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The Levels of Creative Design Processes with Computer Graphic Tools

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ABSTRACT

This review article aims to describe the layers of creative processes of Design when it is carried out with Computer Graphic Tools (CGT). This article reviews and explores cognitive theories that is largely discussed within the fields of creativity research. Theories and concepts that is discuss includes the adaptation process by Jean Piaget, Divergent and Convergent Thinking that is proposed by Guilford, and Analogical thinking. In line with the discussion is the weaving of these theories with the design process. From the existing literature in these fields of study, the article conceptualized the layers of creative processes of design during its interaction with CGT. An aditional discussion on emerging technologies such as Artificial Intellgience is also discussed. The review is significant especially to understand how designers think in producing artwork using computers.

Keywords: Design Process, Creative Process, Creativity, Psychology, Computer Graphics

INTRODUCTION

Numerous studies have been conducted on the psychology of creativity since the explanation of divergent thinking by Guilford in his paper entitled 'The Structure of Intellect' (Guilford, 1956). Creativity research is a field that is expanding and maturing that has gone through trends such as its descriptive nature, applications and mechanisms (Williams, et al., 2016). Creativity can be studied through the aspect of personality (persons), products, press (environment) and process (Rhodes, 1961). These lenses of creativity open up avenues whereby the researcher looks into and discovers various types of creative activities according to various contexts.

Creativity does play a huge part among designers. The development of new and novel products requires ideas and technical skills. And just like creativity, Design also has its context that it needs to adhere to (architecture, product, graphic, fashion), hence carries certain requirements. Furthermore, nowadays, Design has blended with technology such as Computer Graphic Tools (CGT) and thus has increased productivity. Discussions below will explain the impact of technology on the creative design process.

CGT AND DESIGN

Design tends to go parallel with the development of technologies. The Bauhaus, which many regard as a pioneer of design education prospers as a result of industrialization and the opportunities that it can offer (Naylor, 1985). This is evident when the school moved from Weimar to an industrialized city of Dessau in 1925 which during this period (until 1932) that the school produced their influential work inspiring future design styles. Currently, CGT systems have become one of the staple tools of designing. The unprecedented development of computer technology in the 1990s brings in a new approach, whereby computers can be used to manipulate products and visuals digitally (Paul, 2008). There are even movements whereby an artwork results from technology such as 'generative art' (Bailey, 2020). Instead of using traditional tools, artists and creative individuals explored algorithms and codes to produce visuals. The interesting theme of this movement is that visual representation is determined by computers or the motivation is rather to seek or push the boundaries of technology. Users provide inputs to a system, and the system or software calculates it and produces visual representation. We can see this in software or programs such as Adobe Flash and Processing. This shows that with technology such as computers, ideation can work both ways. This also tells us that in many ways, the tools itself can shape how the final product will be realized.

Other than generating ideas, technology can also limit the creative process. Computer Graphic Tools (CGT) provide specific features that designers must conform to. Rather than having room for ideas, it instead entraps the mind (Kanisauskas, 2016). For example, Adobe Photoshop is seen as a software for editing pictures; however, to draw vector graphics, Adobe Illustrator is more likely to fit the requirements, as drawing vector graphics is not the best feature that Photoshop can provide. Therefore, to have an idea that is a synthesis of edited pictures and vector graphics, the individual must master both software that requires training. In other words, elaboration of ideas when

designing with CGD are circumvented to learned skills. In a more damaging instance is when novice designers seek ideas that are permitted by the CGT systems (Brown, 2009).

Alan Kay once mentioned the struggle between quality and convenience when dealing with computers. While we thought that computers can help us provide more ideas, it otherwise has become a mere tool to complete our work (Kay, 1991). Furthermore, learning new skills on technology requires time for the designer to familiarise (Bonnardel & Zenasni, 2010), especially among novices or inexperienced designers and can potentially be succumbed to technology constraints and circumscribed thinking (Robertson & Radcliffe, 2009). Instead of exploring new skills, the individual opted to use the same comforting technique which can also lead to the same finish. The effect on users is that their activity becomes parameterized. Everything is done according to what the computers are made to do.

