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Design Research Insights on Text Mining Analysis: Establishing the Most Used and Trends in Keywords of Design Research Journals

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Abstract: Design research topics attract exponentially more attention and consideration among researchers. This study is the first research article that endeavors to analyze selected design research publications using an advanced approach called "text mining". This approach speculates its results depending on the existence of a research term (i.e., keywords), which can be more robust than other methods/approaches that rely on contextual data or authors' perspectives. The main aim of this research paper is to expand knowledge and familiarity with design research and explore future research directions by addressing the gaps in the literature; relying on the literature review, it can be stated that the research area in the design domain still not built-up a theory, which can unify the field. In general, text mining with these features allows increased validity and generalization as compared to other approaches in the literature. We used a text mining technique to collect data and analyzed 3553 articles collected in 10 journals using 17,487 keywords. New topics were investigated in the domain of design concepts, which included attracting researchers, practitioners, and journal editorial boards. Such issues as co-innovation, ethical design, social practice design, conceptual thinking, collaborative design, creativity, and generative methods and tools were subject to additional research. On the other hand, researchers pursued topics such as collaborative design, human-centered design, interdisciplinary design, design education, participatory design, design practice, collaborative design, design development, collaboration, design theories, design administration, and service/product design areas. The key categories investigated and reported in this paper helped in determining what fields are flourishing and what fields are eroding.

Keywords: keywords analysis; design research; visualization trends; text mining; research directions; design insights

1. Introduction

The topic and/or discipline of design is becoming very important and relatively young but has matured rapidly in the last decade with the increased use of digital phenomena in different fields [1]. As a result, research related to design is growing exponentially.

Scholars/researchers are investigating and exploring a variety of disciplines of Design research and disseminating under several of the fields (i.e., engineering, CAD, management, ergonomics, business, education, and art and design); to extend the experience and knowledge in this domain for this arena [2].

The design was defined by a range of variety of design research definitions. Many definitions point to the importance of this subject in several design domains [1,3–5]. Rachel Cooper, one of the founders and editorial chairs of 'The Design Journal' was defined 'Design' in his journal publication which is called 'Design Research Comes of Age' as an initial trial issue published in 1997 (volume 0, issue 1) stated: "When we say 'design' we mean: the design disciplines covering products, places, and communication (i.e., graphic design, information design, product and industrial design, fashion and textiles, interior design and designer/maker issues), design management (design strategy, design policy, marketing and design, design and manufacturing, innovation), design theory (design methods, psychology, and design, creativity and design), Eco and environmental design, gender issues in design. We anticipate these topics will be addressed from an educational, historical, technological, or practical perspective. We believe these disciplines can provide a rich perspective, each informing and contributing to the depth and breadth of design research" [6].

Ralph and Wand [7] defined the concept of design after they reviewed of literature of existing definitions and stated: "The report views the design activity as a process, executed by an agent, to generate a specification of an object based on: the environment in which the object will exist, the goals ascribed to the object, the desired structural and behavioral properties of the object (requirements), a given set of component types (primitives), and constraints that limit the acceptable solutions.

The main and/or major directions in Design research are related to anyone who really is so interested in design to cultivate his/her understanding of how designers think and work [8,9]. Moreover, design offers designers/non-designers the opportunity to create/create effective, efficient, original, and impressive designs. In this sense, the design goes beyond a set of design tools or practical skills and is a process [8]. Nevertheless, the design concept is expanding to include more diverse disciplines and disciplines. Therefore, it is essential to add value and quality to our lives as humans [10,11].

The movement of Design research as a discipline toward facing dilemmas in the coming years. Design research as a discipline and the concept of 'Design' has seen tremendous extension/enlargement of interest in recent years; in particular, from management, health, education, design industry, ICT and its applications, and business books as Design terms considers an interdisciplinary [12,13]. Moreover, the amount of Design research is growing with the increase in the number of journals, conferences, books, and magazines dedicated to design as a discipline. Design research is an interdisciplinary topic that covers various sciences (i.e., social, practical, computer, health, education, engineering, culture, history sciences, etc.). Several studies [8,14–16], reviewed Design research as a discipline to achieve a foundational understanding of this domain. These studies focus on a variety of topics cover ranging from investigating the main research streams on the 'Design research' concept. The primary research topics identified in the literature are concerned with the ability not just to build rigorous depth of knowledge but also the breadth of the discipline. Design research has consistently identified innovation, users, materials, production, etc. However, some domains in Design research (i.e., social innovation, policy design, open design, and design for specific industries and engineering, such as design for health, culture, education, IT, and design against crime are becoming very popular [4].

The main aim of this research study is to investigate and comprehend the dominant areas or subfields of design research through an analysis of indexed keywords that were included in journal publications' abstracts (i.e., research articles). Our analysis focused on keywords related to journal articles in design research. To the best of our knowledge, this study is the first documented effort to use a cutting-edge method termed "text mining" to examine the chosen Design research articles in a research article. This method/approach hypothesizes that its results depend on a study term's existence (i.e., keywords), which can

be more reliable than other methods/approaches that rely on contextual data or authors' opinions. Text mining also takes into account its frequency to reflect the dominance and applicability of a phrase or keyword in the data.

This research's motivation can easily be noticed when you think about the difference between this study and Google scholar or other search engines. Web searches, in general, may resemble text mining, but there are significant differences. Based on specific search keywords, search is the retrieval of documents or other results. The output typically consists of a hyperlink to text or information located elsewhere and a brief description of what can be found at the other end of the link. These kinds of searches are frequently carried out using search engines like Google, Yahoo, or Bing, and your company may also use an enterprise search solution.

Finding the entire existing work is the goal of using its material. The purpose of text mining is to analyze text. Instead of just looking for, linking to, and retrieving papers that contain specific data, the objective is to extract useful information. In contrast to searches, the outcomes of text mining depend on the researcher's intended use of the data. While search functionality aids users in locating the particular document(s) they need, text mining goes far beyond search to identify specific facts and claims in the literature to create new value. The work is the first attempt to use text mining to examine research directions in design research.

This paper contributes to Design research and practice by detecting/exploring main research trends in the design research discipline and spotting light on previous and new prospective research priorities. Additionally, this research study provides perceptions/observations concerning new dimensions important in the design and associated areas. Compared to other literature methodologies, text mining with these qualities typically allows for higher applicability and validity. The Findings of this study reveal the research interest and the trends of the design research discipline. This research study utilized one of the largest samples of publications (i.e., papers). A total of 17,486 words from design journals were used in this research report. A quantitative analysis was conducted to prevent author bias when analyzing research and how we look at and analyze the data collected. Future scholars might examine and cluster the information acquired in this research study (data available in Appendix A can be used manually). The following section presents Design research directions and the research methods conducted in state of the art. The third section illustrates this research paper's research method and questions. Section four describes a report of results by analyzing and discussing data results. Finally, conclusions, including contributions and limitations, are stated in the fifth section. The popular design terms and abbreviations, are listed in Appendices A and B sequentially.

2. Design Research

The following two sections will review the previous studies and related works on design research dimensions and research methods conducted or applied. It is essential to investigate such topics to examine how text mining will contribute to identifying correct dimensions not reported in the previous research.

