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The100 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 regard, the study aims to identify and analyse the characteristics of top-cited papers published in the Web of Science under 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. In addition, the names of the top journals were *Design Studies*, *International Journal of Industrial Ergonomics*, and *International Journal of Design*. Industrial design is proposed as a new Web of Science category.

Key words: Evaluation. Highly cited. Industrial design. Interdisciplinary. Product design.

1 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, and service design, whereby various methods and strategies within these fields have been established. Industrial designers need to work with various experts in other fields, such as engineers, materials scientists, sociologists, psychologists, and marketing professionals (Tovey, 1997). Industrial design involves the development of products to suit the mass market (Dorst, 2008). There are a series of creative activities that define the formal qualities for industries in their production processes (Black, 1983). Industrial designers interpret and transmit their ideas and visions to the environment through their designs (Kazmierczak, 2003).

Bibliometrics is defined as the application of mathematical and statistical methods to papers, books, and other means of communication for the analysis of scientific publications (Repanovici, 2010). To recognize research trends, bibliometric methods are usually used for evaluating 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 the 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 study, bibliometric analysis is applied to the field of industrial design. A peer-based evaluation procedure is implemented on the abstracts of top-cited papers.

Every year many publications are released by researchers on subjects pertaining to industrial design. Highly cited papers have a greater chance of visibility and thus attract greater attention of researchers (Wohlin, 2005). Evaluating the top-cited publications' content is very useful to obtain information about trends in specific fields to gain perspective of the progress of research (Fardi, Kodonas, Gogos, & Economides, 2011). How does this sentence add value? It is useful for the reader? It can aid researchers to find the best field or best journal to succeed with their publication. Although, a citation itself is not a scientific tool for assessing a publication, it is a valuable metric that recognizes research parameters (Shadgan, Roig, HajGhanbari, & Reid, 2010). Citation indexes as a type of bibliometric method show the number of times an article has been used by other papers (Fooladi *et al.*, 2013). Citation analysis helps researchers get a preliminary idea of the articles and research that make an impact on 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 publications need to be evaluated to display the research trends in a specific research area.

The evaluation of reviewed papers and obtained information, such as keywords, categories, and research areas can help institutes find suitable topics for funding research. Collaboration amongst researchers has allowed for prominent themes within industrial design to establish themselves and influence the future of industrial design. Therefore, this study aimed to identify and analyse bibliometric data of top-cited papers that were published in the Web of Science from 1980 to 2014 on the topic of industrial design.

2 Methodology

This study evaluates industrial design research that was published by the Institute for Scientific Information (ISI). In addition to examining publication distribution and other information that will be discussed, the statistical characteristics of industrial design research will be defined. Also, the charcteristics of a publication, such as the author's country and affiliation, web of science categories, and research areas that are used, will be analysed. Finally, we will evaluate information associated with the author's keywords, abstract analysis, and trends in industrial design during the period of 1980 to 2014. The purpose of this study is to highlight the key information that is used amongst researchers as a basis for gaining insight from industrial design literature.

The information obtained from the online platform of Thomson Reuters' Web of Science on July 20, 2014 was used in this article. To recognize research related to industrial design, documents were searched using the keyword "industrial design" (meaning that at least one of the titles, abstract, or author keywords found should contain the phrase "industrial design"). As industrial design doesn't have a specific category within the ISI subject field, searching for specific industrial design articles can be a time-consuming process for end users, who will have to filter an extensive number of articles that are spread out over several categories. Hence, the user interface of ISI is not tailored for those authors attempting to gain specific content related solely to industrial design. We found that, in many cases, the articles analysed within the field of industrial design could be found in unrelated fields such as computer science, materials science, and even social sciences, on topics related to culture, business and marketing. In the first step of the methodology, industrial design was searched in the online Web of Science database. In this step, 1899 publications were found, demonstrating that the search engine needed to be refined. By refining the Web of Science categories and excluding unrelated research areas, 833 publications were found by searching "industrial design" through the "Topic" search tool (Figure 1).

