16 CRITICAL THINKING AND CONCEPT DESIGN GENERATION IN A COLLABORATIVE NETWORK

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The key focus of this paper is to introduce an approach to collaborative concept design which makes use of critical thinking styles and methods. It consists of four stages aimed to generate concept ideas, in response to identified needs, to explore them, to develop a set of solutions, and to finally choose a solution through critical examination of the solution set. Experimental findings and results obtained from an implementation of this approach in a blended learning classroom are also presented and discussed.

1. INTRODUCTION

Collaborative concept design refers to intensive collaboration among designers, who strive for and create a shared understanding of the product concept (Volpentesta and Muzzupappa, 2006). Mamykina et al., (2002), Rodgers et al., (2001) and Ulrich et al., (1995) define a *product concept* as a description of the form, function, and features of the product which is usually accompanied by a set of specifications, an analysis of competitive products, and an economic justification of the project. They define c*oncept development* as the first phase in the product development process where the needs of the target market are identified, alternative product concepts are generated and a single concept is selected for further development. They define c*oncept design* as the work (task clarification, hypothesis formulation, solution searching) done on a product concept by designers in the concept development phase in order to determine a product concept architecture. Concept design is a process that often requires participation of individuals from different disciplines, e.g. electronics, software, mechanical, industrial and management engineering, in sharing knowledge, performing design tasks and organizing resources.

A fundamental part of this process is constituted by collaborative generation of what is called "the seeds of innovation", i.e. ideas for a new product concept (Flynn et al., 2003). Such activity is creative in the sense given in Farid-Foad et al. (1993) and Martins et al. (2003) where creativity is defined as the capacity to produce new and useful ideas, or the combination of existing ideas into new and useful concepts, to satisfy a need in a specified organizational context. The importance of collaborative creativity is readily apparent when one considers that most creative pursuits in industry involve many individuals with various competencies working

together to develop a product concept that cannot be created by a single individual alone (Mamykina et al., 2002). A collection of differently skilled designers can, in principle, go beyond individual knowledge and reach new concept ideas because design problems are understood from different perspectives (Barlow, 2001; Ivanitskaya et al., 2002; Alves et al., 2006).

Creativity involves critical thinking, i.e. observing laterally the information that has been available to everyone else's observation but that no one else has been able to interpret with a fresh perspective, (De Bono, 1990). In Sofo (2004) critical thinking is said to be "about stopping to reconsider what we take for granted. It means re-evaluating our habits to improve the way we do things. Thinking critically is a journey of exploration. It is about re-discovering something we already know. It will take as back to where we started so that we will understand in a new way. Thinking critically is a shift in perspective, even if it is just a very small shift. It is about increasing our own awareness of how we think, letting go of strongly held beliefs, and creating a new mental model, a new mindset". Moreover, some of the most potent outcomes of critical thinking can occur when groups or teams of people engage in the concept design process together, offering multiple perspectives and providing opportunities for designers to practise different approaches to problem solving.

Recently, critical thinking methods have been used in product concept design by Johnson et al. (2007) who reported a comparative study on the results of a competitive design project undertaken simultaneously by two multidisciplinary new product development teams. They play an important role in the first two phases of the design process, namely: 1) planning and clarifying the task (or idea development) and 2) conceptual design. These two phases are mostly creative and are much less costly than the later stages of the design process (Pahl & Beitz, 1996). It thus makes sense to maximize its output by providing a larger number of ideas/concepts for further exploitation. The basic rationale is "the greater the number of ideas/concepts at the start of the new product development process, the greater the probability of ending up with successful products" (Alves et al., 2006).

In a previous paper, a double-sided approach was proposed to blend the "creativity" of various designers in a Virtual Breeding Environment (Volpentesta et al., 2007). In this paper we present a modified and reduced version of the approach particularly focused on the concept generation (without considering the question of how to configure virtual groups and teams). The approach we introduce here can be applied in a *Collaborative Network of Designers*, (CND), that supports a master company in creating a new product concept to respond to some identified potential opportunities. In such CND, designers, from many dispersed organizational units, should provide the critical mass required for knowledge overflows and synergies that favour creativity in new product concept development. The entire process is performed by a virtual group and a team coordinated by a concept design manager.

A critical thinking method was applied to the work of virtual groups who generated ideas and solutions successively evaluated by a team in a collaborative section. Lastly we present some experimental findings from a project conducted in a blended learning classroom. Our goal is to demonstrate how collaborative creativity may constitute an added value to design activities, above all in the early phases of a new product development life-cycle.