With the capabilities of the internet, namely, to provide various information according to keyword searches, they overload the ability to focus on idea generation, hence, the overflow of information. Furthermore, the availability of these resources such as open-source images allows manipulations to create visuals which in turn raises the question if this act is creative or mere consumption of previously made products (Magner, 2017). Technology affects how ideas are produced and therefore affects the processes of creativity that include thinking and learning. Further discussions will largely focus on types of creative processes as it pertains to how design is carried out with CGT systems, ways in which ideas are developed with CGT, ways in which creativity can thrive and suggestions for future studies.

CGT Systems And The Creative Design Process: Divergent And Convergent Thinking

A crucial aspect of creativity is Divergent Thinking(DT). It is the most discussed concept in creativity research with numerous studies and assessment techniques and instruments have been produced (Long, 2014). Besides being the most widely studied area of creativity DT might be the reason as to why creativity differs from intelligence. This is due to its reliability in predicting where original ideas come from. Under the production sub-process of the intellect, divergent thinking produces figural or symbolical representations. An indicator of ideas can be observed through ideational fluency, flexibility and elaboration (Guilford, 1956).

DT is relevant to designers as they are expected to produce ideas. In many instances, ideation itself is considered a huge part of the design process or design thinking along with inspiration and implementation (T. Brown, 2008). The constant demand for new ideas is common as product development tends to add or eliminate concepts along with the timeframe of a design project. This leads to new problems that require new solutions. To constantly produce new ideas implies the fluency of ideas that is an indicator of DT.

In certain cases, designers need to throw away ideas and seek solutions from different perspectives. However, just like a writer that suffers from ‘writer’s block’, designers too

at any given time can suffer from fixations. Furthermore, one of the reasons for fixation among designers, and to a certain extent even among experts, is the reliance on 'prior art', whereby the same styles or concepts are applied across all projects as it is easier and comforting to create similar things (Crilly, 2015). A study reports that products developed too early and quickly through CGT might cause the designer to use a certain available solution and thus it becomes fixated and hence, a similar solution (Robertson & Radcliffe, 2009). The study also suggests developers of CGT systems to be aware of "feature creep" as favoring over features that might hinder core tasks as the focus shifts towards elaborating new parameters and cluttering interfaces instead of ideas.

Although elaboration is an indicator of DT, it should be imposed on core tasks rather than technology features. The reason behind this is that designing is a process of pattern synthesis as opposed to pattern recognition. In other words, visuals, sketches or drawings are actively constructed to find solutions rather than focusing on understanding and analyzing problems (Cross, 1982). Therefore, for this reason, that it is common to see most design practices and their sub-disciplines maximize the use of 'sketching' through elaborating abstract patterns into concrete ones and elaborated further towards the actual objects or products.

However, ideas alone do not guarantee a successful product as it also are required to be useful. Usefulness gives the product meaning and purpose. Along with originality, it is also considered as the standard definition of creativity (Runco & Jaeger, 2012). In various design disciplines or creative fields, this concept can be translated into objectives or goals such as 'user-friendly', 'functional', 'eco-friendly', 'communicative', 'pleasing', 'marketable', to mention some. Meaning and purpose makes the product objective and thus allows users to put judgments and value. It is what makes the product successful. Therefore, ideas need to converge to these intended values.

Guilford describes that *"In convergent thinking, there is usually one conclusion or answer that is regarded as unique, and thinking is channeled or controlled in the direction of that answer"* (Guilford, 1956). In contrast to DT, Convergent Thinking (CT) happens when designers reflect on their work and give judgment whether their work is adequate for its intended value. Ideas can go out of control and CT filter those to identify appropriate ones. In the design process, DT can be seen during the early stages of design where the focus is not limited, whereas CT happens at a later stage during which designers decide, refine, test and implement ideas into its contexts (Gabora & Kaufman, 2010). However, technology such as CGD systems is developed for production needs that include accuracy, automation and especially routine tasks (Locher, 2010). This reduces creative options, as conforming to technology features is largely convergent. In other words, ideas are channeled not according to the core task, but to what the technology can provide.

It is also important to note that DT and CT is a concurrent process during the creative design process. It can also be seen as a cycle of generating and deciding ideas; much like how design is practiced through the loop of spaces between inspiration, ideation and implementation (Brown, 2008). Without DT, ideas cannot be generated, while stagnation and orthodoxy prevails if CT dominates (Cropley, 2006). This is also

evident through a study that shows the concurrent processes of DT and CT in design (Goldschmidt, 2016).

