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MODELING COLLABORATIVE DESIGN CREATIVITY

An Interactive Cognition Approach

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Abstract: A model for collaborative design creativity is proposed based on an interactive cognition approach. The model is composed of both external and internal processes, which are affected by various individual and team factors. Individuals may affect the teamwork only through external processes via external outputs. Together, each individual contributes to the team's shared design entities, which move from preineventive states to more matured knowledge entities.

1. Introduction

The conceptual engineering design process can either make or break a product. During this initial process, around 75% of the total cost for a project is determined (Ullman 2010). Making small changes in the conceptual design process can have large impacts later on in making a project successful. Therefore, it is critical to come up with creative ideas during the conceptual design process.

Most if not all large system designs are made in a collaborative effort. While collaboration is employed to deal with the size and complexity of the design projects, another important effect of collaboration is that it stimulates creativity. This poses the question, *how can the collaborative process be made more creative?*

Finke and Ward (1992) proposed a creative cognition model to study creativity. They suggest a cyclical model, where the generation of entities leads to the exploration and interpretation of entities which again leads to generation of entities. The ways in which ideas generated, interpreted and explored are governed by constraints. As the cyclical process continues, the entities move from being initial ideas to fully formed ideas. Benami (2002) applied this model to study creative conceptual design process. His model had a cycle where design entities stimulated cognitive processes which produced design operations which generated design entities. As this cycle goes on, it raises design entities from preinventive entities (rough ideas) to

knowledge entities (fully formed ideas). Amaible et. al. (1996) looked at processes and practices in organizations which promote individual creativity. She specifically found different aspects of the team, organization, and supervisors which could assist in increasing creativity.

As for creativity which results from teams working together, West (2002) looked into the collaborative creative process. He proposed a model for the various factors which affect the internal aspects of people in the creative process. However, his research falls short of discussing specific details and requires further experimental or empirical validation. Paulus (2000) explored brainstorming, and its effects on creativity. In his research, he found that two things interfere with creativity, namely, cognitive interference and social inhibition. He then explored various ways to mitigate cognitive interference. The results demonstrated that brainstorming together was less effective than teams working separately. Sarmineto and Stahl (2008) explored group creativity in interactions. In their research, they propose that group interactions can be broken into the categories of referencing, remembering, or bridging, which are discussed in more detail later.

Recently, Shalley and Perry-Smith (2008) proposed a model for team creative cognition, which focused on the entrepreneurial start up teams. They suggest that team members' outside ties facilitate each team member's creative cognition. Each team member's creative cognition is then infused into the teams overall creative cognition. However, the amount each team member can contribute depends on the stage of team evolution and the socio-cognitive centrality (or common shared knowledge with the rest of the team) of each team member. Wilde (2010) takes a similar approach to creativity except he focuses more on the interpersonal level than the individual's network. In his study, he examined personalities on teams and discovered those teams which were most successful in long term projects were those who had a diverse set of personalities.

Our approach to modelling collaborative design creativity focuses on each individual's cognition processes as well as the interactions between them, hence called *an interactive cognition approach*. Many previous studies have either only looked at individuals, or have only looked at the effect of collaboration and have treated the individual as a black box. Based on Benami's (2002) model of the creative cognition process for individuals, we break down individuals' cognition and design processes and capture the interactions.

Focus and Hypotheses

In the area of creative collaboration in engineering design, there are many settings in which one could study the effect of collaboration, e.g., the group size, types of control and coordination. Figure 1 illustrates various areas which can be studied.

