Hotspots and Trends in Creativity and Design Research: A Knowledge Graph Analysis

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Abstract: Design creativity is the process or result of extending, presenting and interpreting creative ideas and concepts in a design way, the role of design creativity in corporate creativity activities has drawn increasing attention from the academic community. However, limited research has tried to holistically summarize the research trends and hotspots in the context of creativity and design. Through knowledge graph analysis, this paper analyzed the academic literature from Web of Science and visualized the knowledge domain in creativity and design research from 2010 to 2019. It has been found that the number of creativity-related design papers is increasing rapidly with a total of 498 papers. The top 15 co-occurring keywords include "design creativity", "innovation", "design making", "engineering design", "design education", "divergent thinking", "representation", "student", "knowledge", "aesthetics", "design process", "perception", "product design", "fixation" and "quality". The research that focuses on this topic could be summarized into eleven clusters namely industrial design, disability, design activity, explanatory design, design education, assessment, users, design fixation, design theoretic, TRIZ, and art education.

Keywords: Creativity · Design Research · Citespace · Graph Analysis

1 Introduction

Design creativity is the process or result of extending, presenting and interpreting creative ideas and concepts in a design way. It includes industrial design, architecture design, packaging design, service design, graphic design, fashion design and so on [1]. Take the role of creativity in product design as an example, either product functions or forms have undergone a dramatic change [2]. Regarding smart products that have ushered in new development opportunities, it is necessary for traditional products to consider the current rapidly changing market needs [2]. Exploring new development directions of traditional products under the background of rising manufacturing costs and innovation, we might reconsider the significant role of creativity in enterprise development and design process [3]. In the process of transformation and upgrading, enterprises get rid of the factor-scale development mode, and creativity in the design process plays an imperative role in transmitting business into a more sustainable model [3]. In the

long run, the continuous improvement of production factors will reduce the cost difference between enterprises, and creativity and innovation might become the key impetus for enterprises to shape their new core competitiveness [4].

Another example is promoting creativity in design process and education. Kids, students, or junior designers tend to have a higher intention to pursue the difference in their works' performance, form, connotation and style in their design process. In other words, not following the established thinking patterns, they try to break the routine, expand thinking outward, give their works unique connotations, and show their insight into art [5]. Thus, the vitality of design is the unconventional expression of personality, where the value of design creativity lies [6]. When applying creativity into enterprise development, it could help enterprises to include unconventional expression of personality as well as integrating roles of technology and market factors in design activities. Dosi [7] proposed that market pull and technology promotion are the main driving forces for creativity and innovation. Based on the perspective of product development, Vergant et al. [8] considered design creativity as the third driving force behind the market and technology and explored the relationship between three factors. To be more specific, creativity has a directional guiding role in the choice of corporate development strategy. While the level of technological innovation reflects the driving force of the company's development, the design creativity reflects the decision of the company's product development direction.

Although creativity in the design research is an interdisciplinary field which contained design framework, computer science, management & marketing, and innovation system [9-10], limited research has tried to holistically summarize the research trend and hotspots. Indeed, it is theoretically significant to visual the knowledge graph of the role of creativity in the design research, which facilitates relevant researchers to understand this research hotspot and the development trends. Thus, this paper tries to fill in this research gap by analyzing and visualizing the network of co-occurring keywords and the research clusters via Citespace. Based on the data from Web of Science Core Collection and a visualization tool, Citespace, we tried to get a whole picture of the patterns and trends of the role of creativity in design research from 2010 to 2019 [11].

2 Paper Preparation

Regarding the data collection process, the articles were collected according to the Boolean logic of Web of Science search using the subject index (TS) = "design" and "creativity"; the document type is "article"; the language is English, and the timespan is 2010-2019. All the documents are collected from the Web of Science (WoS) Core Collection of Thomson Reuters including SCI-Expanded, SSCI, A&HCl, CPCI-S, CPCI-SSH, ESCI, CCR-Expanded, and IC. A total number of 498 articles were retrieved and exported to Citespace for further analysis [12].

As a Java application for scientometric processing and visualizing scientific works [11], Citespace could analyze academic literature on their co-citation references, co-authors, and co-occurring keywords [12]. In order to explore the nature of a knowledge domain, co-occuring keywords, betweenness centrality, and time-related cluster networks, are used to describe the research trends and the research focus [12]. More spe-

cifically, there are mainly six steps to process the data: time span allocation, thresholding, pruning, clustering, and visualization. It is normal to not set pruning in the program, because the nature of the scientometric data set is usually very sparse [12].

Therefore, we can check the knowledge graph of a specific topic by visualizing the relationship between different articles. Retrieve article records of titles, keywords, abstracts, and identifiers and use them to analyze current research frontiers. Therefore, by identifying nodes with higher intermediateness, it is easier to access the connections and relationships between different articles [12]. The relationship between keywords is highlighted with solid line in Figure 1. Lighter lines indicate earlier times, while darker lines indicate later times.