2.1. Design Research Dimensions

The term 'design' is a strategy or portrayal formed to demonstrate the aspect and purpose or mechanisms of an entity modeling before it is prepared [17,18]. Studies within the field of design may be perceived to be evolving. However, some associated design methodologies' castigations, such as, production, organizational designs, comprehensive design vocabulary emerges, strategic planning, engineering design and interface design have an extended post [19–21]. Chai et al. [22] Explored the fundamental subjects of design study by retaining a bibliometric and system breakdown. The research examined references and co-records from design use cases. As an alternative to exhausting the typical study routine of grouping writer co-citations, this research miner conducts the study at the discrete publication level [23].

Anthropological contributors directed a methodical diagramming study to categorize and examine thirty crucial pragmatic case studies on software outlining applications, consisting of twenty-four original researches and six replications, to describe the study design of experiential research. It was observed that by exhausting shared trials and modus operandi, academics can design novel training, reproduce in effect studies, and be able to associate the outcomes. Nonetheless, the authors witnessed that multiple framework issues (such as tentative measures, usages, and partaker familiarities) limited the comparability level of the results.

It is essential to know how we define "design", "design study", and "prospect" of design examination. Chakrabarti et al. [24] identified three categories of associations that must exist: (1) design occurrences, (2) design study arrays, and (3) relations and models to indicate the design study. They offered an introduction classification for the two of these and described the likely methods of achieving each. The understanding of (a) internal growth and (b) external acknowledgment for widely suggested applications was enhanced by this consolidation. It suggested developing (a) a maiden classification of singularities allied to design, (b) a maiden categorization of design study domains, (c) a data warehouse of design study research articles, and (d) a dictionary of expressions and notions used in the research articles within respective study zone [25]. Domain-specific design goals included product launch time, market portion, benefits, industrialization capacity, budget, assemblage, innovation, discernability, aesthetics, and functional value. Utilizing this, the subject matter "Design for budget" developed further diligently and was associated with "Design for life" than, at a guess to, "Design for appropriateness".

Numerous aspects of the design environment were measured; thus, modeling progression can be utilized hands-on. The modeling method of this reasoning reflects the impact of the properties of the informal setting and the features of the producer. Nonetheless, there are rare instances of associating and relating the expert's setting and features to the design element. To accomplish this phenomenon, projected study adapted [26] predicament-resolution to conduct design discipline research in a controlled manner. This progression contained the subsequent five phases (a) problem designation, (b) exploration and analysis, (c) resolution scheme, (d) execution, and (e) assessment [26].

This broadsheet [27] discovers the density and reasoning liability allied to quantified optimal research. The difficulty is examined about design dimensions such as the sum of accessible substitutes (i.e., numerous design dimensions), the number of characteristics used to outline these options, the sum of stages for those traits, the array of feature points, and the number of particular circumstances offered to each respondent. These design scopes are methodically diversified according to a trial design in an initial design order; the following option encompassed the characteristics of respective substitutes (e.g., portable epochs and mobility rate mechanisms). To research the difficulty of the trial author detailed a 'heteroskedastic logit prototypical' with the rule limitation described as a task of the scheme dimensions. This permitted them to detach the properties of optimal intricacy from the borderline efficacy approximations. Research outcomes illustrate that five design dimensions distress the optimal discrepancy or disturb selection reliability [28–30].

A study [28] was conducted to classify the features of design studies in restraints other than design discipline. The design was diligently created and improved through tight relationships with various inculcations. Researchers developed a framework for interpreting the controversial interdisciplinary practice of design projects [29]. The taxonomy of design research, and the significance of design relations. Investigators adopted this outline to examine, illustrate and choose what categories of lessons on design have been directed in the collective disciplines and what style of design they were cast off for. The examined argument may benefit discourse logical and communication obstacles to design-positioned, design-correlated, or design-worn study diagonal use cases. The review also donates to the expansion of sagacity of the synthesizing perspective for the title "design". Though analyzing the subjective material to comprehend the feeling of design in varying attainments took a while, this understanding did ensure a few precincts.

2.2. Research Methods Conducted in the Design

Service dominance reasoning that provides a practical design. Rooted in the fundamental concept of service dominance, the critical co-concept, two essential perspectives are helpful for novelty testing of the services involved. On the one hand, the focus is on integrating resources within and between different levels of care that can demonstrate different value potentials and thus improve perspectives [30–32]. The second is service-dominant reasoning, competing with recipients individually for control and viewing co-concepts of valuation as reserve assimilation and shared service-providing actors that value concepts beyond established decision-making sites. It is worth mentioning that service-dominant logic portrays deficiencies in the applied procedures that enterprises consider as prerequisites to monitor the ways they can collect the distinct comprehensions into the value of co-conception and redesign their possessions to transform through augmentation of significance [32].

Another study used the text-mining approach in the design research [33]. Nie and Sun [34] used this approach, building on her two dimensions of bibliometrics and network analysis to identify academic sector themes. Specifically, we evaluated design research fields using bibliometrics and clarified research themes in each academic field of design research using network analysis. Various design techniques are classified step by step and presented as a collection of subsystems [35]. In this framework, the design progression includes the theoretical concept of a "new entity or system" at the highest level of illustration, with the more salient elements predominating at, the lower levels of representation. Illustrated Broadside [36] proclaims that program design is a new dimension in design. To articulate this argument, researchers propose: (a) Hypothesis: It is true that procedure consists of design, (b) Counter-thesis: Procedure implies design. (c) Fusion: Abandon Hypothesis: The program indeed contains design results. Process design is a (novel) part of design research and training. It is fair to conclude that inventors have directed additional research areas to answer existent complications and an innovative epoch of Computer-Assisted Strategy Design is evolving under the direction of program informatics with significant prospects for design. The mixture of examination, applications, and learning in procedure design presents countless chances for transnational design groups [34].

The previously mentioned work by Kavousi et al. [37] shows that meta-reasoning is a crucial part of planning knowledge initiation and improvement and is a significant portion of innovative progression in design. Furthermore, the subsequent prototypical clarifies how modules of meta-reasoning relate and offer understanding to researchers in the quest to boost design progression and its effects on users. In another study [33], researchers deciphered a Multidisciplinary Design Optimization (MDO) problem in which the progress of stabilizer-contrived yields is tailored for different consumers in dissimilar market subdivisions. Three sectors, i.e., consumer inclination modeling, additive manufacturing (AM) assembly valuation, and physical technicalities, are unified in the MDO problem. The prime choices of modules, resources, AM progressions, and dimensional limitations were examined to exploit the functionality effectiveness, contesting discrete consumers' particular routine necessities and diminishing the overall budget. The study smeared an unbiased heritable procedure with the anticipated gene scrambling configuration to resolve the MDO problem. The MDO delivered a set of possible policy resolutions from which the producer would choose the suitable ones grounded on its market approach. In addition, the study in [35] investigated the positioning of the research field through keyword identification in the design research field using an exploratory survey of the emails' corpus. A related study was conducted by Lloyd [38] on design research society to investigate many themes in design disciplines, such as objects, experiences, practices, and networks; design and translation; and design for tangible, embedded, and networked technologies based on the systematic view of design.

The aspect-based sentiment analysis (ABSA) consists of two subtasks—aspect term extraction and aspect sentiment prediction. Existing methods deal with both subtasks in a pipeline manner, in which some problems in performance and real application exist.