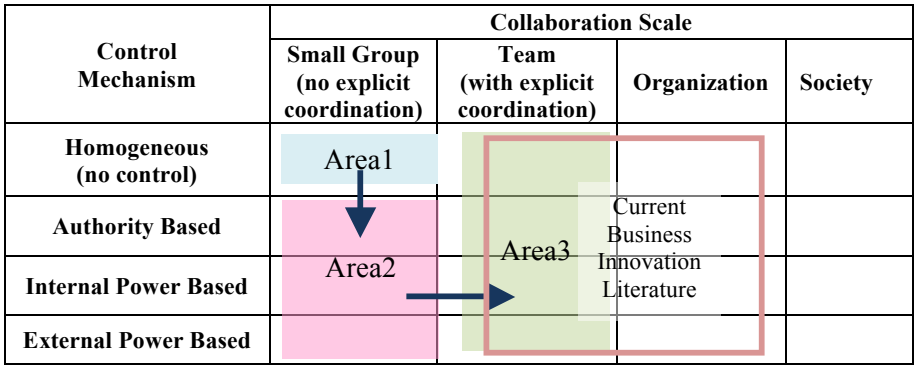

Figure 1: Types of Collaboration Groups

Vertically are control mechanisms. A *homogenous* group is composed of individuals who are equally positioned and have neither specific authority nor power. In an *authority based* group, there is a member who has been specified as the "boss" and is in charge of decisions. The *internal power* situation occurs when there are elements of either political or technical power at play in the group, and all group members are not equal. Some group members will be more powerful than the others. *Outside power* occurs when individuals outside the group have direct power over the inner workings of the group.

In addition, horizontally is shown the different sizes and organizational structures. The first is a small group, which contains several people where there is no one filling the role as a coordinator. The second group is a team, which is differentiated from the small group as there is a coordinator. The organization is when there is a group working within an organization which has already set rules. In addition, as size increases, a professional or social society may be considered. Our research is currently focused on Area 1. After developing and experimenting with a fully formed model in Area 1, we plan to extend the model to Areas 2 and 3.

To investigate the effect of collaboration on design creativity, we have developed the following hypotheses:

H1: Collaboration increases opportunities of making analogies and stimulation that may enhance individual creativity.

H2: There two processes that contribute to the opportunity increase. One is randomness and the other cognition. The dominant process can be either and depends on the settings of interactions.

H3: Social influences resulted from differentiation of authority and power may impact the collaborative creativity.

H4: Interactive cognition results from two/more creative cognition processes interacting through external design operations and design entities.

H5: Interactive cognition enhances or impedes creativity depending on divergent or convergent effect of interactions.

Proposed Model

To test our above mentioned hypotheses, we propose to develop an *interactive cognition model* for *collaborative design creativity* based on our previous work of creative patterns and stimulation of individual designers (Benami 2002, Jin and Benami 2010). In our proposed model, shown in Figure 2, the design process of an individual designer is divided into *internal* ones—i.e., cognitive processes and unobservable design operations—and *external* ones—i.e., observable design operations. While internal processes and their associated design information remain to be within the individual, external processes and information create a channel for individuals to interact with each other. We hypothesize that it is the external processes and design information that facilitate interactive cognition that influence individuals' and group's creativity performance.

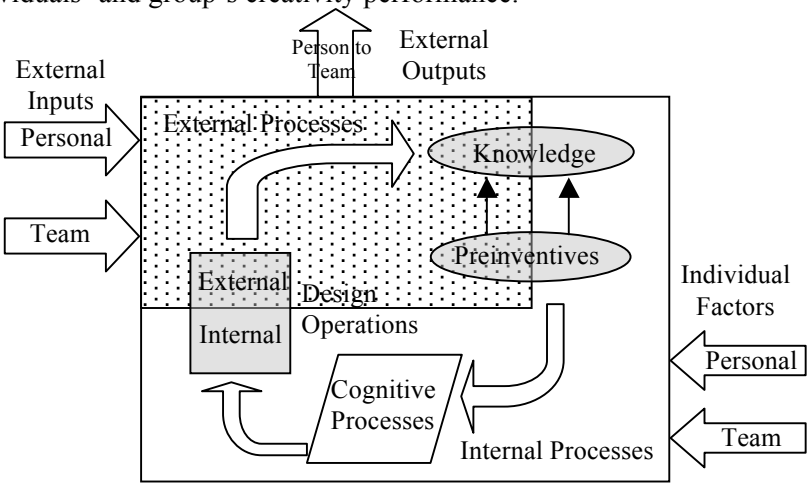

Figure 2: Proposed Model for Collaborative Design Creativity

As shown in Figure 2, in addition to internal and external processes, we introduced *individual factors* that affect internal processes, *external inputs and outputs* that affect the external processes and represent interactions among designers. Following are descriptions of the processes and factors.