All the information searched on the Web of Science containing author name and address, publication title, publication year, journal name, author keywords, number of citations, Web of Science categories, and research areas were downloaded onto a Microsoft Excel file. A key metric used when assessing the popularity of an article is reflected by the Impact Factor (IF). The IF assesses the average number of citations received per article, allowing a measure ranging 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 was made of the impact factor (IF) related to each journal. At first, using the records that were obtained from the downloaded report of the search, all the publications were sorted by number of citations per year, and the top 100 publications were selected. For the selected 100 top-cited articles, it was required that these were all related to industrial design per the abstract. Publications include both single-author

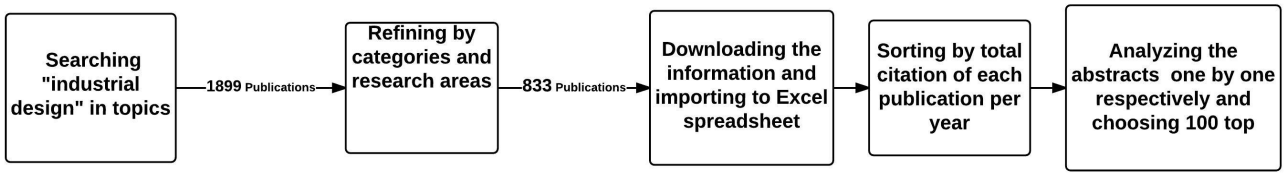

Figure 1: Methodology
Source: The authors.

and multiple-author types. In a publication, the first author is someone who was more involved in preparing and writing the document than the other authors (Gaeta, 1999). Each publication also displays the different countries where the authors are from and would be categorised as an international collaborative publication if the authors were from more than one country (Chiu & Ho, 2005).

3 Results

In total, 833 publications on industrial design were published between 1980 and 2014. The number of articles fluctuated between 1 to 15 from 1989 to 2013, when there was an increase in the number of articles published per year (Figure 2). The most frequent type of publication were articles (81%), followed by proceedings papers (16%), and book, book chapter and editorial material (1% each).

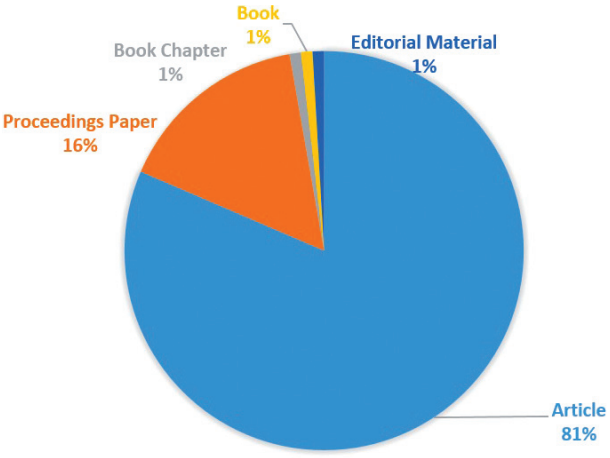

Figure 2: Publication type
Source: The authors.

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 (eight publications) and 2009 (seven publications). It also shows the total distribution of citations in a year. This amount fluctuated between two citations in 2013 and 214 citations in 2004. The total number of citations in 2004 belongs to seven publications, three of which are among the 100's top-10 cited. Additionally, the first two highly-cited publications received a total of 73 and 68 citations respectively during 2004 (Table 1).

Table 1: Number of publication per year and total citations

Year	Number of publications	%	Total year citations	%
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

Source: The authors.