Ref. [36] investigates the end-to-end ABSA and proposes a novel multitask Multiview network (MTMVN) architecture. Specifically, the architecture takes the unified ABSA as the central task, with the two subtasks as auxiliary tasks. Meanwhile, the representation obtained from the branch network of the main task is regarded as the global view, whereas the representations of the two subtasks are considered two local arguments with different emphases. Through multitask learning, the main task can be facilitated by more accurate aspect boundary and sentiment polarity information. Furthermore, Most State-Of-The-Art (SOTA) Neural Machine Translation (NMT) systems today achieve outstanding results based only on large parallel corpora. The large-scale parallel corpora for high-resource languages is easily obtainable. However, the translation quality of NMT for morphologically rich languages is still unsatisfactory, mainly because of the data sparsity problem encountered in Low-Resource Languages (LRLs). In the low-resource NMT paradigm, Transfer Learning (TL) has been developed into one of the most efficient methods. It is not easy to train the model on high-resource languages to include the information in both parent and child models, as well as the initially trained model that only contains the lexicon features and word embeddings of the parent model instead of the child languages feature [39]. Additionally, Cross-Document Coreference Annotation Tool (CDCAT), a new multi-language open-source manual annotation tool for cross-document entity and event Coreference, can handle different input/output formats, pre-processing functions, languages, and annotation systems. This new tool allows annotators to label a reference relation with only two mouse clicks. Best practice analyses reveal that annotators can reach an annotation speed of 0.025 coreference relations per second on a corpus with a coreference density of 0.076 coreference relations per word [38]. Finally, refs. [40,41] illustrates the Clarification of research design, research methods, and methodology: A guide for public administration researchers and practitioners, and tabular Comparing and contrasting research methods and methodology concepts.

To sum up, based on our literature review, it can be stated that the design area of research has not yet developed a theory that can standardize the area. Previous studies have focused mainly on research directions. Moreover, previous studies have demonstrated diverse methodologies and a wide range of topics. Moreover, previous studies have not presented a single study that comprehensively identifies or draws conclusions for research directions in this area. Thus, in this paper, there was the first recognized attempt under the obligation to acknowledge domain regions through text analysis using keywords from design studies. The sections immediately following describe the research methodology and data analysis.

3. Research Methodology

This research paper pursued three research questions that enhanced our experience and knowledge of the design research discipline. Given below are the research questions:

RQ1: What are the major design research topics observed in the dataset?
RQ2: What changes in design studies were observed during the sample period from January 2007 to March 2019?
RQ3: What are the vital design research topics that determine the direction of future research?

Many keywords were used in the study, including articles related to design and research topics. We used a set of published keywords along with the article's abstract, year of publication, and other information about the keywords, such as indexed keywords. The most famous studies available in the field, ranked by the index of the (ISI Collection) Web of Science website, were used in the study. Those journals' titles were used that comprised the word 'design'. The primary criteria for selecting the journals was the strong relation of design discipline to ICT, sciences, education, ergonomics, engineering, technology, and service/product design and development. Based on that, some journals were excluded for two reasons: first, not having been indexed by the Web of Science (ISI-core collection database) and/or considered as an Emerging Source Citation Index (ESCI), such as 'she Ji: The Journal of design, economics, and Innovation'. However, some journals were indexed

in the web of science (ISI-core collection), as they had some relation to design, such as 'Innovation and Management Review'. However, it was excluded based on the research team's evaluation criteria. Second, some journals were excluded that did not cover key topics, such as journals: design and culture, design for culture, design for health, and journal of design history.

On the other hand, some publications (i.e., editorial board, introduction, reviews, articles, and other sources) were published under the mentioned journals (See Table 1). Roughly were excluded for not having the keywords that serve the research goal and/or for not aligning with the paper topic (i.e., design discipline). Therefore, these publications were omitted based on the research team's opinion and judgment criterion. We specifically selected each journal because we wanted to assess trends in more specific areas. Additionally, by extension, this would have represented changes occurring in a broad spectrum of fields. Figure 1 illustrates the research methodology used for the review of existing work.

Table 1. Journal list and summary of articles and keywords ranged from 2007–2019.

Code	Journal Name	Total Articles	Total Keywords
1	Research in engineering design	271	1315
2	International Journal of technology and design education	441	2185
3	Design studies	390	1798
4	Design journal	1152	5271
5	Co-design-International journal of co-creation in design and the arts	186	955
6	Journal of Engineering design	275	1288
7	International journal of design	252	1218
8	Journal of Engineering design and technology	231	1255
9	Ergonomics in design	81	677
10	International journal of art and design education	274	1524

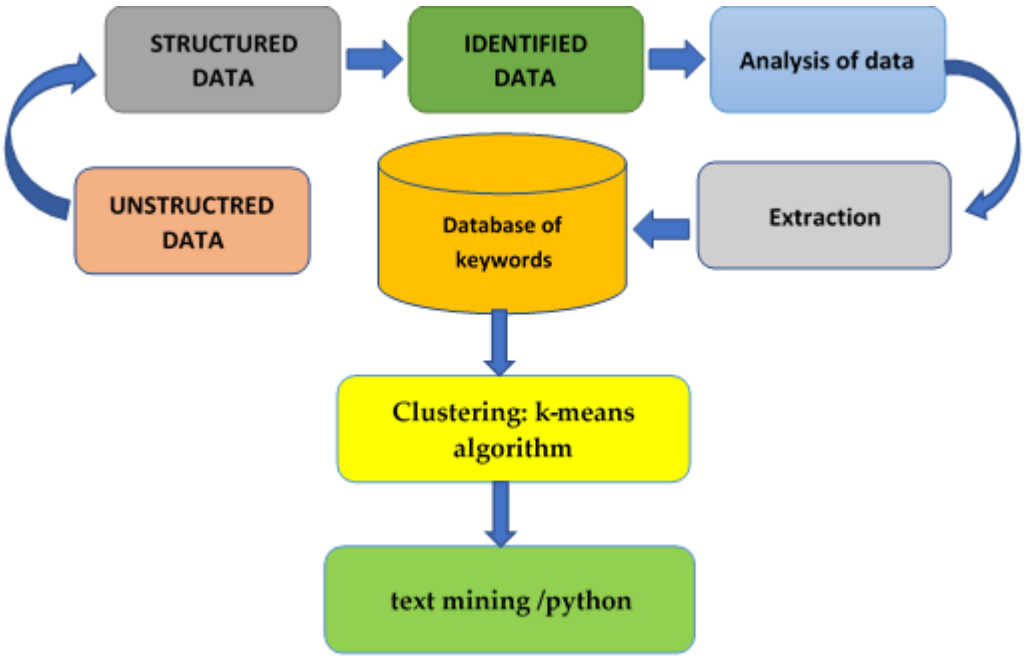


Figure 1. Research methodology used for the review of existing work.

We used the research published in the journals listed in Table 1 with the corresponding study and publication years. The data covered the years 2007 through March 2019. This research report uses 3553 research articles from ten journals and 17,486 keywords. The research titles, publication year, names, and issue numbers were also added to the data collected. We also included publications from each author's website by harvesting data

mining techniques from the data set (structured and unstructured), where the keywords were designated under abstract and separated by a comma or semicolon. The research data were entered into an excel sheet (CSV) file for analysis because this is a Python language-acceptable file format. We created a Python script that extracts knowledge intelligently, automatically, consistently, and reliably from HTML and XML files to compile pertinent and important data. The data patterns that were employed to achieve the intended result were found by a smart correlation engine that was programmed. The results of the experiment demonstrated that a programmed script can mine data repeatedly at the identical levels of accuracy as a human but at highly efficient manner with privilege of ease to convert (e.g., HTML (input) to CSV (output) file format), operate, collect, and associate data.

4. Data Analysis and Discussion

In the following two parts, we will describe the two analysis directions. Using the descriptive analysis, we could relate our literature review and gain a better understanding of the domains. This allowed us to move on to the next step, which involved employing text mining techniques.

