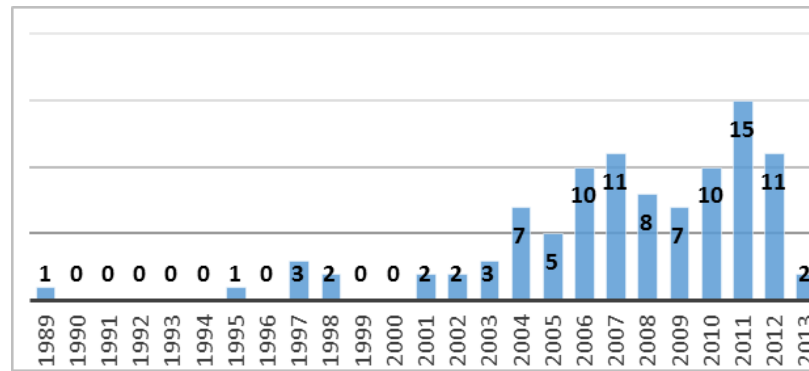
Figure 3: Number of Publications per year

Table 1: Number of Publication per year and Total Citation

Year	Number of publications	%	Total year citation	%
1989	1	1	39	4.35
1995	1	1	16	1.79
1997	3	3	55	6.14
1998	2	2	18	2.01
2001	2	2	14	1.56
2002	2	2	48	5.36
2003	3	3	21	2.34
2004	7	7	214	23.88
2005	5	5	96	10.71
2006	10	10	108	12.05
2007	11	11	74	8.26
2008	8	8	35	3.91
2009	7	7	29	3.24
2010	10	10	62	6.92
2011	15	15	36	4.02
2012	11	11	29	3.24
2013	2	2	2	0.22

Table 2 and Table 3 displays the top 18 most active authors from 1980 to 2014 (total publication >1) that positioned their publication in the 100 top cited articles. The 100 documents had 208 authors. Petiot, JF with 2 publications and 77 citations, is followed by Hsiao, SW with 74 and 2 publications. After him are Cagan, J, McCormack, JP and Vogel, CM with one publication and 73 citations. The next is Yannou, B with the one publication and 68 citations. Finally, McDonagh, D has 3 publications obtaining 57 citations and Tsai, HC with one publication in 100 top cited in which was cited 29 times.

Table 2: Most Active Authors in relation to Total Citation

Author	Total publication	Total citation				
Petiot, JF	2	77	68	9		
Hsiao, SW	2	74	55	19		
Cagan, J	1	73	73			
McCormack, JP	1	73	73			
Vogel, CM	1	73	73			
Yannou, B	1	68	68			
McDonagh, D	3	57	41	12	4	
Tsai, HC	1	55	55			
Bruseberg, A	1	41	41			
Chen, W	1	41	41			
Haslam, C	1	41	41			
Liu, HB	1	41	41			
Sudjianto, A	1	41	41			
Nakada, K	1	40	40			
CHEN, SE	1	39	39			
PARENT, RE	1	39	39			
Betts, P	1	31	31			
Evans, MA	4	29	11	9	5	4

Table 3: Most Active Author in relation to Total Publication

Author	Total publication	total citation
Evans, MA	4	29
McDonagh, D	3	57
Sener, B	3	17
Chen, CH	3	16
Campbell, IR	3	18
Petiot, JF	2	77
Hsiao, SW	2	74
Pedgley, O	2	23
Crilly, N	2	21
Yang, MY	2	15
You, ML	2	15
Candi, M	2	13
Huang, YX	2	11
Khoo, LP	2	11
Goldschmidt, G	2	8
Pei, EJ	2	9

All these 100 top cited documents were published by 44 publishers and the 11 most active journals are displayed in Table 4. The top one is "Design Studies" with 20% of the 100 top cited measuring an average of 1.304 IF and after that comes "International Journal of Industrial Ergonomics" with 11% of publications averaging at 1.214 IF. The list was followed by "International Journal of Design" with 9% of all publications rating at 0.955 IF. Notably, there are many journals that did not relate to "Industrial Design" directly but were used by researchers for publishing because the subjects were multidisciplinary and can be related to other fields of study.