As much as ideas are required to be accessible, so does technology. Previous discussions have mentioned the effects of CGT as it is largely dominated by CT. For Design to be successful with technology, the boundaries that the designer has with it needs to be tolerated. Furthermore, this also shows that technology is external to ideas. However, other processes that relate to creativity can be used to understand how it can be overcome. One such process is Analogical Thinking and it will be in the discussion below.

CGT AND THE CREATIVE DESIGN PROCESS: ANALOGICAL THINKING

Analogical Thinking(AT) happens when "knowledge transfers from one situation to another by a process of mapping" (Gick & Holyoak, 1983). Mapping works by generating similarities between a base domain and a target domain (such as primes or cues). Similarities generated can reach different levels of abstraction and combined with different concepts that can construct different outcomes. The connection of AT with creativity is that it can be used to describe the synthesis of two concepts to produce new and novel ones. The steps involve (1) selection of sources - retrieval of concepts from memory, (2) mapping of a prime - then mapped to a target to draw out similarities, (3) evaluation - adapting the inferences of similarities by noticing ideal aspects and (4) learning from the success or failure of the analogy.

A study among students on idea generation has shown that exposure to external prime tends to dictate the outcome of the product or project as external examples stimulate stored information and limit or circumvent other potential and relevant analogies from other target domain or knowledge base (Dahl & Moreau, 2002). Furthermore, originality seems to occur more through far analogies. In the study, students who are not given primes or cues produced more original ideas than students who were shown primes. The findings show that analogies work in a continuum, whereby concrete and near analogies tend to frame the outcome of the product as the structures are similar and therefore hard to break away from. Meanwhile, if not given a prime, students will analogize target domains mainly distant and abstract from their base domain and thus it provides greater selections, more conceptual mappings, more details to evaluate and better learning opportunities. Therefore, creativity can be enhanced if analogies are extensive.

Another study of AT between interdomain sources shows that it can evoke new ideas and thus stimulate creativity (Bonnardel & Marmeche, 2004). This is benefited especially by expert designers as they are more sensitive towards external sources. This shows that experienced designers can benefit from far analogies due to their experience that allows them to become sensitive on concepts to be mapped and thus identify similarities. Unlike novices, whose expertise are lesser.

Consequently, if novices were to use computers such as CGT systems, the workings of AT might encourage the use of similar features as it is learned and thus provides concrete cues to be mapped especially among novices. Moreover, if projects are given

by highlighting products than function, analogs become more concrete as products tend to imply something already present. Hence, function on the other end describes the purpose, it is a means to an end.

Therefore, for Creative Design to thrive with CGT, it is important to have various schema of its features so that it can be included or recalled in the initial stages of the Creative Design Process. Therefore it will ensure there are plenty of domains that can be analogized with the base domain which can be synthesized to create novel ideas.

Creative Design Processes And The Development Of Ideas And Solutions

An important feature to note is that designers think constructively which means that while designing, the designer is actively constructing new meaning on top of previous experiences (Cross, 1982). Perhaps, design is constructive because creating a new product requires new knowledge; otherwise, it is not original. A detailed examination of Piaget's work by Ayman-Nolley (2010) explains how new ideas are produced and realized through the dialectic process of *assimilation* and *accommodation*. Although intertwined, these two processes are distinct whereby assimilation is part of the creative process in which new ideas are accepted and put into form (creative product) by accommodation. In creative design therefore, using technology or CGT is largely accommodation as it is in this setting that products are actualized. The review further commented on the need for further understanding as these processes involve other factors that are not observable.

Piaget describes assimilations as "the incorporation of objects into patterns of behavior," where these patterns are "the whole gamut of actions capable of active repetition." In contrast, accomodation refers to how "the individual never experiences surrounding stimuli as they are, but rather these stimuli modify the assimilitaroy cycle, accomodating the individual to themselves" (Piaget, 2001). These constructive ingredients perhaps can be more explained through DT, CT and AT.

From the discussion so far, we can infer that the process of design is dialectic as it involves the adaptation of both external and internal factors while actively engaged in the dynamic relationship with the environment such as CGT. External elements—such as briefs, problems, and tools like CGT—serve as stimuli that prompt designers to think creatively. This article proposes that these stimuli provoke creative thinking at a surface level. To go beyond this, the creative process must move outside familiar solutions such as using the same CGT techniques. Therefore, it is important to avoid routine tasks.