4.1. Descriptive Analysis

The research dataset inserted into Microsoft Excel was managed and used to perform a cluster and frequency analysis. In the beginning, we considered the distribution of publications per year, as shown in Figure 3. Research in design fields attracted and flourished in the ultimate few years, which appeared normal due to the vogue of the design domain and technological improvement. Furthermore, a few of the selected set of journals/publications were founded between 2007 and 2011 (See Figure 2), which brought an essential decrease in the number of keywords' frequencies (See Table 2). The next step of the analysis was to produce an initial keyword distribution, where the frequency of top/popular keywords was expected (See Table 2). Unsurprisingly, the design showed the top keyword with the highest frequency among all keywords. It seemed like the desired result based on our selection of journals. Table 2 offers perceptions of other keywords that abundance the domain. The frequencies of the keywords are very different; the data limits the repetition of the keywords and explains the use of high-frequency associated keywords. Table 2 represents the keywords with the highest frequency. While Figure 3 shows the distribution of publications per year and leads to the publication distribution per journal. Keywords such as design education, design, creativity, co-design, design process, participatory design, innovation, and product design appeared as the top keywords with the highest frequency in the literature that attracted more research in the last few years. Furthermore, we found that the keywords, such as design thinking, technology education, design research, collaborative design, conceptual design, sustainability, and design cognition, drew more attention and attraction.

Table 2. The keywords with the highest frequency.

Keyword	Keyword	Keyword Count
0	Designeducation	185
1	design	181
2	Creativity	163
3	product design	122
4	co-design	117
5	Designprocess	115
6	Participtorydesign	108
7	Innovation	107
8	Designthinking	97
9	Technologyeducation	87
10	Designresearch	86

Table 2. *Cont.*

Keyword	Keyword	Keyword Count
11	Collaborativeresearch	79
12	Conceptualdesign	78
13	Sustainability	77
14	Designcognition	74
15	Designtheory	70
16	Servicedesign	69
17	Engineeringdesign	66
18	Industrialdesign	66
19	Designpractice	64
20	Interactiondesign	62
21	Collaboration	58
22	Designmethods	54
23	Designtools	49
24	Casestudy	48
25	Education	45
26	Aesthetics	44
27	Communication	44
28	Designactivity	42
29	Evaluation	42
30	Architecturaldesign	42
31	Socialinnovation	42
32	Productdevelopment	39
33	Designknowledge	37
34	Learning	36
35	Pedagogy	35
36	Technology	35
37	Arteducation	35
38	Protocolanalysis	34
39	Designmanegment	33
40	Researchmethods	33
41	Architecture	32
42	Usability	31
43	Participation	31
44	Healthcare	31
45	Designmethodology	30
46	user-centereddesign	30
47	Problemsolving	29
48	Simulation	28
49	Sustainabledesign	28

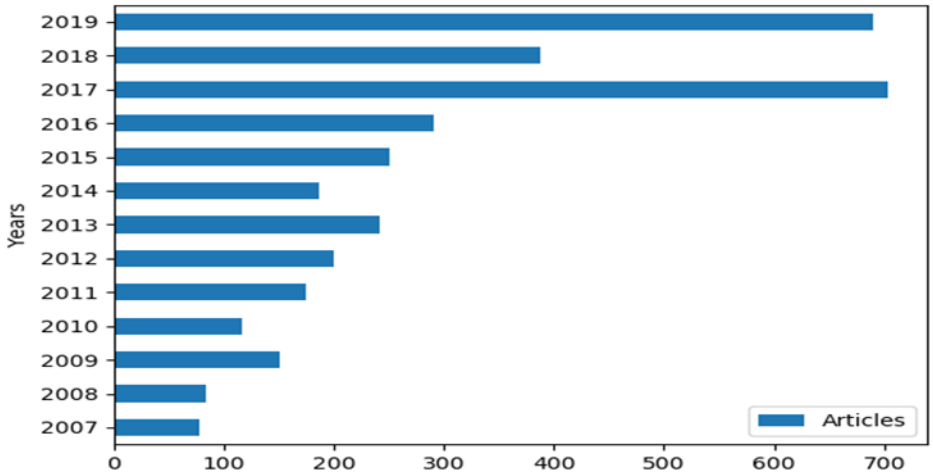


Figure 2. Distribution of publication per year.

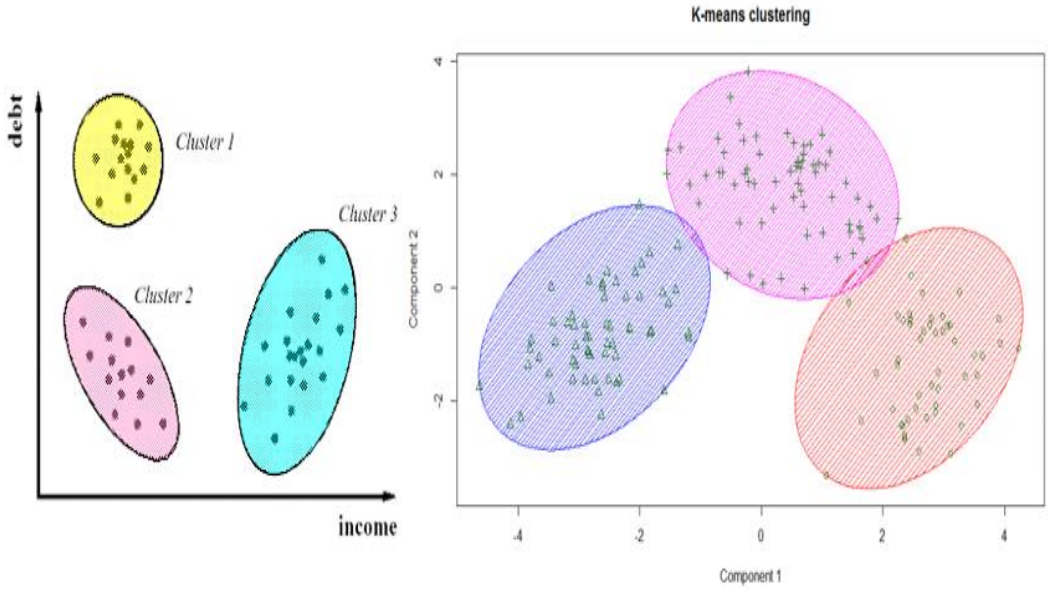


Figure 3. Clustering in more quantitative.

4.2. Text Mining Analysis (Clustering)

The document clustering text mining model was utilized to answer the study's research questions. Clustering is a collection of data reduction techniques used to group similar observations in a dataset so that observations in the same group are as similar as possible, and observations in different groups are as different as possible.

In this study, K-means was used, which is a cluster analysis method that groups observations by minimizing Euclidean distances between them. The difference between two observations on two variables (x and y) is plugged into the Pythagorean equation to solve for the shortest distance between the two points in Euclidean distances (length of the hypotenuse). Figure 3 illustrates clustering in more quantitative.

In this approach, clusters of keywords were created using the k-means clustering algorithm. Because it is practical, easy to use, and successful, the k-means method is frequently employed in clustering algorithms. This process does not need supervision, nor does it have predefined labels or classes. This process involves the formation of clusters determined by the similarity of keywords. A corpus summarization is provided by the clustering of algorithms that may be used to offer insight into what is contained in the corpus [42,43]. The "k" within the k-means clustering algorithms represents a predetermined number of clusters. The algorithm generates k random points as initial cluster centers. The algorithm then assigns each point to the nearest cluster center. A convergence criterion is then achieved by re-computing the new cluster centers until there is no more change occurring [44]. The method illustrates in Figure 4.