Table 4: Most Active Journal in relation to Total Publication

Journal	Total publication	Total Cites	Impact Factor
DESIGN STUDIES	20	1126	1.304
INTERNATIONAL JOURNAL OF INDUSTRIAL ERGONOMICS	11	1828	1.214
INTERNATIONAL JOURNAL OF DESIGN	9	124	0.955
JOURNAL OF ENGINEERING DESIGN	7	618	1.381
DESIGN JOURNAL	6		
APPLIED ERGONOMICS	3	2692	1.332
DESIGN ISSUES	3		
CODESIGN-INTERNATIONAL JOURNAL OF COCREATION IN DESIGN AND THE ARTS	2		
COMPUTERS IN INDUSTRY	2	1845	1.457
JOURNAL OF MECHANICAL DESIGN	2	3702	1.165
VISUAL COMPUTER	2	1094	1.073

Table 5 displays the distribution of the institutions that are placed in 100 top cited publication during 1980 until 2014. There are 144 institutions that published the document individually or in corporate with other institutes. The most active institutes with total documents are displayed in Table 5. Delft Univ Technol showed 6 publications and Middle E Tech Univ showed 5 top cited articles, followed by Loughborough Univ Technol, Natl Cheng Kung Univ and Univ Loughborough with 4. Natl Yunlin Univ Sci & Technol, Univ Cambridge and Univ Illinois have 3 publications; 14 publications are collaborated by 70 institutes. Loughborough Univ Technol had the most collaboration in publication with 4 (28.57%) publications; it is followed by Delft Univ Technol, Middle E Tech Univ, Natl Cheng Kung Univ, Univ Loughborough, Natl Yunlin Univ Sci & Technol and Univ Illinois with 2 (14.28%) collaboration.

Table 5: Most Active Institute regarding Total Publication

Row Labels	TP	TPR(%)	SP(%)	CP(%)	FP(%)
Delft Univ Technol	6	1(6)	4(4.65)	2(14.28)	5
Middle E Tech Univ	5	2(5)	3(3.48)	2(14.28)	4
Loughborough Univ Technol	4	3(4)	0	4(28.57)	1
Natl Cheng Kung Univ	4	3(4)	2(2.32)	2(14.28)	2
Univ Loughborough	4	3(4)	2(2.32)	2(14.28)	3
Natl Yunlin Univ Sci & Technol	3	6(3)	1(1.16)	2(14.28)	1
Univ Cambridge	3	6(3)	3(3.48)	0	3
Univ Illinois	3	6(3)	1(1.16)	2(14.28)	3

Table 6: Most Active Countries regarding Total Publication

Row Labels	TP	TPR(%)	SP(%)	CP(%)	FP(%)
England	19	1(19)	12(13.95)	7(50.00)	15(15)
USA	16	2(16)	11(12.79)	5(35.71)	13(13)
Taiwan	12	3(12)	9(10.47)	3(21.43)	10(10)
China	8	4(8)	6(6.98)	2(14.29)	7(7)
Turkey	8	4(8)	6(6.98)	2(14.29)	7(7)
Italy	7	6(7)	7(8.14)	0	7(7)
Netherlands	7	6(7)	5(5.81)	2(14.29)	6(6)
Australia	5	8(5)	2(2.33)	3(21.43)	2(2)
France	5	8(5)	5(5.81)	0	5(5)
Finland	3	10(3)	3(3.49)	0	3(3)
Japan	3	10(3)	3(3.49)	0	3(3)
South Korea	3	10(3)	2(2.33)	1(7.14)	3(3)

