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A quantitative approach for assessment of creativity in product design

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ABSTRACT

Most of the assessment of creativity in product design is based on the outcome, not the design process from which the creative ideas are derived. In this paper, we revealed the correlation coefficient of 20 factors critical in the product design process and the quality of design creativity via investigation of the design processes and outcomes of 30 senior student designers. Six closely related factors were identified as variables to calculate the design creativity. An assessment formula was proposed: the corresponding correlation coefficient is the weight factor of each variable, and the sum represents the design creativity degree. Our quantitative approach can improve the validity and reliability of assessment of creativity in product design.

1. Introduction

One of the most important criteria for the quality of performance in design is the creativity applied to the product [19]. Many researchers have developed methods to assess the creativity of product design [27,19,20,51]. However, these subjective and qualitative judgments, in relation to the traditional measurement of creativity, have proved to have insufficient validity and reliability [16]. In most traditional product design studios, assessment of design creativity is based on consensual agreement among evaluators. Aside from the issue of subjective judgment, the selection of appropriate evaluators is a great challenge. Expert judges are difficult to find, and they may develop rater fatigue after a certain number of ratings. In academia, the traditional way that teachers assess creativity has often relied on the assessors' subjective judgment along with a tacit understanding of what is creative. Commonly, there are not enough raters involved in one class, which makes the practice inappropriate from a quality assurance perspective [57,58]. The students may argue that the teacher cannot recognize their creative efforts. Hence, it is urgently needed to build an objective and unified standard for assessment of creativity in design so that the validity, reliability and applicability of assessment can be improved.

Furthermore, creativity is more likely to emerge from the design process, in what is often characterized by the occurrence of a significant event, a 'creative leap' [27]. However, to date, evaluators of creativity are not always well informed of how a design developed, or they are apathetic about the extent to which a final outcome reflects the reasoning of the designer throughout the design process [16]. In other words, most of the assessment of creativity in design is based on the design outcome instead of the design process [26,52]. In recent years, computational creativity has provided a computational perspective on human creativity, but the notion of evaluation is still based on the judgment of whether an idea or artifact is creative or not [60]. The existing method for assessing creativity in design is insufficient, without consideration of the design process.

To address these issues, the purposes of this research were to:

- Investigate the product design process, and consider it as an evaluation criterion in assessment of creativity in product design.
- Reveal the correlation between the quality of design creativity and the product design process.
- Propose a quantitative approach to assess creativity in product design, in order to provide a rigorous method and tackle the constraint of subjective opinions of experts.

In order to achieve these goals, the methodology in this paper was divided into four parts. First of all, stages and steps in the product design process were identified based on a literature review, and the creativity-related factors in the design process were summarized according to previous endeavors in the literature. Second, 30 design-cases were collected and the verbal protocols were analyzed based on the above-mentioned factors of the

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design process. Third, the quality of design-creativity of the 30 cases was evaluated by eight experts using the Consensual Assessment Technique. Last, Statistical analysis were employed to calculate the correlation coefficients of all the factors in the product design process and the quality of design creativity. Based on this analysis, an assessment formula was proposed: the corresponding correlation coefficient is the weight factor of each variable, and the sum represents an estimate of the design creativity. Moreover, another experiment was conducted for the evaluation. The result proved that our quantitative approach can reflect the relationships between the crucial factors of the design process and the quality of creative performance. From this, we now believe that this objective method can improve the validity and reliability of assessment of creativity in product design.

The remainder of this paper is organized as follows. In Section 2, we looked at previous studies for understanding creativity in product design, and assessment of creativity. Our methodology is explained in detail in Section 3. In Section 4, we describe our experiment, including the participants, the procedure, the data analysis, and the representation of our approach for the assessment of creativity. We conclude, in Section 5, with a discussion of the potential implications of our approach, and the limitations as well.

2. Literature review

This research is concerned with assessment of creativity in both the product design process and the design outcome. We undertook a critical review of the literature on product design process analysis and creativity assessment methods in order to place our research on creativity assessment within the context of product design.