Table 2 and Table 3 display the top 18 most active authors from 1980 to 2014 (total publication >1) that positioned their publication among the 100 top-cited articles. The 100 documents had 208 authors: Petiot, J. F., with two publications and 77 citations, is followed by Hsiao, S. W., with 74 and two publications. After him are Cagan, J., McCormack, J. P., and Vogel, C. M. with one publication and 73 citations. The next is Yannou, B., with one publication and 68 citations. Finally, McDonagh, D. has three pub-

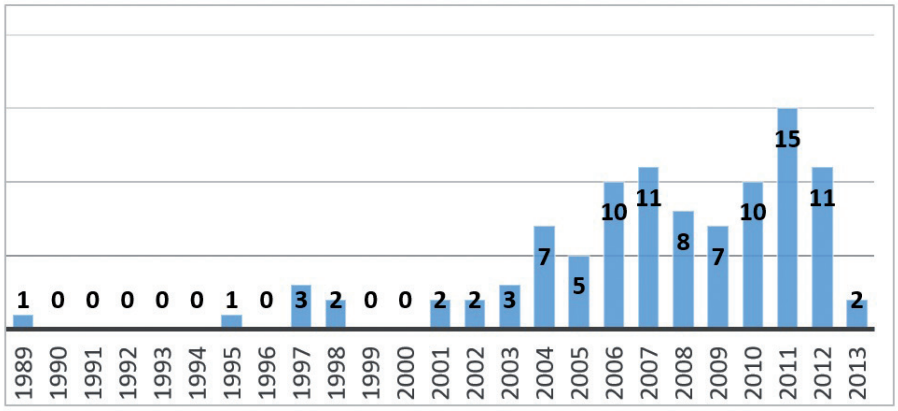

Figure 3: Number of publications per year
Source: The authors.

lications, obtaining 57 citations and Tsai, H. C., with one publication among the 100 top-cited, having been cited 29 times.

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

Table 5 displays the distribution of the institutes that are placed among the 100 top-cited publications between 1980 and 2014. There are 144 institutes that published the document individually or in cooperation with other institutes. The most active institutes and their document total are displayed in Table 5. Delft University Technology had six publications and Middle

Table 2: Most active authors ranked by total citations

Author	Total publications	Total citations				
Petiot, J. F.	2	77	68	9		
Hsiao, S. W.	2	74	55	19		
Cagan, J.	1	73	73			
McCormack, J. P.	1	73	73			
Vogel, C. M.	1	73	73			
Yannou, B.	1	68	68			
McDonagh, D.	3	57	41	12	4	
Tsai, H. C.	1	55	55			
Bruseberg, A.	1	41	41			
Chen, W.	1	41	41			
Haslam, C.	1	41	41			
Liu, H. B.	1	41	41			
Sudjianto, A.	1	41	41			
Nakada, K.	1	40	40			
Chen, S. E.	1	39	39			
Parent, R. E.	1	39	39			
Betts, P.	1	31	31			
Evans, M. A.	4	29	11	9	5	4

Source: The authors.

Table 3: Most active author ranked by total publications

Author	Total publications	Total citations
Evans, M. A.	4	29
McDonagh, D.	3	57
Sener, B.	3	17
Chen, C. H.	3	16
Campbell, I. R.	3	18
Petiot, J. F.	2	77
Hsiao, S. W.	2	74
Pedgley, O.	2	23
Crilly, N.	2	21
Yang, M. Y.	2	15
You, M. L.	2	15
Candi, M.	2	13
Huang, Y. X.	2	11
Khoo, L. P.	2	11
Goldschmidt, G.	2	8
Pei, E. J.	2	9

Source: The authors.

Table 4: Most active journals ranked by total publication

Journal	Total publications	Total citations	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

Source: The authors.

Table 5: Most active institutes ranked by total publications

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

Source: The authors.

East Technical University had five top-cited articles, followed by Loughborough University of Technology, National Cheng Kung University, and Loughborough University, with four each. National Yunlin University of Science and Technology, University of Cambridge, and University of Illinois had three publications. Fourteen publications involved collaboration between 70 institutes. Loughborough University of Technology had the most collaborations in publications with four (28.57%) publications; it is followed by Delft University Technology, Middle East Technical University, National Cheng Kung University, Loughborough University, National Yunlin University of Science and Technology, and University of Illinois, with two (14.28%) collaborations.