From 1980 to 2014, researchers from 25 countries published 100 top cited articles. Table 6 shows the countries with more than 3 publications in these 100. England topped the list with 19 publications, after that USA with 16, Taiwan (12), China (8), Turkey (8), Italy (7), Netherland (7), Australia (5), France (5), Finland (3), Japan (3) and South Korea (3). Likewise, the table displays the number of publications from a single country and publications that issued by collaboration of international countries. Most of the publications (86%) were issued by single country authors and the rest which totalled at 14 (14%) were issued by international collaboration. These 14 publications are cooperated by 12 countries. England with 7 publications and USA with 5 are on the top, followed by Australia and Taiwan with 3 and after that China, Netherland, Germany and

Turkey with 2 collaboration and at the end Iran, Hong Kong, South Korea and Israel with 1 collaboration. As it mentioned, England collaborated in 50% of international publication. It is followed by USA with 35.71% and Taiwan and Australia with 21.43%. Also England has 15% of first author of 100 top cited publications. USA with 13% comes after England and after that Taiwan is with 10%. China, Turkey and Italy has 7% of first author.

Figure 4 shows the research areas that are explored from exported data through the Web of Science online core collection. It shows us that Engineering is on the top with 69 publications and Art with 21 publications come after that. It is followed by Psychology, Computer Science and Materials Science with 6 publications. It displays the whole research areas that could be researched for "Industrial Design" documents.

The information that obtained from the online Web of Science shows all 100 top cited documents classified in 17 categories. **Error! Reference source not found.** displays the frequency of the categories. The top category is Engineering, Multidisciplinary with 39%, 'Engineering', 'Manufacturing' with 38% and in follow the other top categories including 'Art' and 'Engineering, Industrial' with 21% and 'Ergonomics' with 16%.
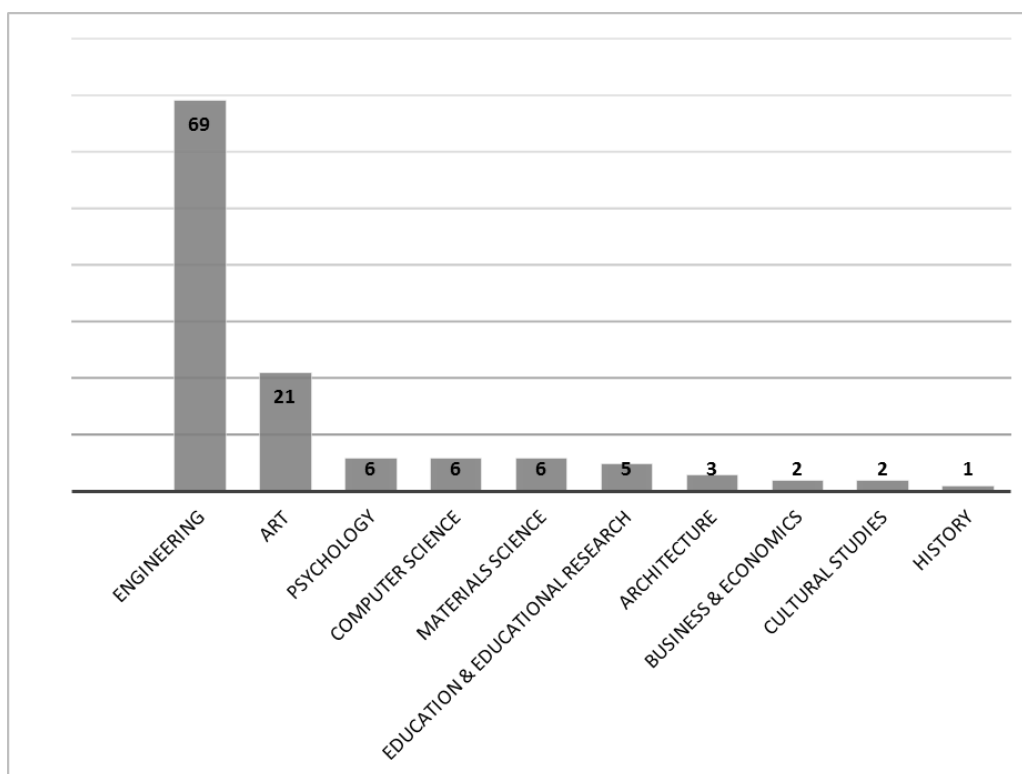
Figure 4: Web of Science Research Area
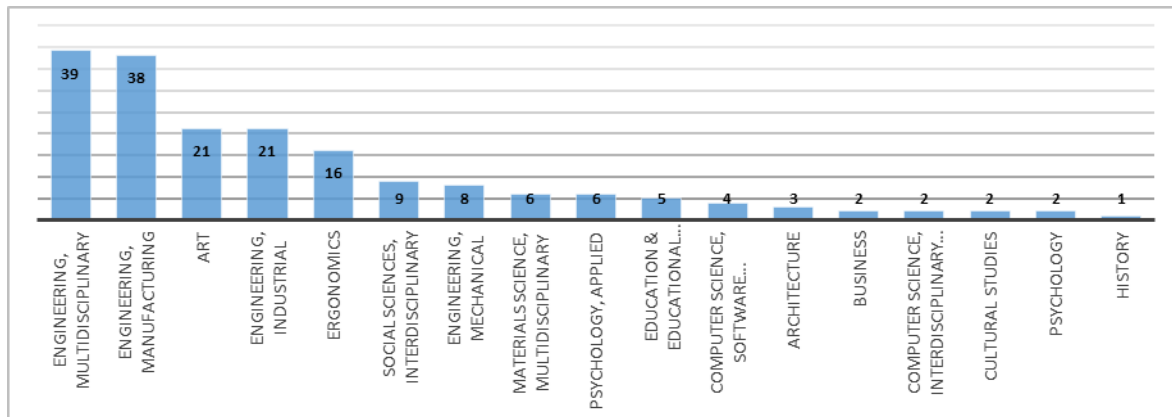
Figure 5: Web of Science Categories