The betweenness centrality is calculated by the equation below:

$$\text{Betweenness Centrality } (Node_m) = \sum_{m \neq n \neq p} \frac{\rho_{np}(m)}{\rho_{np}}$$

To specify, ρ_{np} refers to the quantity of shortest paths between node n and p, and $\rho_{np}(m)$ refers to the quantity of those paths that go through the $Node_m$.

In this way, knowledge graph analysis can help illustrate the current research priorities and emerging areas of design research related to creativity. Unlike scholars' traditional summary of creative-related design research, knowledge map analysis can more objectively test the research frontier on the role of creativity in design research and application.

3 Results and Discussion

Keywords in the field of creativity in design research can reveal the focus of this field. As shown in Figure 1, all papers with a time span from 2010 to 2019 were analyzed, and the co-occurrence network of keywords was checked by the minimum spanning tree (MST) algorithm. Each node displays a keyword whose size indicates the frequency of common key-words of all the papers. Colored links between nodes show their chronological order: dark (purple) is related to later trends, while light (red) is related to previous trends. The network shows the relationship between each keyword and the top 15 cited concurrent keywords. More specifically, keywords surrounded by dark (purple) colors show higher intermediateness and importance. In general, nodes with high frequency and intermediate centers are considered as key nodes in the network. [11]. As suggested in Table 1, “creativity” enjoyed the highest frequency of 203, followed by “innovation” (52), “decision making” (39), “engineering design” (23), “ design education” (21), “divergent thinking” (19), “representation” (17), and “student” (13). Thus, “creativity”, “innovation”, “decision making”, “design education”, “divergent thinking”, and “representation” are considered as the key factors in the network.

Table 1. Co-occurring keywords centrality and count for creativity in design

Key words	Betweenness Centrality	Starting Year	Counting
Design creativity	0.07	2010	203
Innovation	0.11	2010	52
Decision making	0.14	2010	39

Engineering design	0.07	2011	23
Design education	0.24	2010	21
Divergent thinking	0.09	2012	19
Representation	0.02	2015	17
Student	0.30	2011	13
Knowledge	0.09	2013	13
Aesthetics	0.03	2013	13
Design process	0.03	2011	13
Perception	0.03	2015	12
Product design	0.02	2014	9
Fixation	0.14	2014	8
Quality	0.01	2013	7

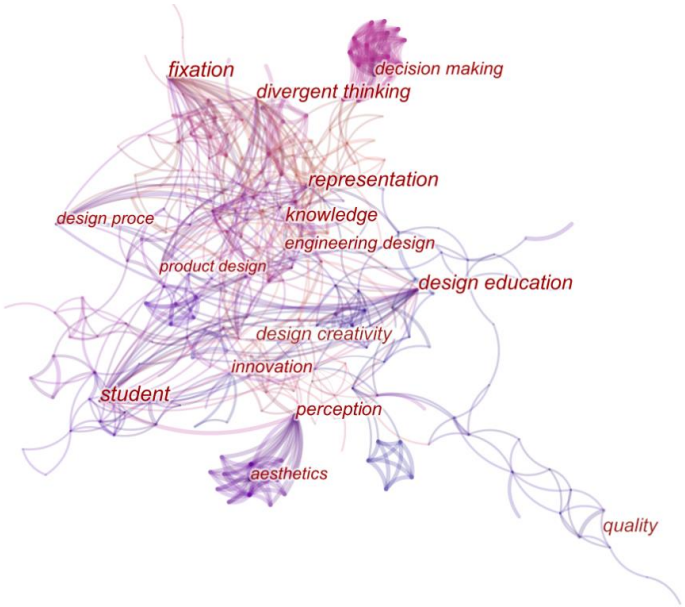

Fig. 1. Co-occurring keywords for creativity-related design research

Silhouette is a measure of how similar a node is to its genus cluster compared to other clusters. Its value ranges from -1 to 1. A larger value indicates that this node more closely matches its genus cluster rather than adjacent clusters. If most nodes have a high silhouette value (silhouette score> 0.5), then the number of clustering is appropriate [12]. Thus, all papers can be summarized into eleven clustering labels according to time series, as shown in Figure 2. Detailed descriptions and typical paper summaries of each cluster are as follows.

