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Author:
Carulli, Marina; Reidsema, Carl

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Implications for Design Education from an Experimental Study of Collective Learning for Multidisciplinary Design

Marina Carulli[1], Carl Reidsema[2]

[1]Department of Design, Politecnico di Milano, Milano, Italy

[2]School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney 2052, Australia

ABSTRACT

This paper presents the hypothesis that learning occurs during a design activity carried out within a multidisciplinary team more effectively than in a design activity carried out by a mono-disciplinary team. The "Learning in Design" framework is demonstrated within the existing literature [1], and extended through a model of "Collective Learning in Design" [2]. Indications are that "Collective learning" is more effective compared to Individual Learning due to specific learning mechanisms inherent in Collective Learning [3].

An experimental analysis of "multidisciplinary team design" composed of an industrial designer and a mechanical engineer was conducted using protocol analysis [4]. The research focuses on this form of team typology due to the increase in industry demands for improved innovation and more rapid product design cycle times [5,6]. This phenomenon comes from the traditional link between these two disciplines and the trend for industrial design organisations to incorporate greater technological functions. In the first step the authors discuss the distinctive elements of the two professional roles, their academic educations, typical domain knowledge, product development methods, areas of expertise within the design process, as well as thinking styles [5, 7, 8, 9, 10].

Then, the authors show the characteristic elements of Collective Learning, and present those linked with the professional role of team members [2,3]. The authors argue that these elements within the Collective Learning model may have a strong influence on the future design education strategies for designers and engineers.

INTRODUCTION

The increasing complexities of the industrial world, consequence of growing competitiveness, market globalization, decreased product lifecycles and other factors have profoundly influenced company structures and the roles of design professionals within them.

In particular, the increase in industry demands for improved innovation and more rapid product design cycle times has led to changes within the roles of industrial designers and engineers [5,6]. Their roles are increasingly undefined with the expanded use of multidisciplinary design team structures.

This trend results in two different strategies: the first is the use of designers with multidisciplinary education and training, and the second corresponds to the use of multidisciplinary team design. While the first approach presents the integration of different roles in one agent, the second approach provides for different agent roles, and permits the integration between them. In particular, the integration between these two agents means the integration between their knowledge, skills, design methods ands thinking styles.

The first difference between these two agents concerns their education and training. Design education is a relatively recent, still controversial phenomenon, while engineering education is nowadays considered as "traditional" [7]. The designer's education, in fact, was traditionally carried out directly through practice and only recently have designers been mandated a period of academic study. Moreover, there are still differences among schools, linked with the design disciplines intrinsic dualism ("art" versus "technical discipline"). The engineer's education, on the contrary, was organized as formal education in the late seventeenth century, and has grown into rigid silos of expertise defined by the content of the engineering science and applied engineering subjects [11].

The second difference concerns their design methods: the typical definitions, evident in the literature, suggest the engineers' method is "mechanical", while the designers' method is "spontaneous". Although these definitions are drastic and perhaps a caricature, they stereotypically reflect the different approaches used by designers and engineers. Some attempts have been carried out to define the engineer's design method, but these are often "prescriptive" and rigorous, and "… usually offer a more algorithmic, systematic procedure to follow…" [2].

Conversely, methods attributed to designers chart a route through the process from beginning to end, without steps in a rigid structure [7]. More often these procedures involve the idea of flexibility and "cycle" instead of any "linear route".

The difference between knowledge and skills involves different knowledge and its use during the planning activity: usually the designer's role emphasises the conceptual design stage, while the engineer's role is strongly linked with the evaluation and technical detailing stages. This division, even if not exact, indicates the planning focus of the two different agents and thus corresponds with their typical knowledge.

A designer, working in the conceptual stage, usually focuses on the "system's architecture" and core concepts that are "developed during conceptual design and that fundamentally differentiate one product form other competitive products." [12]. The engineer's role, instead, is more focused on product behaviours and features, and for this reason his work centres around technical feasibility.

The designer's approach seems "freer and more creative", because his knowledge of the technical constraint at the beginning of the process is very low, and hence, his freedom is very high, while the opposite can often be true of the engineer (see Figure 1).