The analysis of author keywords shows that 144 keywords are used for the 100 top cited publications from 1980 to 2014. The top keywords used, are displayed in Table 7 (more than 2 frequencies). The most frequent keywords include "Industrial Design" and 'Design' which are stated 30 times and after that 'Product Design' and 'Product' with 8. This is followed by 'Kansei' with 7, 'Modelling' with 6, '3D' and 'Aesthetics' with 5. As the keyword "Design" is very important for "Industrial Design" Table 8 shows the kind of "Design" and its sub categories.

Table 7: Author Keywords

Author Keyword	
Design	30
Industrial Design	30
Product Design	8
Product	8
Kansei	7
Modelling	6
3D	5
Aesthetics	5
Case Study	4
Collaboration	4
Computer-Aided Design	4
Innovation	4
Product Development	4
Creativity	3
Interaction Design	3

Table 8: Design Keyword

Design Keywords	
Industrial Design	30
Product Design	8
Design Education	6
Design Practice	5
Computer-Aided Design; Design Engineering	4
Design Activity; Emotional Design	2
Conceptual Design; Cultural Aspects Of Design; Design Approach; Design Cognition; Design Creativity; Design Decisions; Design Expertise; Design Guidelines; Design History; Design Issues; Design Leadership; Design Management; Design Method; Design Processes; Design Research; Design Science; Design Success; Design Thinking; Design Value; Ecodesign; Empathic Design Research; Green Design; Humanized Design; Interaction Design Aesthetics; Interface Design; Optimum Design; Package Design; Philosophy Of Design; Product Form Design; Professional Organizations In Design; Reliability Based Design; Social Design; Transport Design; Visual Design Representations	1