From 1980 to 2014, researchers from 25 countries published 100 top-cited articles. Table 6 shows the countries with more than three publications among these 100. England topped the list with 19 publications, followed by the USA with 16, Taiwan (12), China (8), Turkey (8), Italy (7), the Netherlands (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 resulted from international collaborations. Most of the publications (86%) came from single-country authors and the rest, which totalled 14 (14%), from international collaborations. These 14 publications involved cooperation between 12 countries. England, with seven publications, and the USA with five are on top, followed by Australia and Taiwan, with three, then by China, the Netherlands, Germany, and Turkey, with two

Table 6: Most active countries ranked by total publications

Row Labels	TP	TPR(%)	SP(%)	CP(%)	FP(%)
England	19	1(19)	12(13.95)	7(50.00)	15(15)
United States of American (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)

Source: The authors.

collaborations, and finally Iran, Hong Kong, South Korea, and Israel, with 1 collaboration. As mentioned, England collaborated in 50% of international publications. It is followed by the USA, with 35.71%, and Taiwan and Australia, with 21.43%. Also England had 15% of first authors among the 100 top-cited publications. USA, with 13%, comes after England, followed by Taiwan with 10%, and finally China, Turkey, and Italy, with 7%.

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. It is followed by psychology, computer science and materials science, with six publications. It displays the entirety of 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. Figure 5 displays the frequency of the categories. The top categories are engineering, multidisciplinary, with 39%; engineering, manufacturing, with 38%; art and engineering, industrial, with 21%; and ergonomics, with 16%.

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 two frequencies). The most frequent keywords include industrial design and design, which appear 30 times,

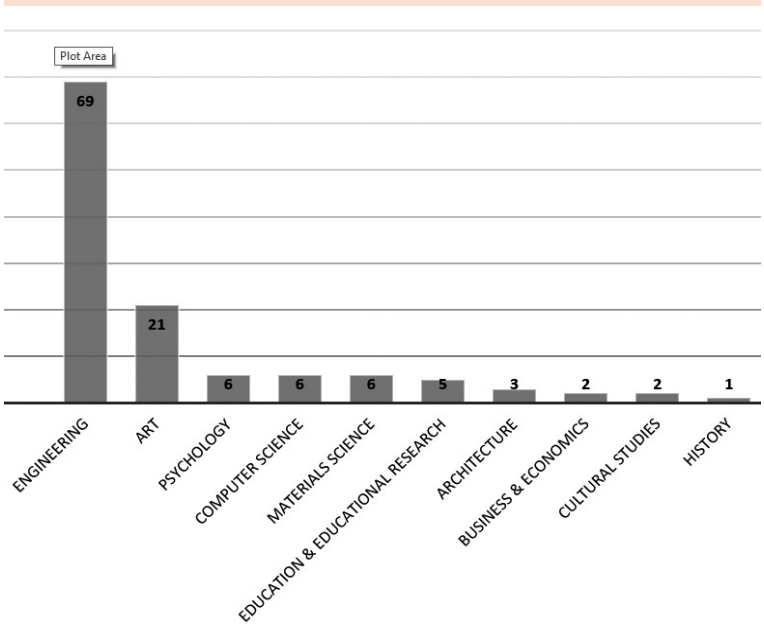

Figure 4: Web of Science research area
Source: The authors.