Text mining analysis can, therefore, be conducted using several tools. For instance, in this study, Python <www.python.org> was used to perform the text mining technique. Python is an open-source language that is commonly used for text processing. Moreover, it is popularly used because its packages are highly flexible [45]. NumPy, pandas, and sci-kit-learn python packages were used in performing k-means clustering. Besides, NLTK (the Natural Language Toolkit package) was also used to perform pre-processing tasks on the data [46]. For instance, a 'regular expression' in Python was used to convert the texts to lowercase and remove punctuation and numbers [45]. Figure 5 shows the distribution of publication per journal with number of articles in each.

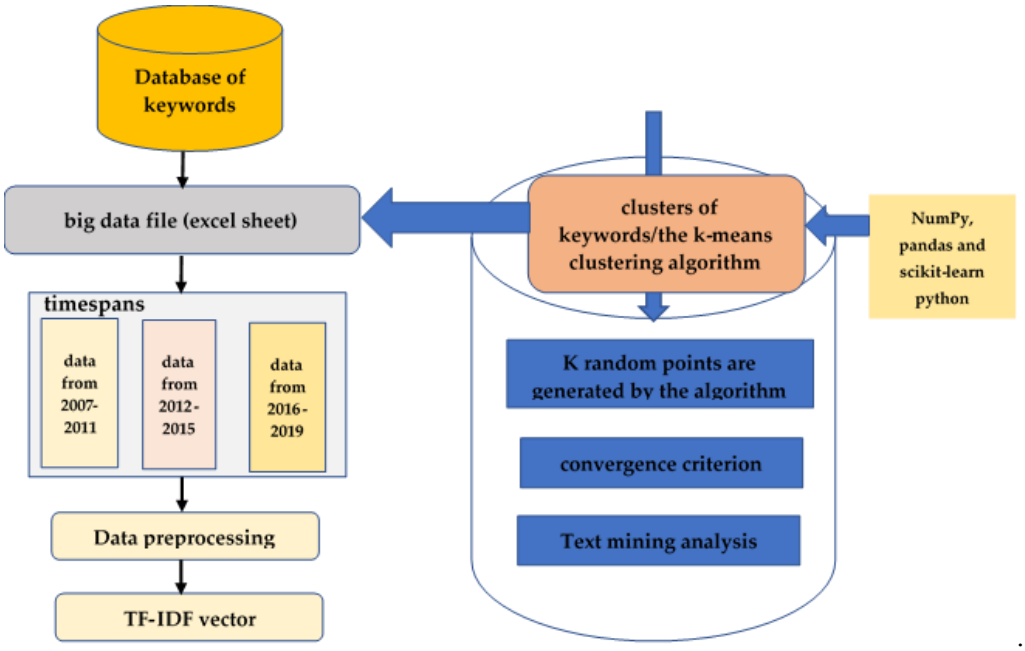


Figure 4. Flow diagram of the entire approach.

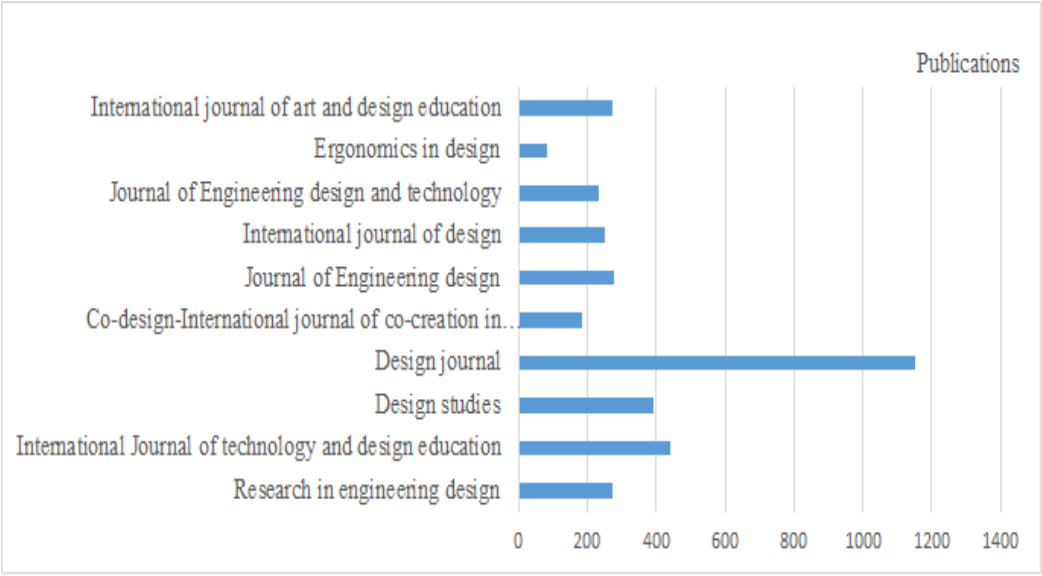


Figure 5. Distribution of publication per journal.

In order to classify the keywords into text mining models (i.e., clusters) using the k-means clustering method, we combined all articles' keywords into one big data file (excel sheet) and manipulated each article's keywords one by one as one document (i.e., 3553 documents). Thus, we imported the data into Python and divided the whole dataset into three different time-span (i.e., corpora) based on their related publication year (variable; See Figure 6). The first time span (corpus) comprised data from 2007 to 2011, and the second time-span comprised data from 2012–2015 and third time-span comprised data from 2016–2019. This division was essential to answering the research questions and analyzing the design of research disciplines for each corpus.

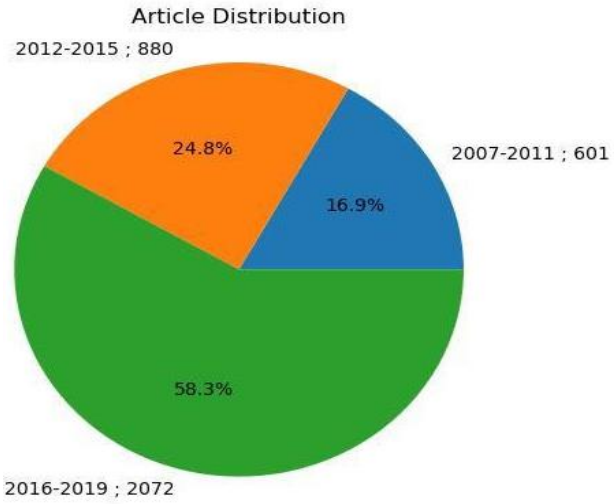


Figure 6. Research articles distribution according to three time spans.

4.3. Clustering Results

We changed the time span and uniformed all the keywords by setting lowercase letters to produce the expected results. Any other insignificant signs that include marks, signs, words, numbers, and full stops were removed from the clusters because they had no values in the analysis. We generated equations to manipulate the compound terms, for example, to have the design process as a single term as seen; this will help research and interpretations.

TF-IDF is a weighing schema commonly and widely used during text mining research [46]. This research involved the calculation of the TF-IDF vector for each document instead of using a simple term document frequency by keywords. TF is term frequency while IDF is the inverse of document frequency [47]. The frequency of a particular word in a document is counted using the term frequency. The IDF's value determines a word's importance in a document. Additionally, inverse document frequency is determined by taking the quotient of the number of documents containing the term (DF) and the total number of documents (N) and finding its logarithm (log(N/DF)). The IDF value represents the frequency at which a word appears in a document file. This value may increase when some documents contain specific words among other documents. In this regard, the most frequent words represent each cluster.