Based on the latent semantic index (LSI) clustering algorithm, eleven clusters were showed via processing sematic abstract of all the papers in Figure 2: industrial design, disability, design activity, exploratory design theory, design education, assessment, users, design fixation, design theoretics, TRIZ, and art education. To be more specific, as

for industrial design, the typical paper is "Managing Creativity: A Gap Analysis Approach to Identifying Challenges for Industrial Design Consultancy Services" [13], which emphasizes the creativity application in an abstract system-level modelling and simulation framework (ARTS) for industrial design consultancy. As for disability, the research mainly discussed the creative application in ergonomic design for disability. For example, Wignjosoebroto et al. [14] designed a wheelchair for aging disable people. For design activity, the research mainly analyzed the personal creativity modes from design perspective and even introduced the way to exploiting creativity modes for team members [15]. Different from design activity, creativity in user-driven creativity treated user as the center for successive design strategy and further discussed the process how user-driven creativity helped design application [16]. As for exploratory design theory and design theoretics, the former one concentrated on examining the innovative exploration in different design structure [17] while the latter one generally discussed the framework for design theory and creativity practice and introduced a set of knowledge transformer between them [18]. Regarding design education and art education, they are all paying attention to education and related activities; however, the emphasized fields are different: while the former one examined the process to foster creativity of people through design education, the latter one analyzed how design interacted with art, music, drama, and design to support students' creativity [19-20]. Both assessment and design fixation focused on design practice and process. Assessment focused on the feedback strategies in promoting creativity but design fixation mainly discussed its unintentionally limit and mechanism in design research and practice [21-22]. Last, as for TRIZ, a typical paper, "Research and Practice on the Theory of Inventive Problem Solving (TRIZ): Linking Creativity, Engineering and Innovation", mainly discussed a framework which could balance different factors in the design process, such as creativity, engineering, innovation, cost, and trade-off [23].

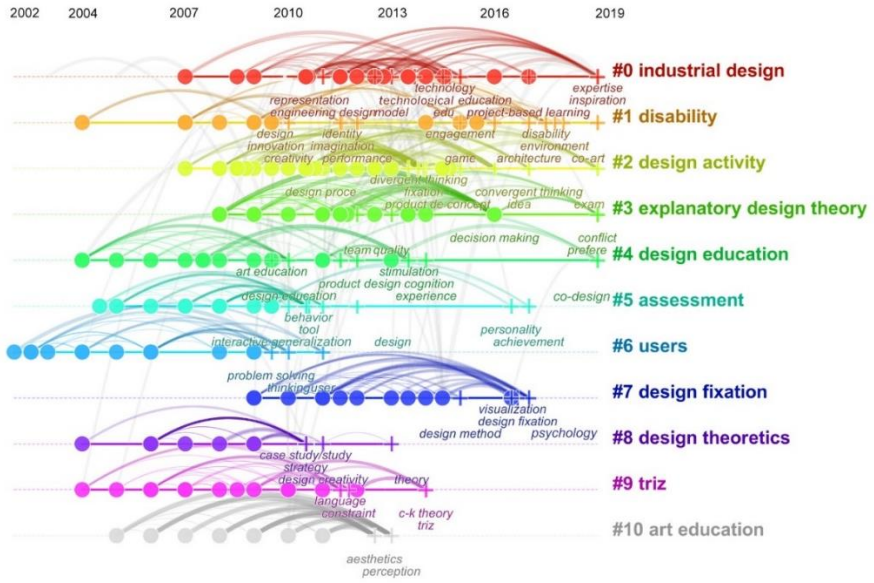

Fig. 2. Research clusters for creativity related design research in time series

4 Conclusion

In conclusion, the current paper tries to discuss the role of design creativity in creativity related researches which have drawn increasing attention from the academic community. However, limited research has tried to holistically summarize the research trend and hotspots. Indeed, it is theoretically significant to visual the knowledge graph of the role of creativity in the design research, which could facilitate relevant researchers to understand this research hotspots and the development trends. Thus, this paper tries to fill in this research gap by analyzing and visualizing the network of co-occurring keywords and the research clusters via Citespace. Through knowledge graph analysis, this paper analyzed the academic literature from Web of Science and visualized the knowledge domain in creativity and design research from 2010 to 2019. It has been found that the number of creativity-related design papers is increasing rapidly, with a total of 498 papers.

Results from the top 15 co-occurring key-words showed the research hotspots on the role of creativity in design research mainly lay in concept exploration ("creativity" and "innovation"), creativity representation ("perception", "representation" and "aesthetics"), thinking pattern ("design making" and "divergent thinking"), product design ("engineering design", "product design" and "quality"), and education ("design education", "design process", "student", "knowledge" and "fixation"). As for the research trends, this topic could be summarized into eleven clusters namely industrial design, disability, design activity, explanatory design, design education, assessment, users, design fixation, design theoretic, TRIZ, and art education. Time series data showed two trends: before 2016, the research trends might be more focused on assessment, users, design fixation, design theoretic, TRIZ, and art education, while the research focus begin to shift to industrial design, disability, design activity, explanatory design and design education after 2016. It suggested research trends might evolve from theoretical exploration and assessment determination to theory application and explanation, which is consistent with the theory of cognitive evolution on creativity [24].

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