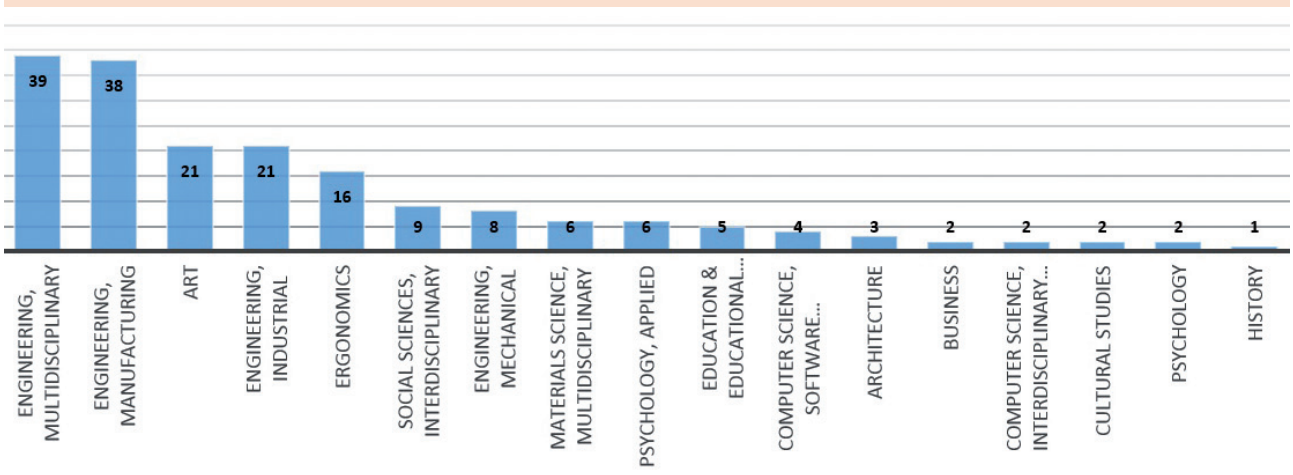

Figure 5: Web of Science categories
Source: The authors.

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

Source: The authors.

followed by "product design" and "product", with eigth. Then "Kansei", with seven; "modelling", with six; and "3D" and "aesthetics" with five. As the keyword "design" is very important for industrial design, Table 8 shows the kind of "design" and its sub-categories.

The total citations obtained from the Web of Science online platform shows the five top-cited in these 100 publications. These five publications were published between 2002 to 2006 and obtained 278 citations (31.02% of all citations). A total of 100 papers were published which were cited 896 times, and among them only five papers received 31.02% of all citations. The first top-cited publication is "Speaking the Buick language: capturing, understanding, and exploring brand identity with-shape grammars", which was published by the "Design Studies" journal, with 73 citations and a journal IF of 1.304. The second publication was "Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics" that is released by "International Journal of Industrial Ergonomics", with 68 citations and a journal IF rating of 1.214. Additionally, this journal also had the third top-cited article; "Applying a hybrid approach based on fuzzy neural network and genetic algorithm to product form design", with 55 citation (Table 9). The fourth 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 an IF of 1.332.

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

Source: The authors.

When choosing the first 100 top-cited publications, 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, 11% in product development; 10% in industrial design philosophy;

Table 9: The five best publication

Journal	Title	Year	Citation	Authors
Design studies	Speaking the Buick language: capturing, understanding, and exploring brand identity with-shape grammars	2004	73	McCormack, J. P.; Cagan, J.; Vogel, C. M.
InternationalJjournal of Industrial Ergonomics	Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics	2004	68	Petiot, J. F.; 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, S. W.; Tsai, H. C.
Journal of Mechanical Design	Relative entropy based method for probabilistic sensitivity analysis in engineering design	2006	41	Liu, H. B.; Chen, W.; Sudjianto, A.
Applied Ergonomics	Visual product evaluation: exploring users' emotional relationships with products	2002	41	McDonagh, D.; Bruseberg, A.; Haslam, C.

Source: The authors.

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 Requirements	3
Kansei	3
Marketing	2
Material	2
Decision-making	1
Computer-aided Design	1
Representation	1
Cultural Design	1
Innovation	1
Customer-oriented	1

Source: The authors.