2. COLLABORATIVE GENERATION OF A CONCEPT

The approach we present is aimed to tackle the problem of how a master organization can manage the collaborative creativity of product concept designers working as a virtual group and as a team in a network environment. According to Furst et al. (1999), we define a *group* as a "collection of individuals whose contributions to a product or a process are additive and can be collated and presented by a group manager as the result of group effort. Performance evaluation and accountability for a group will occur at the individual rather than the collective level"; we define a *team* as a "collection of individuals who interact more extensively than group members to produce a deliverable, who are evaluated based on the team outcome and who are accountable as a team (instead of or in addition to individual accountability) for team outcomes". We define a *virtual group* (or *virtual team*) as a group (team) whose members are geographically, temporally, and/or organizationally dispersed and brought together across time and space by way of information and communication technologies to accomplish an organizational task. The following roles are taken into consideration (see Fig. 1):

1. Concept Design Manager (CDM) from the master organization;
2. Creative Designers Group (CDG) formed by some designers in CND;
3. Evaluation Designers Team (EDT) formed by some designers in CND.

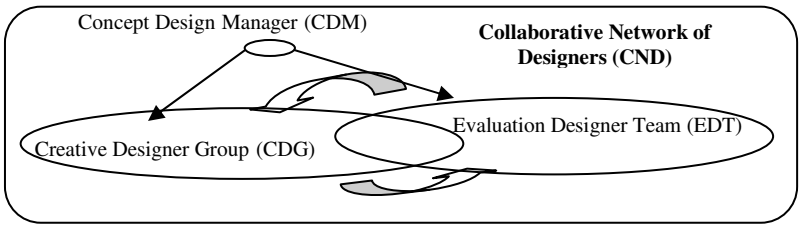


Figure 1- Roles in a CND

Many researchers in the psychology of community have shown that team (also called *real group*) creativity is not as effective as group (also called *nominal group*) creativity (Taylor et al., 1958; Demhis et al., 1993), when problem solving tasks are tackled. Other studies, on the contrary, have shown that the utilization of a team is more successful in the creative process at the ideas/solutions evaluation phases, (War et al., 2005; Ulrich et al., 1995).

In our approach, members of the CDG that may be geographically dispersed are required to work independently on creative problem solving task and their outputs are successively collected by the CND to form a cumulative output. Members of the EDT interact face to face and work together in a collaborative session to evaluate ideas and solutions previously collected.

The approach comprises a cascade of four stage-gates consisting in defining concept visions, functional schema, functional layouts and construction solutions for a digital mock-up of an innovative product (e.g. a device):

1. the first stage generates product concept visions (cs_i) in response to a request forwarded by the CDM to the CDG;
2. the second stage receives as input cs_i and generate functional schema fs_i related to each of them. The purpose of a functional scheme is to define the functional structure of the product, i.e. macro system components and their interactions;
3. the third stage receives as input fs_i and gives out functional layouts (fl_i) each of which specifies the preliminary layout ,i.e. mutual position of each sub-systems and their possible volumes, and principle solutions for each subsystem.
4. the fourth stage generates some constructive solutions (cs_i) with respect to selected fl_i.

A graphical representation of the process is shown in Figure 2.