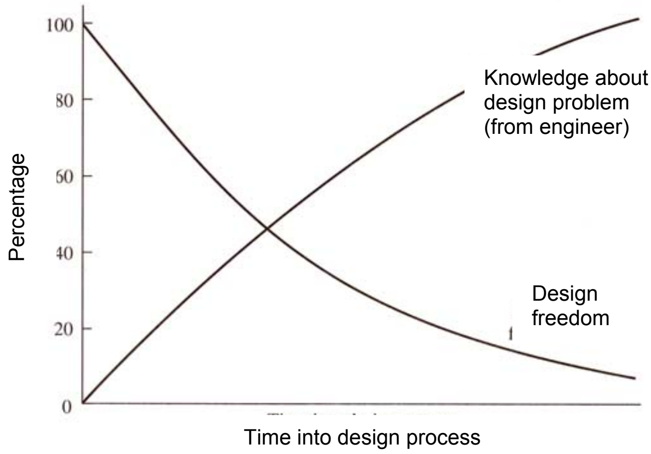

Fig. 1 Evolution of Design Knowledge (from [12])

One of the most important skills linked with the designer's role, and increasingly with the engineer's role, is creativity. The authors accept the definition of creativity "as the ability to conceive and bring into being something that does not exist"; moreover, "creativity is the intersection of expertise, thinking skills and motivation" and "… how flexibly and imaginatively people approach problems" [9]. Within design, creativity is used to resolve problems and to generate solutions: we can say then, that this kind of creativity is "productive thinking" [7]. As the design evolves towards the evaluation of technical feasibility, the use of creativity becomes more limited. This observation, regarding design freedom and level of knowledge suggests the designer's role is intrinsically more creative than the engineer's role.

I. LEARNING IN DESIGN

The link between the cognitive activities involved in both learning and design have been a matter of research interest for over a decade. The inter-relationship between these two activities has been demonstrated and described as ''designers learn during design, as a result of designing and indeed learn to design.'' [12,13]. Different types of learning in design have been investigated, including: Individual learning, Collective Learning, Team Learning and Organizational Learning [13,14,16].

Collective learning exists within team design, although not all team design activities are linked with a learning activity [2]. Although, in some cases, the learning and design activities cannot be separated, in general, agents acquire and transform knowledge through their interactions with each other and the external environment.

In the most recent extension of the Collective Learning in Design research, a model of "collective learning in Design" was developed to show how a group of agents (either humans or computer systems) interact with, and learn from each other within a design team (See Figure 2). This model describes the nature of collective learning in design based on three elements: the team design goal, input knowledge, and output knowledge [2]. Learning is thus considered as a process of acquiring, modifying or generating (transforming) knowledge from input knowledge that has been triggered by internal or external events.

II. HYPOTHESIS

The hypothesis that learning occurs during a design activity carried out within a multidisciplinary team more effectively than in a design activity carried out by a mono-disciplinary team, would seem to be counter-intuitive. The starting point of this hypothesis is the contention that "designers learn when they encounter knowledge which is sufficiently different from their present state of knowledge" [12]. The authors' observation, as previously discussed, suggests that there are some differences between designers and engineers.

III. EXPERIMENT

An experimental session of "multidisciplinary team design" was conducted and analysed using the well known verbal protocol analysis technique to test this hypotheses [4]. The design team consisted of two agents: one designer and one engineer. This team structure was considered to be the smallest possible still representative of the collective design definition. The choice to carry out this simplification makes it easier to identify and analyse the characteristics of a multidisciplinary team. Both the designer and the engineer chosen for the experiment are representative of their professions with similar educational backgrounds, ages and professional experience. The experiment was recorded using a video camera to record words, gestures, expressions, and sketching to allow for post-analysis (transcription, segmentation, decoding and interpretation).