7% in modelling and case study; 4% in history and consumer behaviour; 3% in ergonomics, consumer requirements, and the Kansei method, which were the most researched areas according to the abstract data analysed. The important point of the abstract analysis is that it shows the trends of each research topic during the last 34 years. It is displayed in six individual diagrams for each specific topic (Figure 7-12). Publication releases on the six topics shown have been increasing, especially within the last 10 years.

4 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 rising. A substantial number of authors contributed in two or more publications. However, there were authors that had only a single publication among the top total cited. There were 59 documents that were published by a single author and 41 publications in which there was collaboration between at least two authors. A total of 41 collaborated publications resulted from cooperations between 12 countries and 69 institutes. By analyzing the abstracts, we discovered that specific topics are preferred by researchers. We conclude that there are

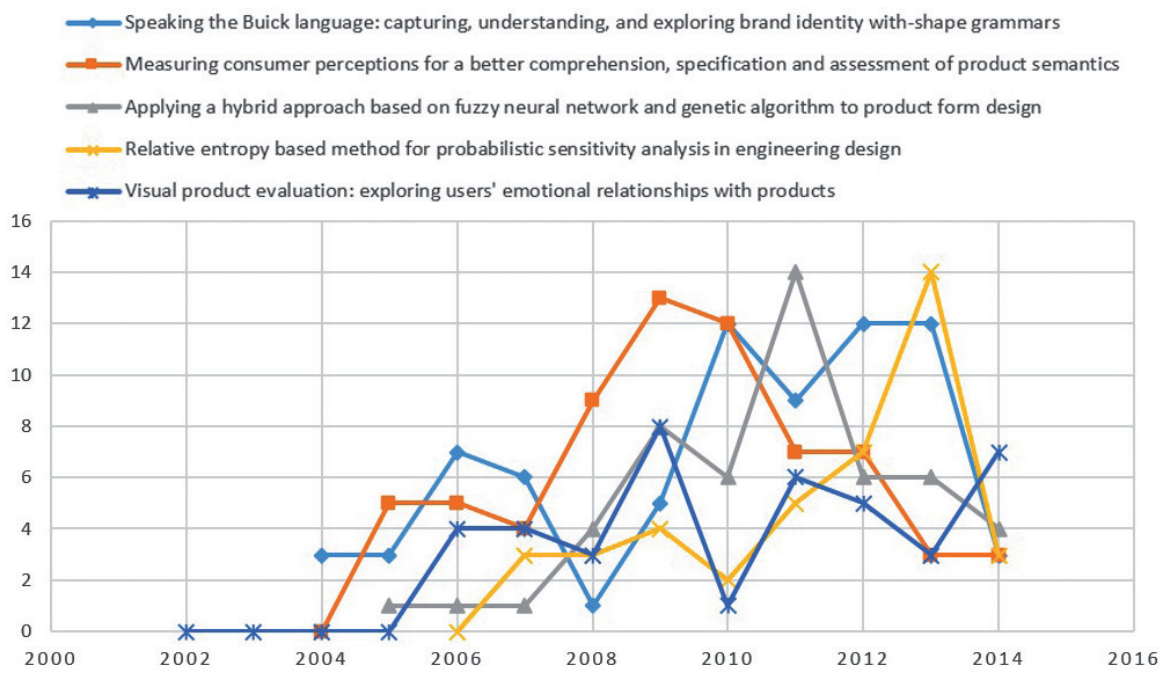

Figure 6: Trend of citations for the five top-cited articles
Source: The authors.

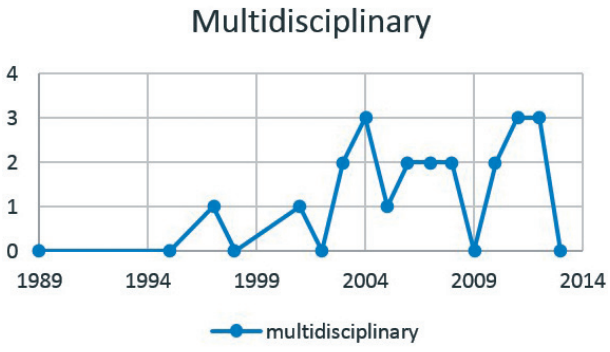

Figure 7: Multidisciplinary
Source: The authors.