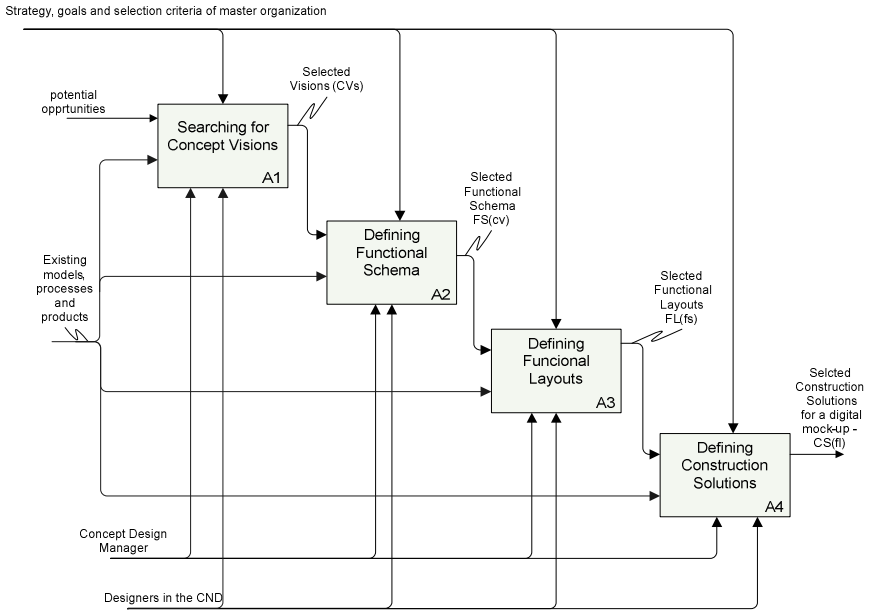


Figure 2 - Graphical representation of the process in IDEF0 notation

Each stage consists of five sequential steps that can be summarized as follows (see Table 1): a request for proposal (ideas or solutions) is transmitted by the CDM to the CDG; responses (coming from the CDG) are collected by the CDM and assessed in a collaborative session by the EDT (using the six thinking hats method); the most suitable ideas or solutions are ranked and selected for successive development by the CDM.

Each evaluation step of any stage consists of a collaboration session performed by the EDT and is based on the De Bono's "six coloured hats" method, (De Bono, 1990). The "six coloured hats" is a critical thinking method of organizing thinking patterns so that a person who is thinking can adopt a specific thinking style at any time, instead of having to try to combine all thinking styles at once. Multicolour printing has been considered the best analogy to explain this method. Each colour is printed in a separate step and in the final step, all the colours are combined.

Table 1- Steps and roles in each stage.

Steps in each stage	**Roles**
Launching a call for proposal	CDM
Generating ideas/solutions	Designers in CDG
Collecting ideas/solutions	CDM
Evaluating ideas/solutions	Designers in EDT
Ranking and selecting ideas/solutions	CDM

This method has been used already to design product concept by Johnson et al. (2007) who reported a comparative study on the results of a competitive design project undertaken simultaneously by two multidisciplinary new product development teams.

In the application of this method we consider six "coloured" sub-sessions. During each of them all members of the EDT metaphorically wear a hat of the same colour of the sub-session. These hats indicate the type of thinking being used by EDT's members and the type of contribution they are required to give, (see Tab. 2).

Table 2 - A framework for critical thinking in collaborative evaluation sessions.

Colour	**Type of thinking**	**Type of contribution**
White	Impartial and objective; neither interpretations nor opinions are taken into account; search for information related to the proposed ideas/solutions.	Use data requests and precise questions in order to obtain new information or supplement incomplete information.
Yellow	Positive and constructive; search for benefits, values, and reasons to be optimistic about the proposed ideas/solutions.	Positive assessments that cover a spectrum ranging from the logical and practical at one end to dreams, visions and hopes at the other end.
Black	As devil's advocate to see why something won't work; search for faults, problems, risk and dangers related to the proposed ideas/solutions.	Negative assessments that point out what is wrong, incorrect or defective and ways in which something is contrary to experience or established knowledge.
Red	Awareness of hunches, premonitions and intuitions about the proposed ideas/solutions. Feeling and emotions are legitimized as essential components of thinking.	Expressions of feelings so that they can be integrated in the thought map and also made part of the evaluation system that selects the route on the map.
Green	Creative, lateral and fertile in order to see beyond the familiar, the obvious and the "good enough".	Creative statements and sowing seeds for alternative ideas or solutions.
Blue	Cool and controlled; thinking about thinking that is necessary for the evaluation of ideas/solutions.	Organization and summarization of outputs of other coloured sub-sessions, Requests of opening another coloured sub-session with the definition of the objects to which thinking is to be applied and the thinking tasks to be performed.

3. AN EXPERIENCE IN EDUCATIONAL ENVIRONMENT

The project consisted of selected activities developed in a blended (virtual and traditional) learning classroom attending the master course in Industrial Design held at University of Calabria in A.Y. 2007/08.
Students and teacher could interact and collaborate using a variety of tools, such as:

- information sources - on line and off line learning materials (books, encyclopedias, teacher's notes, digital libraries,…etc.), software reference guides, students' curricula;
- technological infrastructure – a set of ICT tools for asynchronous and synchronous interaction, search for and access to information sources and virtual services, symbols construction and manipulation;
- sketch and cad tools.

The blended classroom has been regarded as a CND where product concept design has been developed. During a week period, teachers played the role of concept design manager, while 12 students (9 students with Mechanical, Management and Civil Engineering background and 3 students with Architectural background) played the role of concept designers.