The total citation gained from the web of science online platform shows the 5 top cited in these 100 publications. These 5 publications were published between 2002 to 2006 and obtained 278 citations (31.02% of all citations). 100 papers were published which were cited 896 times and among them only 5 papers allocated 31.02% of whole citation. The first top cited publication is "Speaking the Buick language: capturing, understanding, and exploring brand identity with-shape grammars" that is published by 'Design Studies' journal with 73 citation and journal IF 1.304. The second publication is "Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics" that is released by 'International Journal of Industrial Ergonomics' with 68 citation and journal IF rating of 1.214. Additionally, this journal highlights the third top cited articles; "applying a hybrid approach based on fuzzy neural network and genetic algorithm to product form design" with 55 citation (Table 9). The forth top cited with 41 citations are a "relative entropy based method for probabilistic sensitivity analysis in engineering design" that is published by 'Journal of Mechanical Design' with an IF of 1.165. Lastly, we also looked at "Visual product evaluation: exploring users' emotional relationships with products" that is released by 'APPLIED ERGONOMICS' with IF 1.332.

Table 9: The 5 Best Publications

Journal	Title	Year	Citation	Authors
DESIGN STUDIES	Speaking the Buick language: capturing, understanding, and exploring brand identity with-shape grammars	2004	73	McCormack, JP; Cagan, J; Vogel, CM
INTERNATIONAL JOURNAL OF INDUSTRIAL ERGONOMICS	Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics	2004	68	Petiot, JF; Yannou, B
INTERNATIONAL JOURNAL OF INDUSTRIAL ERGONOMICS	Applying a hybrid approach based on fuzzy neural network and genetic algorithm to product form design	2005	55	Hsiao, SW; Tsai, HC
JOURNAL OF MECHANICAL DESIGN	Relative entropy based method for probabilistic sensitivity analysis in engineering design	2006	41	Liu, HB; Chen, W; Sudjianto, A
APPLIED ERGONOMICS	Visual product evaluation: exploring users' emotional relationships with products	2002	41	McDonagh, D; Bruseberg, A; Haslam, C

When choosing the first 100 top cited publication, the abstracts of the 135 documents were analysed; the researches refer to some specific topics shown in Table 10. The table highlights that 22% of publications were done in multidisciplinary areas. Furthermore, 19% of the content was related to "Industrial Design" methods and frameworks, with 16% of publication content relating to design processes. 12% was in education of "Industrial Design" and 11% was about product development, 10% "Industrial Design" Philosophy 7% in Modelling and Case study, 4% history and consumer behaviour, 3% ergonomics and consumer requirement and Kansei method which were the most researched area according to the abstract data analysed. The important point of the abstract analysis is that it shows the trends of each research during the last 34 years. It is displayed in 6 individual diagrams for each specific topic (Figure 7- Figure 10). The 6 topics shown have been increasing in publication releases, especially within the last 10 years.