2.1. Product design process analysis

Having a full understanding of the process that leads to creative designs is of great interest to both academia and industry. For our research, we referred to the literature relating to two aspects: defining the product design process, and the creativity-related factors in the design process.

2.1.1. Defining the product design process

First of all, we clarify the scope of our research on product design. We argue that product design can be split into two distinct but connected disciplines, engineering design and industrial design. Engineering design concentrates on the factors in product design which concern the product functions. In other words, it aims to make the product work using scientific material and manufacturing knowledge [59]. Moreover, industrial design addresses more the form of the product. It aims to satisfy the customer with its human centered approach [37].

From this, we informed the design process models from both of the two disciplines. Most of the models can be distinguished into descriptive models and prescriptive ones [22]. A generic descriptive model developed by Cross [22] represented the principle of these models. The descriptive models reflected the 'solution-focused' nature of design thinking: identify the needs, and then explore alternative solutions (evaluate, refine, and develop solutions). Sometimes, evaluation highlights problems with the initial solutions, then a new design concept will be generated, and the process starts again. The design process is an iterative loop of design activities [73,64].

On the other hand, the prescriptive models are often regarded as providing a particular design methodology by offering more algorithmic and systematic design procedures. Such models also suggested the basic structure of the design process: analysis-synthesis-evaluation, which were defined by Jones [46]. Archer [5] also developed a three-phase prescriptive model of the design process (Fig. 1); including interactions with the world outside of the design process itself, such as the designers' training and experience, and information sources. Six types of designer activities were identified. Activities related to analysis, synthesis, and development, were considered the Creative Phase.

Howard et al. [43] analyzed the commonalities of, and differences between, the phases that the previous engineering design processes contain. The general agreement among the authors is that the design stages, are summarized as four major design phases: analysis of task, conceptual design, embodiment design, and detailed design [43].

2.1.2. Creativity-related factors in the product design process

In product design, 'creative' is often taken as a qualification of a final outcome, but cognitive psychology associates it with activity and certain processes that have the potential to produce 'creative' artifacts while designing [34,78]. Therefore, some design processes aimed at improvement of creativity have been proposed in the literature, for example, Hsiao and Chou [44] suggested a creativity-based product design process including three essential stages: divergence; transformation; and convergence.

The factors which can affect creativity in the design process are also discussed a lot. Studies of expert and outstanding designers suggest that problem framing ability [70] is crucial to high-level performance in creative design [24]. Ennis and Gyeszly [30] noted that acquisition of information was an integral part of the product design process. The C–K theory [39,40], which describes design as a process of movement between a concept space and a knowledge space, assumed that a certain quantity of knowledge must be gained during each phase of the process in order to complete a design [43]. In a study of 50 designers, Fricke [33] concluded that 'solid' background knowledge and high heuristic competence were significantly correlated with design quality. Those students who had more transitions along the steps in the design process, proved better performers regarding design quality [54]. In summary, the creativity-related factors reviewed in the literature include:

- *Design process:* the time arrangement of the design stages and the steps within the stages, and the transition between them.
- *Information gathering:* the amount and the categories of information requisition.
- *Alternative solutions:* the amount of alternative solutions generated during the design process.

Based on these three aspects, we would define crucial factors in product design process in order to investigate and present the design process precisely.

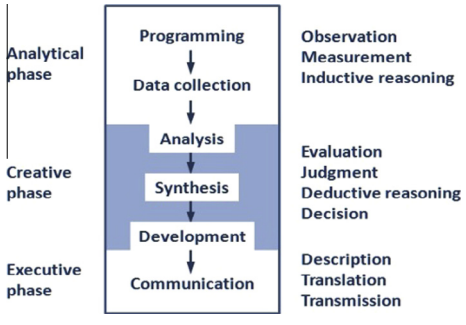

Fig. 1. A prescriptive model of design process [5].

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