Rather than start with the phases of planning and clarifying the task, the experience started from a proposal to generate a concept for "an innovative bookcase for a living room". Due to the requirements of the proposed device, we conducted only 3 stages of the methodology introduced in section 2, namely, the Concept Vision, Functional Layout and Constructive Solution stages.

As showed above, each stage is made up of five sequential steps. The first step consisted in the launch of a *Request for Concept Vision* (RCV) for the considered device; it was submitted by the concept manager to designers. Then all designers were required to generate their concept visions (step2).
After having collected 12 concept visions (step 3), CDM set up 4 EDTs, each of them with 3 students with different backgrounds in order to obtain a multidisciplinary team.

Each EDT was charged with the task of evaluating 3 concept vision ideas according to the "six hats" method (step 4). Within an EDT, each student analyzed the proposed project wearing, in rotation, a different hat. The rationale was to drive the designer's critical thinking in concepts evaluation. At the end of the evaluation process, the teacher gathered the report cards and selected the three most promising concept visions (see Tab. 3).

Table 3 - Concept visions selected by the CDM

Concept	***cv3***	***cv5***	***cv9***
	Bookcase with integrated multimedia tools	Bookcase with door for separating different spaces	Flexible and modular bookcase

Moving from the three selected concept visions, three requests for functional layouts (RFL(*cv*)) were successively submitted to the designers. Four functional layouts (*fl1* … *fl4*) for *cv3*, seven (*fl5* … *fl11*) for *cv5* and one for *cv9* (*fl12*) were generated. They were evaluated by EDTs and three functional layouts were selected by the CDM (see Figure 3).

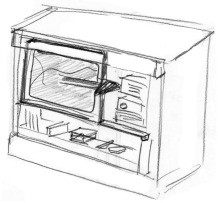
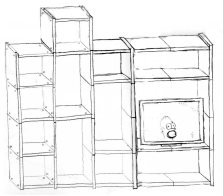
fl2 for cv3	*fl8 for cv5*	*fl12 for cv9*
		

Figure 3 - Functional layouts selected by the CDM

In the last stage, CDM submitted requests to the designers to define construction solutions for any selected layouts (namely: RCS1 for *fl2*, RCS2 for *fl8* and RCS3 for *fl12*). Responses were collected and the most promising was selected by the CDM (see Figure 4).

cs5 for fl2


Figure 4 - The final concept of an innovative bookcase for living room

The final solution does not identify a definitive product, but it constitutes a useful input for future work on a complete product concept development. This concept is thus the result of a collaborative experience among different designers and it can be seen as the outcome of a creative process involving different individuals (see Fig.5).

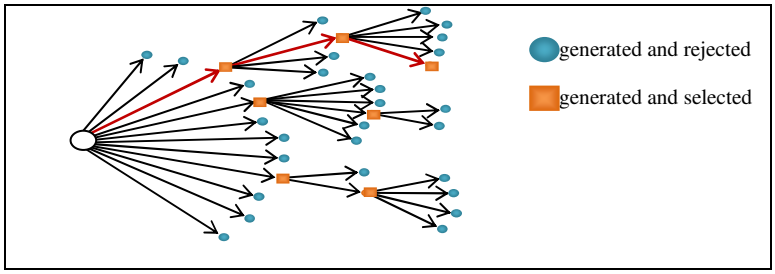


Figure 5 - A graphical representation of all explored paths of creativity

4. CONCLUSION

This paper has addressed how a master organization can manage the collaborative creativity of product concept designers working in many geographically dispersed organizational units. Our methodology proposes two novel aspects. The first one can be found in the widening of the idea generation activities to the conceptual design phase in product design. In this process, new creative contributions coming from

concept designers in a CND are progressively generated and combined disclosing new exploratory directions (Fig.5). On the other hand, the traditional approaches proposed in the literature (Pahl et al., 1996), embrace the funnel metaphor, (Flynn et al., 2003) that consists of a series of "stage-gates" where several initial ideas equally promising go through the funnel, are evaluated, selected and refined and, at the end of the process, only one of them is developed concretely. A second novel aspect consists in a collaboration session performed by the designers, based on the De Bono's "six coloured hats" method. In particular, we have applied the six hats method during the evaluating session and not for generating ideas (Johnson et al.,2007). Lastly, we have described results obtained from a project we conducted in a blended learning classroom. Direct observation and involvement in project development have provided some credible basis for the validation of our approach. The experience has shown how collaborative creativity may constitute an added value to project activities in the early phases of a new product development life-cycle. We intend to conduct more significant experiences studies and develop more interpretative perspectives in our future work.

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