Table 10: Abstract Analysis Topics

Abstract Analysis	
Multidisciplinary	22
Method; Framework	18
Design Process	18
Education	12
Product Development	10
Industrial Design Philosophy	10
Modelling	7
Case Study	7
History	4
Consumer Behavior	4
Ergonomics	3
Consumer Requirement	3
Kansei	3
Marketing	2
Material	2
Decision Making	1
Computer Aided Design	1
Representation	1
Cultural Design	1
Innovation	1
Customer Oriented	1
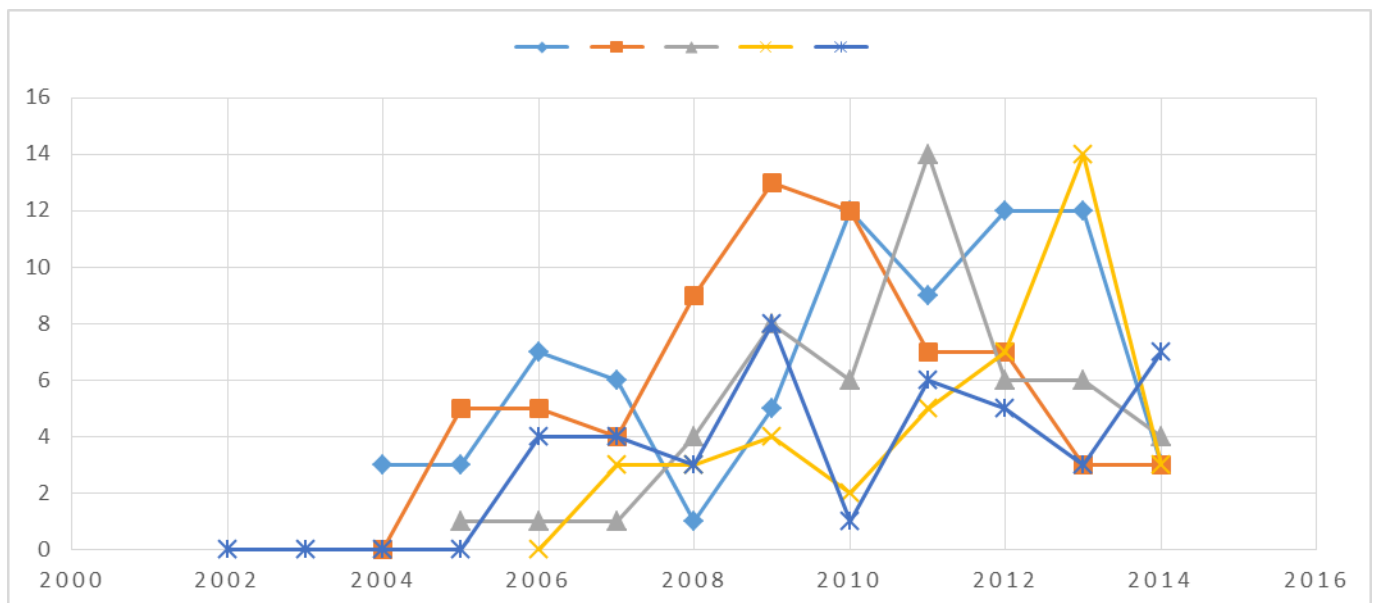
Figure 6: trend of citation for 5 top citation articles
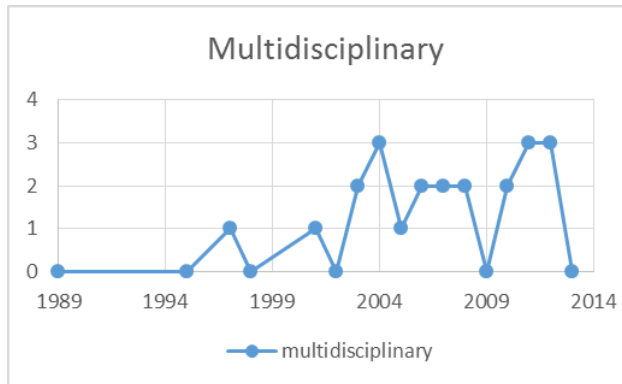
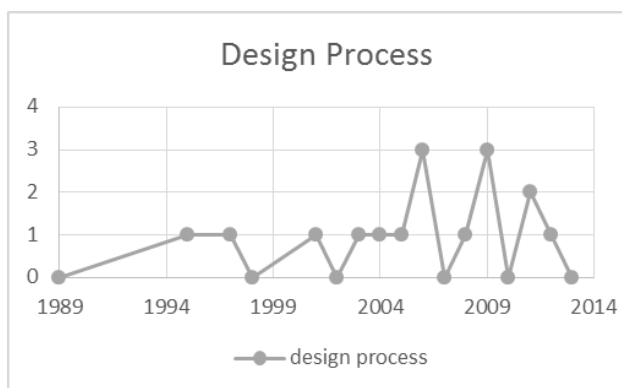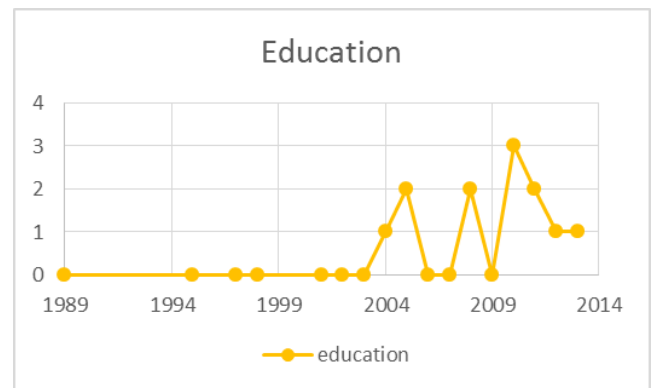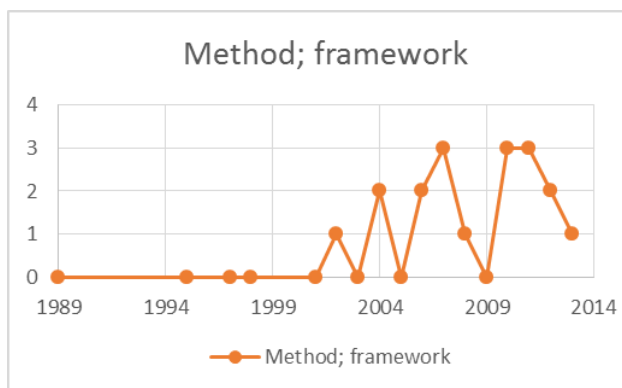Figure 7
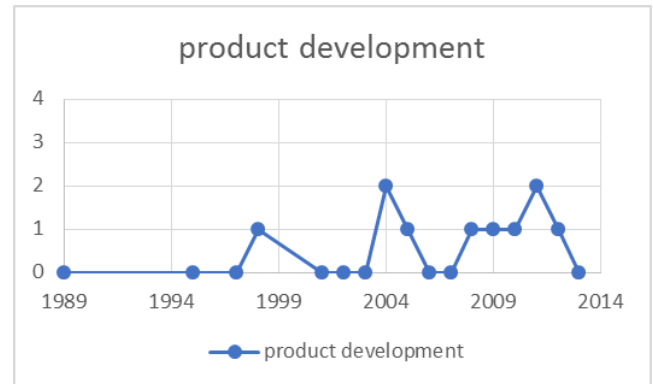
Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