Individual factors and external inputs and outputs

Individual factors include those that bring influences to a designer's internal cognitive and design processes, as shown in Table 1.

During collaborative design there are various *external inputs* coming into individuals and making them aware of externally displayed elements. External inputs come from the external processes of talking, sketching, pointing, writing, observing, and simulating. Furthermore, *external outputs* are the communication going from the individual back to the rest of the team. Table 2 indicates contents of these inputs and outputs.

Table 1: Individual Factors

Types	Description
Personal factors	Reflexivity: The amount each team member thinks on the overall goals of the project (West 2002).
Team factors	More group knowledge diversity leads to more creative groups to a certain point. If knowledge does not overlap at all, however, collaboration becomes harder (West 2002). Encouragement from the team/supervisors will increase a person's likely hood of being creative. (Amabile et. al. 1996) Cognitive interference may happen including production blocking (e.g., one forgets their idea because someone else is talking (Paulus 2000)), task-irrelevant behaviours (e.g., team members cause others to go off on task irrelevant discussions (Paulus 2000)), and cognitive load (e.g., having to think of, or pay attention to, what others are saying, reducing brainpower to develop one's own ideas (Paulus 2000).
Outside factors	Workload pressure (e.g., being overworked causes decreased creativity (Amabile et. al. 1996)); challenge pressure (e.g., difficulty of the project may increase creativity (Amabile et. al. 1996) or increase the implementation of creative ideas (West 2002).

Table 2: External Inputs and Outputs

Types	Description
External Inputs	Personal Factors: including *participation* in decision making (enhances creativity (West 2002)), how *receptive* a person is to new ideas, the physical and mental *ability* of each team member. Team to Person: *who is on the team* in terms of optimizing personality to bring in the largest number of ways to solve the problem (Wilde 2010), *socio-cognitive centrality*, how much knowledge the team member has compared to the rest of the team (Shalley and Perry-Smith 2008).
External Outputs	Person to Team: *Voicing and participating* in decision making enhances creativity (West 2002), *social inhibition* (Paulus 2000), which make the team setting less effective due to social aspects such as, *social anxiety*, *illusion of productivity*, *matching*, and *downward comparison* Socio-cognitive centrality. How much knowledge the team member has compared to the rest of the team (Shalley and Perry-Smith 2008), more general team knowledge leads to more sharing of their ideas.

Internal processes and external processes

Following Benami (2002) and Jin and Benami (2010), we divide internal processes into two categories, namely, cognitive processes including *memory retrieval, association, transformation, problem analysis and solution analysis* and internal design operations including *sketch, talk, write, point, simulate, question, supposition, declaration, suggestion, explanation*, and *computation*. The design information is modeled as either *function*, or

form, or *behavior*. Furthermore, the external processes are those design operations including *talk*, *point*, *sketch*, *write*, *simulate*, and *observe*.

Throughout the creative process, the shared design entities move from preinventive forms to knowledge entities. The idea that the sum of the team creates a shared creativity has similarly been presented by Perloa and Merlo (2000) and Shalley and Perrysmith (2008).

Concluding Remarks

An interactive cognition model of collaborative design creativity is proposed. Unlike previous models, this model breaks apart the process and the individual, treating neither as a black box. Instead, in our model each person has a design cycle, which can be broken up into external and internal processes. Both the external and internal processes can be affected by the team, through external inputs and individual factors. Together, each individual contributes, through external processes, to the team's shared design entities, which move from preineventive entities to a single knowledge entity as the collaborative design process goes on.

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