Nevertheless, in using the k-means cluster for this study, the K-means clustering algorithm was used in defining the number of clusters (k). The best numbers of clusters for this study were specified based on a trial and error approach [47]. This was done by comparing the values of k that were clustered against the value of k that is most applicable in each dataset. Ten clusters were used in this study. The research shown in Figure 6 is the general distribution of publications grouped by category of time-span. About 16.9 % of the publications were made between the time-span of 2007 to 2011. Additionally, during the period between 2012 and 2015, 24.8 % of the publications were made, while 58.3 % of the publications were made in the period between 2016 and 2019. The total number of keywords for every time span is shown in Figure 7. About 16.1% (2813) of the total keywords (17,486) related to all gathered publications fall from 2007 to 2011. On the other hand, 24.7% (4318) fell from 2012 to 2015, while 59.2% (10,355) fell from 2016 to 2019.

The frequencies of samples were decomposed for the same period, as shown in Table 3. The design research topic is essential, especially in designing the research topic by the keywords' distribution. Table 3 shows the keyword distribution with general terms, where the first time span (2007–2011) included very few keywords related to the design research discipline less than ten times. This research is limited in its coverage of the first time span for the selected papers' titles and related concepts to design topics. However, we provided

a justification based on the frequency of keywords in this period compared to the frequency of total keywords, which were mentioned in the second and third time-spans.

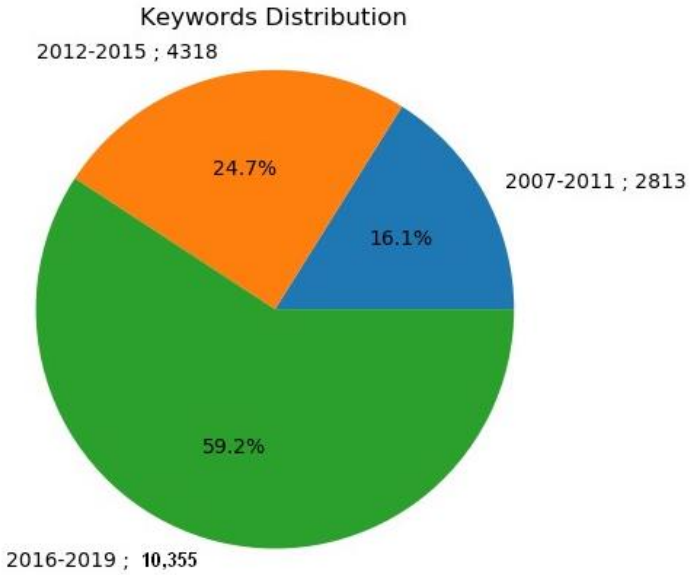


Figure 7. Research keywords distribution according to three-time spans.

Table 3. Sample of terms distribution by the three time-spans.

Term	2007–2011	2012–2015	2016–2019
0 creativity	40	48	68
1 product design	30	31	48
2 design process	27	31	49
3 design education	25	49	97
4 collaborative design	24	18	27
5 design	23	40	117
6 conceptual design	23	27	20
7 technology education	23	25	25
8 engineering design	21	19	15
9 innovation	18	24	30
10 design cognition	17	19	26
11 design theory	16	20	28
12 industrial design	16	32	12
13 communication	14	18	10
14 design practice	14	10	30
15 design management	0	17	18
16 problem solving	13	0	0
17 aesthetics	13	10	21

The results of this part of the research will be discussed based on the clustering method. Following the previous study, we reduced the number of concepts in each cluster to 10 and the number of clusters in each period to 10 conducted by Abu-Shanab and Harb [48]. We renamed each cluster for a better name based on the relationship and cluster associate information. Each cluster has been separated from the other, clearly using the unique words that best describe the cluster. The results have exposed each cluster according to the time differences, which directs future research. Some keywords closely related to the clusters were not included during the labeling of the clusters. Keywords such as technology, designs, technology, and architecture have forced us to verify the existing general keywords cautiously, which has helped the clustering process. We also came up with some restrictions to govern the blurrier of the clusters. The clusters have been estimated for a time-span of three, as shown in Figures 8–10. The conceptual variance represents the similarity

between clusters as portrayed by the intelligent algorithm in the world of miscue [49–51]. Our discussion has been set on the rigorous list of keywords collected from very popular designs that are highly known, as seen in Table 2.

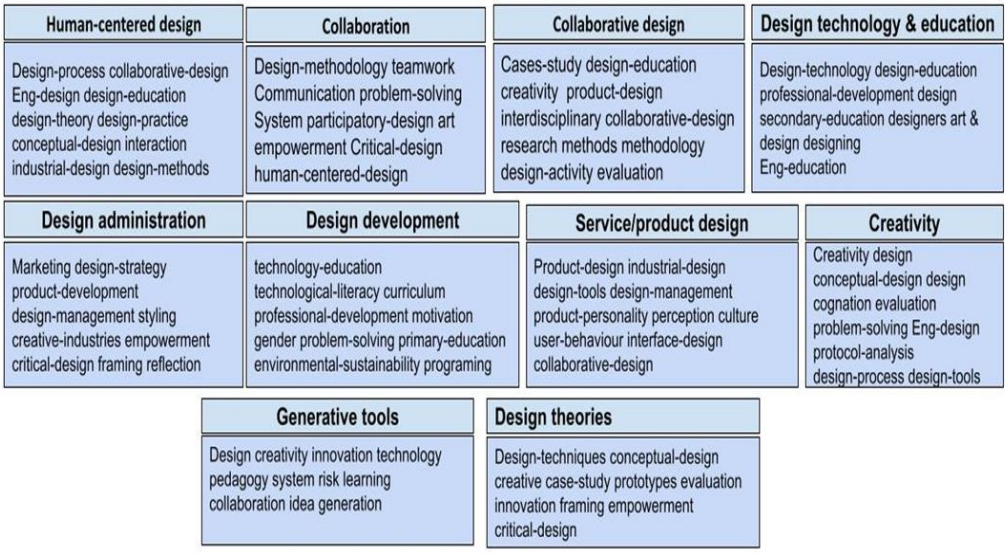


Figure 8. The ten clusters for the time span 2007–2011.

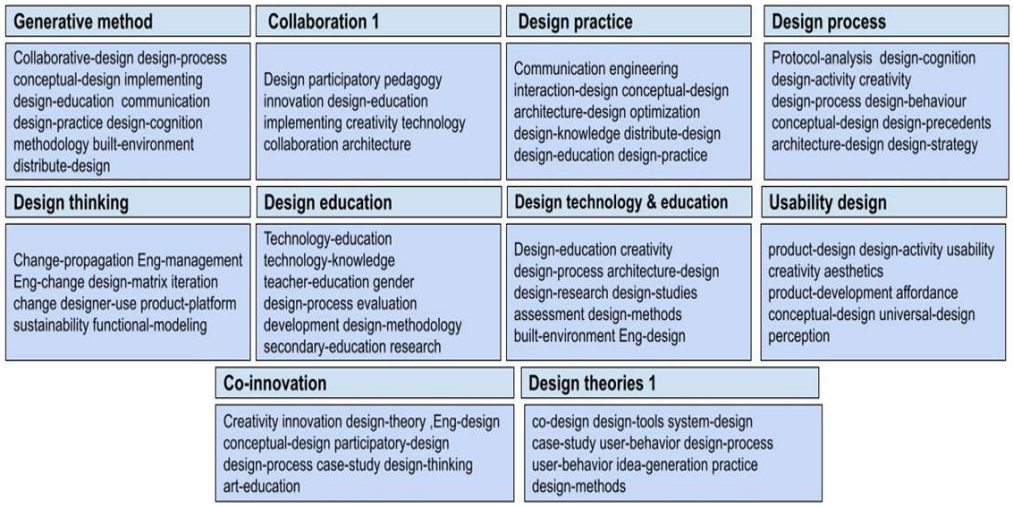


Figure 9. The ten clusters for the time-span 2012–2015.