3. Conclusion

This article has highlighted the 100 top cited publications in "Industrial Design". Compared to the first 14 years, it can be understood that most of the top cited publications were published within the most recent decade and it seems that this number is continuously rising. A substantial number of authors contributed in 2 or more publications. However, there were authors that were only with a publication assigned within the top total citation. There are 59 documents that were published by a single author and 41 publications were collaborated with at least two authors. 41 Collaborated publications released by corporations between 12 countries and 69 institutes. Through analyzing the abstracts, it was discovered that specific topics are preferred for researchers. It can be concluded that there are some topics that can give the researcher's more attention (i.e. the 'multidisciplinary' research in industrial design or researches about 'design process'). This study had a search limitation to the "Industrial Design" word in the topic of documents in the Web of Science Core Collection database. So, The use of a simple search strategy can generate "silence" in data mining. Therefore, future research should use A saturation words curve to solve this problem. Also, for future research, this article suggests that further analysis is needed on the effect of citation used within a collaborative context. This would allow for a sound understanding which would enable the web of science platform to develop their categories in this specific field of study. Hence, ensuring greater acuracy for end users when searching for "Industrial Design" categories. It is clear that no accurate category is available when searching for "Industrial Design" and thus a greater focus in the search engine can improve the usability for researchers and designers.

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