Routine tasks, where existing schemas suffice, require less creative thinking because the problems are well-defined and can be solved by known methods. In contrast, ill-defined problems encourage deeper cognition as it reflects the limits of existing knowledge and the criteria for gaining new information (Kitchener, 1983). These problems push the creative process beyond stimuli-driven thinking into an *analogical level*, where designers further examine known knowledge, such as CAD systems and project briefs, in greater detail. At the analogical level, designers draw on their existing knowledge across multiple domains, breaking down concepts and mapping them onto

new situations. This process enhances assimilation by allowing designers to deconstruct and recombine concepts, and it supports accommodation by encouraging adjustments to existing knowledge and skills. As the designer engages in learning and evaluation, they refine their understanding, moving toward the production level of thinking.

At the *production level*, the designer applies CT to filter and refine ideas, while also using DT to generate or elaborate a wide range of possibilities. As ideas are formed symbolically, the interaction between DT and CT enhances both the fluency and flexibility of ideas, increasing the likelihood of originality. The interplay between these thinking processes reflects the iterative and chaotic nature of the design process itself.

As designing new things requires new knowledge and skills, problems will occur and thus misbalancing the adaptation process. However, the mind will constantly seek this balance through the process of *equilibration* (Pulaski, 1971). When problems occur, equilibration takes place with the mind diverging to produce more solutions and goals at various levels of satisfaction, especially in the middle of the creative design process. Coupled with analogs of technology, the designer again assimilates not just context, but also ways in which these ideas can be put into form. Afterward, these ideas are converged during accommodation to be tested. This process is repeated as more ideas are produced, mapped, restructured, tested and considered until adequate requirements are met and satisfied or have achieved the state of equilibrium. As a result, a new scheme will be produced that caters specifically to produce ideas which means that the designer acquires new skills and knowledge. The creative design process that happens at three levels within the adaptation process is depicted below.

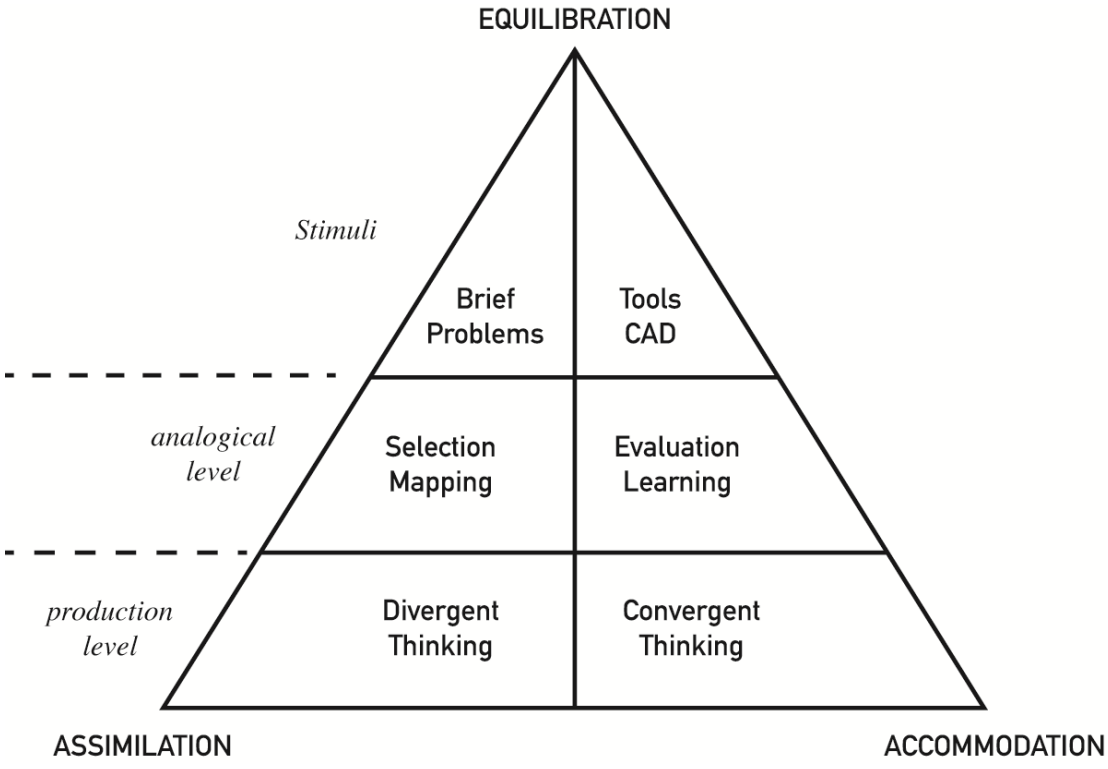

Figure 1. The creative design process with CAD system within the adaptation process. The layered micro-processes of production (Divergent and Convergent) and Analogy (mapping and evaluation) in the constructive process whereby these layers are divided by the tendencies of assimilation and accommodation.