The previous results regarding the clustering step exposed a few research directions to carry on, where some terms appeared in the three time-spans. The following research directions existed in the three periods:

- *Co-creation:* for instance, that work is related to design thinking, innovation, creativity, design process, and design.
- *Co-innovation:* increasing the number in design research fields is a hot topic, and it seems very motivating as it appeared in three periods with a greater concern on collaborative design.
- *Ethical design:* offer new insights/knowledge about the design process within design research.
- *Social practice design:* it is essential to associate terms that focus on its adoption and other elements affecting the area—research related to participatory design, collaboration, sustainability, design innovation, and articulating design.

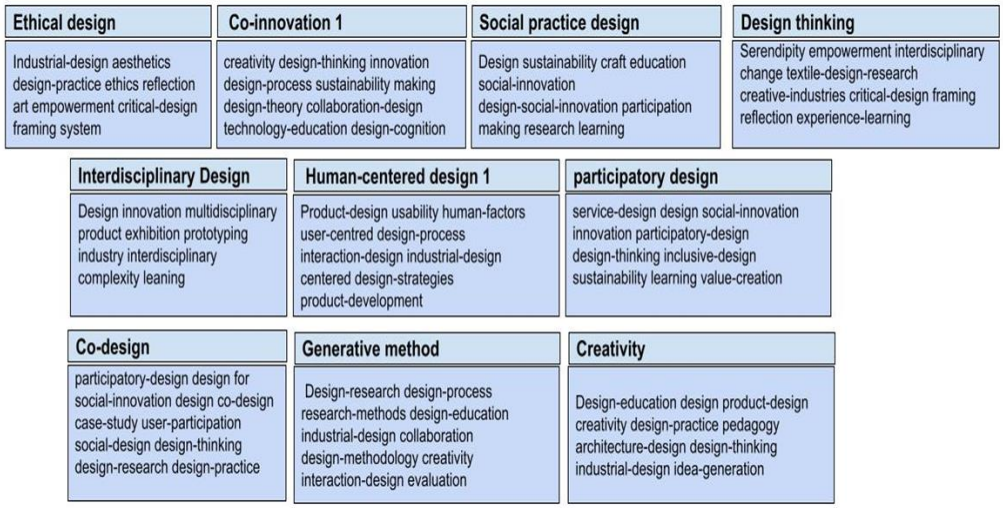


Figure 10. The ten clusters for the time-span 2016–2019.

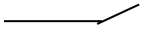
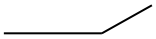
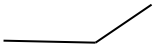
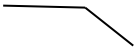
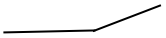
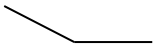
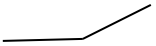
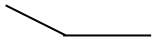
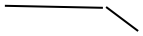
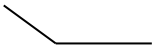
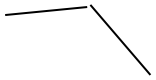
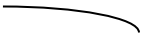
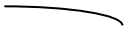
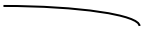
On the other hand, research areas/topics that began gaining popularity later, particularly during the last period (based on word frequencies), were related to design, creativity, education, research, co-design, design process, and participatory design. Identifying the relevance of examining clusters is best explained by analyzing keywords is important. The selection of keywords by the author had issues of significance, whereby it was not consistent. The limitation of keywords would have been the best if it had been concentrated on. Our results were based on the author's arguments in a three-time period. We decided to contrite on the last two periods to bypass the limitations. (From 2012–2019), although this was likely to divest our analysis of depth over time. On the other hand, splitting the data range into last two periods (time-spans) would lead to the same limitation.

4.4. Word Frequency Distribution

A word frequency distribution was used depending on the period with the study of Abu-Shanab and Abu-Baker [52]. Abu-Shanab and Abu-Baker [52] estimated the frequencies of all famous words within the clusters, after which they were summated into major concepts. Their research paid attention to mobile phone purchases and use by applying mixed methods and new methodologies that aided us in this research study. In addition, the estimations that were used also focused on three periods. The data shown in Appendix A was generated using a clustering tool. The clustering tool was used to create the data provided in Table 3. The magnitude was assigned to the frequency regarding the total size of frequencies, after which it was compared with other terms. This would help the readers recognize the popular terms within the data. The list of a popular terms produced by the clustering process was taken and summated manually into logical terms as shown in Table 4. Frequency distribution depends on a sample of the dataset. Text analysis was the basis of determining the frequencies and clustering words in this research.

A summation of keywords followed this step into more general dimensions (See Figures 8–10). Figures 8–10 across the period were drawn using the research directions that interest the researchers. Furthermore, we summed the new set of clusters into ten major dimensions according to each period (See Figures 8–10). The following trend can be seen based on this kind of analysis (i.e., text analysis). On the one hand, we experienced the thriving direction of some clusters such as design, co-design, creativity, innovation, design-thinking, participatory design, sustainability, design education, and design research.

Table 4. General terms and their corresponding frequencies.

Terms	2007–2011	2012–2015	2016–2019	Trend Lines	General Term
Service design	9	9	43		Co-design method and approach
Design tools	9	11	24		
Design research	9	16	54		
Participatory design	9	18	59		
Design methodology	8	8	0		
Collaboration	8	14	32		
Participation	0	0	17		
Design graphic	7	0	0		Anthropomorphic design
Usability design	0	0	17		
Emotion	7	0	0		
Perception	7	8	0		
Interface design	8	0	0		
Philosophy of design	7	8	0		Assumptions, foundations and implications of design
Design fiction	0	0	21		
Technology design	7	0	19		
Design strategy	7	7	0		Eco-design strategy
Sustainability design	8	10	51		
User participation	7	0	0		Co-innovation
User-centered design	0	0	17		
Co-innovation	0	3	23		
Product experience	7	0	0		Co-production
Product development	0	0	10		
Design management	0	17	18		
Ethical design	0	6	19		Social-practice design
Inclusive design	0	0	8		
Speculative design	0	0	17		
Social design	0	0	16		
Social practice design	0	2	21		

On the other hand, we observed diminishing interest in the design strategy, perception, epistemology, philosophy of design, and pedagogy. This was unexpected considering the related literature research. Most of the terms/topics listed in Table 4 appeared to be very motivating though some of them faded in the first period (2007–2011). However, the terms/topics in the last period appeared interesting for the researchers from 2016 to 2019. It is necessary to reveal the logic behind our classification approach, where terms (see Appendix A) such as 'design strategy' might open an argument: is it a design-related issue or any design discipline? Similarly, do aesthetics only belong to usability/user experience or might they fit in a graphic design domain is also a question. Thus, these terms and others will open debates leading to enriching the topic and figures the strength of design research theories and methodologies.