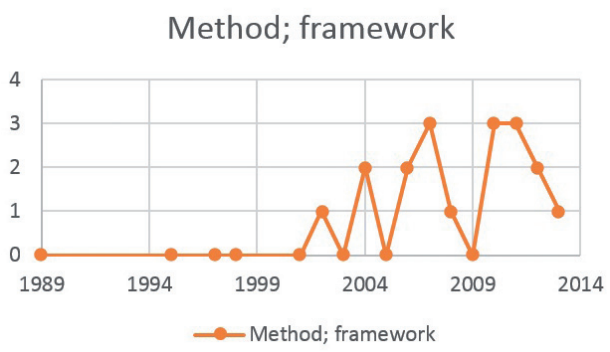

Figure 8: Method; framework
Source: The authors.

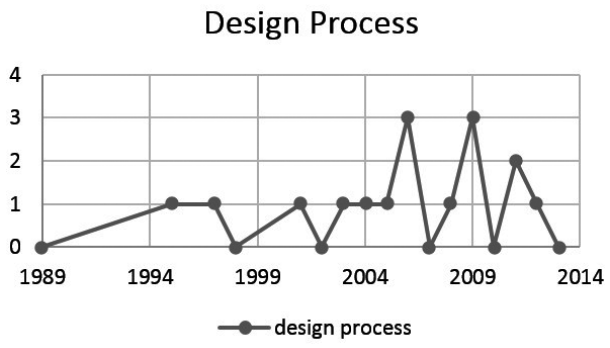

Figure 9: Design Process
Source: The authors.

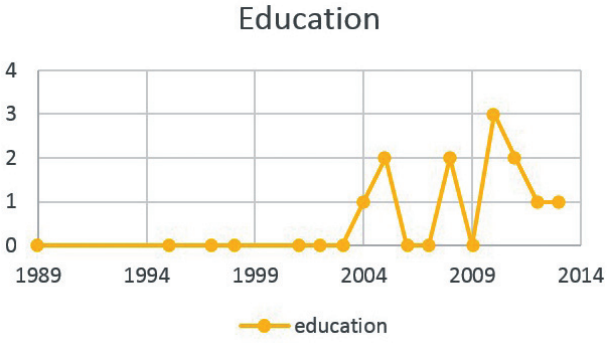

Figure 10: Education
Source: The authors.

Figure 11: Product Development
Source: The authors.

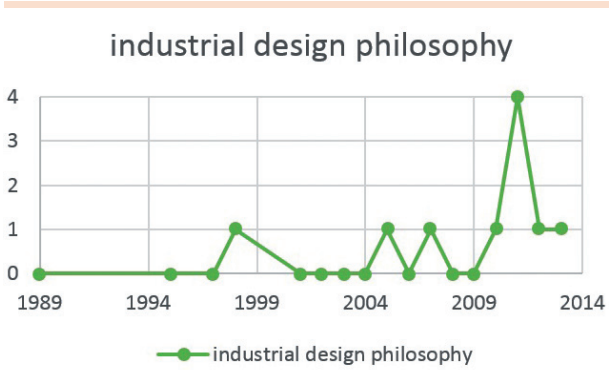

Figure 12: Industrial Design Philosophy
Source: The authors.

some topics that can draw more attention from researchers (i.e. the "multidisciplinary" research in industrial design or studies about "design process"). This study limited search for documents using the phrase "industrial design" as the topic in the Web of Science Core Collection database. Hence, 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 citations 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, thereby 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 papers and thus a greater focus on the search engine can improve the usability for researchers and designers.

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