This also shows that if technical skills on CGT are analogized along with DT during assimilation, putting ideas into development will be easier as the individual is not *suffered by the surrounding stimuli*. This meant that ideas are accommodated according to the assimilated ideas rather than the system. In other words, ideas converge to what the designer thinks. Also, as convergent thinking is linked with knowledge (Cropley, 2006), the greater the knowledge of CGT systems is analogise during assimilation, the more possible it is to discover new knowledge or information which can be used to produce solutions.

Creativity And Artificial Intelligence(AI)

What makes AI a compelling subject for discussion is its ability to generate art that feels complete. This results in a production process that focuses on outcomes; with precise prompts, creative outputs can be produced. While these outputs may be original, they often lack the depth of explanation and intention.

Creativity in design is inherently a process—a framework where ideas can be developed and refined until fully formed. This article argues that an excessive reliance on AI may bypass these critical processes, ultimately diminishing critical thinking. Moreover, such dependence could hinder the development of creative thinking skills.

Runco (2023), a notable scholar in creativity research, has suggested the reintroduction of a standard definition of creativity. He argues that two key dimensions—authenticity and intentionality—should be added to the existing definitions of originality and usefulness. Authentic products are typically rich in meaning. For instance, highly regarded paintings often draw on the artist's identity, historical context, and various other factors. This indicates that creating authentic artwork involves a blend of the artist's intentions during a specific period.

Furthermore, the choices of colors, shapes, and forms are made with careful intention, expression, reasoning, and purpose, thereby enhancing creative thinking. In contrast, AI relies on intentions embedded only in prompts and output selections. Consequently, it lacks the rich explanatory power that great artworks often possess. This suggests that the "how" of a creative product should be prioritized, as it usually involves craftsmanship that stimulates creative thinking. Unfortunately, craftsmanship such as the use of CGTs—a crucial component of creative thinking—is diminished in the presence of AI.

Some scholars advocate for a more moderate use of AI, suggesting it as a collaborative tool. Vinchon et al. (2023) argue that genuine collaboration with AI—termed "Co-cre-Ai-tion"—can be achieved when the creative effort is shared equally between humans and AI. This approach lies between the purely organic act of creativity, where all effort comes from humans, and plagiarism. Different scenarios

arise when using AI, each bringing its own set of thinking strategies. Essentially, Co-cre-Ai-tion encourages a balanced approach to creativity with AI, while plagiarism raises ethical concerns and undermines genuine creativity.

AI is relatively new in the realm of creativity, and discussions about its role are ongoing. Two differing perspectives here highlights the diverse views on AI's influence. It is essential for designers and artists to clearly understand their objectives in order to define AI's role effectively. Creativity often involves various social actors, so the role of AI should be determined based on the context of each creative practice (Atkinson & Barker, 2023).

CONCLUSION

More studies need to be conducted, particularly during the creative design processes involving technology, as most research on creativity has been approached quantitatively (Long, 2014). Since design consists of various sub-disciplines—such as architecture, engineering, graphic design, and product design—the study of creativity should be examined through these specific microdomains (Baer, 2010). Skills in one sub-discipline do not necessarily translate to others.

It's also crucial to acknowledge that computer technology is constantly evolving, meaning that future tools may redefine how the design process is conducted. Therefore, the creative process in design is relative to its specific sub-discipline. Considering that design is influenced by context, it may be beneficial to study creativity through a naturalistic paradigm. As Lincoln and Guba stated, “Change the individuals and you change the reality. Or change the context and you change the reality” (Lincoln & Guba, 2013).

Future studies of this nature may help us understand the relationship between design and computer technology, contributing to the development of future individuals aspiring to work in design. With the emergence of AI, it is essential to explore the boundary between creative freedom and the deterministic nature of technology. Thus, the question of whether AI has the ability to shape our thinking is an important topic that warrants discussion.

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