5. Conclusions

The study aimed to explore the research directions with the design research topic. The study journals selected were of higher quality, congregated different keywords from different articles, and were used in the analysis. Ten journals were chosen for 3553 research articles and 17,486 keywords. This big dataset, a rich sample of keywords, was analyzed to conclude the design research's main directions. New terms/trends were investigated as results in the design domain, attracting researchers, practitioners, and journal editorial boards. It was found that topics like co-innovation, ethical design, design thinking, co-design, creativity, social practice design, and generative methods/tools have been attracting more research. On the other hand, researchers persisted in pursuing topics such as collaborative design, human-centered design, interdisciplinary design, design education, participatory design, design practice, collaborative design, design development, collaboration, design theories, design administration, and service/product design areas. Finally, researchers and/or practitioners' pursuit of a framework as guidelines to study the design research has faded. The design research area is guided by design theories (for researchers' issues), design methodologies (for researchers, managerial, and/or administrative matters), and design methods/tools (for researchers' and practitioners' issues). A term distribution and analysis were founded based on the dataset and trend analysis (See Appendix A). The results identified ten main clusters/categories in each period, with a few overlapping among them during different periods (See Figures 8–10) that govern research in other design areas. The first period (2007–2011) focused on topics like collaboration, human-centered design, collaborative design, design development, design administration, design technology and education, service/product design, creativity, generative tools, and design theories. The second period (2012–2015) focused on productive method, collaboration 1, design practice, design process, design thinking, design education, design technology, usability design, co-innovation 1, and design theories 1. The last period (2016–2019) focused on ethical design, co-innovation 1, social practice design, design thinking 1, interdisciplinary design, human-centered design 1, participatory design, co-design, creativity 1, and generative method 1.

5.1. Contributions

This research study utilized one of the most extensive samples of publications (i.e., papers). Prior research studies relied on the qualitative method and piece-by-piece assessment and had a tiny sample size (i.e., small sample size). A total of 17,486 words from design journals were used in this research report. The key categories examined and presented in this paper could determine what fields are thriving and degrading. In this study, the sample dataset underwent a quantitative analysis. A quantitative analysis was conducted to prevent author bias when analyzing research and how we look at and analyze the data collected. Future scholars might examine and cluster the information acquired in this research study (data available in Appendix A can be used manually). Each researcher will have a unique perspective and thoughts on the subject domains. Finally, the work is the first attempt to use text mining to examine research directions in design research. Additionally,

this research study provides perceptions/observations concerning new dimensions critical in the design and associated areas.

Importantly, we start classifying text as easily as possible using pre-trained BERT models. However, we found that BERT has many parameters and requires high computational resources, which are not available in our lab research. Training a model takes a lot of time and money. For future work, we will combine text mining with another existing embedding model called GloVe to accelerate the training speed of the model.

5.2. Limitations

This research paper was limited by the total number of journals used (web of science (ISI-core collection database) for data gathering. This limitation calls for a more thorough research or in-depth research projects using a more efficient approach. Design research topics are not only decisively published within the list of journals (design research is also published in chapters' books and at proceedings' conferences) used in this research paper (See Table 2). Furthermore, some journals (i.e., The Design Journal and Design Issues) were excluded due to the research team's criterion, even when they considered them significant in the design discipline. They could have led to some compelling results. In addition, the accessibility of data (i.e., keywords fetching) within each time span is considered another restriction, as the first time-span (2007–2011) comprised fewer articles than the second and third time-spans. This research paper declares this limitation important but contributes by providing an initial insight into the design research area.

Another limitation we faced in this research study was our judgment about the clusters/categories built (manual clustering as we categorized each 10 clusters into main categories based on authors' experience, knowledge, and previous studies in design research). The types (See Figures 8–10) built are significant for future design research. Research studies [53,54] found that the design domain is derived from four dimensions based on design aspects. Those dimensions included composition, performance, experience, and communication. The measurements might be considered vague when observing the results of this research study. Therefore, we summarize that the fragmented nature of the design areas among different disciplines and the various topics that shape it (i.e., industrial, ergonomics, engineering, design and technology, ICT, and design and arts) prevent theory conceptualization.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/electronics11233930/s1.

Author Contributions: Conceptualization, M.N.; A.L. and U.T.; methodology, M.N.; software, H.L.; validation, M.N.; A.L.; H.L. and U.T.; formal analysis, A.L. and H.L.; investigation, R.A.Z.; L.A. and A.H.G.; data curation, M.N. and U.T.; writing—original draft preparation, M.N.; A.L.; H.L. and U.T.; writing—review and editing, M.N. and L.A.; visualization, R.A.Z.; L.A. and A.H.G.; supervision, M.N.; funding acquisition, A.H.G. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The Dataset was uploaded within supplementary files via system.

Conflicts of Interest: The Authors declare that there is no conflict of interest.

Appendix A. The Most Popular Terms

Term	2007–2011	2012–2015	2016–2019
creativity	*47*	*48*	68
product design	*35*	*39*	48
design process	*31*	*35*	49
design education	*30*	*52*	97
collaborative design	*29*	*23*	27
design	*24*	*40*	117
conceptual design	*26*	*32*	20
collaborative design	*23*	*25*	25
technology education	*26*	*25*	15
engineering design	*29*	*30*	48
innovation	*17*	*19*	26
design cognition	*19*	*23*	28
design theory	*16*	*32*	12
industrial design	*16*	*18*	12
communication	*14*	*10*	30
design practice	*0*	*17*	18
problem solving	*13*	*0*	0
aesthetics	*13*	*10*	21
interaction design	13	13	21
product development	12	10	0
case study	12	18	0
design methods	11	15	23
architectural design	11	15	0
evaluation	11	12	16
design activity	11	17	0
creative design	10	0	0
teamwork	10	3	0
service design	9	9	43
technological literacy	9	0	0
research methods	9	10	10
design tools	9	11	24
design research	9	16	54
participatory design	9	18	59
design methodology	8	8	0
collaboration	8	14	32
curriculum	8	9	0
sustainability design	8	10	51
interface design	8	0	0
learning	7	0	18
technology	7	0	19
architecture	7	0	0
culture	7	0	0
design strategy	7	7	0
graphic design	7	0	0
emotion	7	0	0
perception	7	8	0
philosophy of design	7	8	0
user participation	7	0	0
product experience	7	0	0
healthcare	0	0	25
interdisciplinary	0	0	21
craft	0	0	22
design fiction	0	0	21
circular economy	0	0	20
design management	0	17	18

Appendix A. *Cont.*

Term	2007–2011	2012–2015	2016–2019
usability design	0	0	17
user-centered design	0	0	17
speculative design	0	0	17
participation	0	0	17
social design	0	0	16
decision making	0	0	16
product development	0	0	10
inclusive design	0	0	8
epistemology	0	0	8
art education	0	11	16
empathy	0	0	16
pedagogy	0	0	16
epistemology	0	0	8
co-innovation	0	3	23
ethical design	0	6	19
social practice design	0	2	21

Appendix B. List of Abbreviations

Abbreviation	Description
CAD	computer-aided design
ICT	Information and Communication Technology
IT	Information technology
MDO	Multidisciplinary Design Optimization
AM	Additive manufacturing
ABSA	The aspect-based sentiment analysis
MTMVN	multitask Multiview network
SOTA	Most State-Of-The-Art
NMT	Neural Machine Translation
LRLs	Low-Resource Languages
TL	Transfer Learning
CDCAT	Cross-Document Coreference Annotation Tool
ESCI	Emerging Source Citation Index
CSV	excel sheet
HTML	Hypertext Markup Language
XML	extensible markup language
TF-IDF	term frequency-inverse document frequency

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