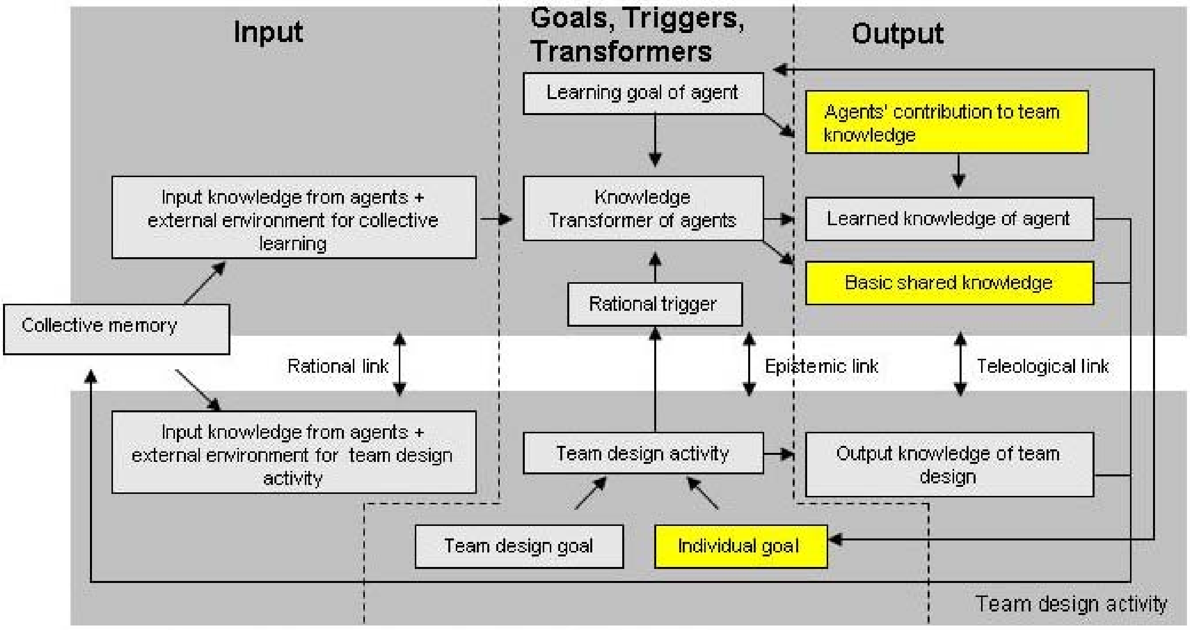

Fig. 2 Extended Model of Collective Learning in Design

The overall goal of the team design project was to develop a domestic food preparation appliance: in particular the team design goal for the session was to reduce the power consumption of the appliance as a refinement of a previous design. At the beginning of the experiment, the design was in its conceptual stage, and during the session several solutions were developed.

The tools supplied for the experimental session were CAD drawings of previous configurations; motor selection tables and charts; pencil and paper for sketching and notations. The sketches drawn by the designers were analysed in conjunction with the verbal data obtained from the video transcripts. The session lasted 45 minutes.

IV. RESULTS

The authors present the following results of the experimental session and its analysis:

- Collective Learning in Design elements are identified,
- New "Collective Learning in Design" elements are identified, and;
- These new elements have a specific influence in "multidisciplinary team design"

Each of the Collective Learning in Design elements were identified in the analysis of the experimental session. Some elements were added to represent a multidisciplinary team design activity. These elements are closely linked with team agents' characteristics (education, methods, knowledge, skills etc.) and act as input knowledge and triggers to the team design activity.

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The new elements of "Collective Learning in Design" identified by the authors (Figure 2) are:

1. "Individual goal": this represents the agents' design and learning goals (if they are different in comparison with team design and learning goals), and if agents use Input knowledge and Learning triggers to direct the design process closer to their individual goals.

2. Basic shared knowledge: this identifies the knowledge shared among agents at the beginning of the design process (to remove the differences of knowledge among team agents), which kinds of knowledge (technical, methodological etc.) are shared and in which way they are learned and used during design process.

3. Agents' contribution to team knowledge: this represents the agents' role during the design process, identifying knowledge request, supply and learning as a single process repeated several time during the design process. Analysing the origin (agent who initiates the process), the frequency and trends, the authors have identified the agents' contribution to common knowledge associated with their roles.

The identification of these elements within multidisciplinary team design suggest that:

4. Individual goals are distinctly different between team agents: the engineer's goal is directed to solving technical problems, while the designer's goal is directed towards identifying new product solutions.

5. Basic shared knowledge is critical within multidisciplinary team design, to demonstrate the knowledge exchange between agents and in the way this exchanged knowledge is used during the design.

6. Agents' contribution to team knowledge identifies the agents' roles, and in particular suggests that the engineer's role is that of "knowledge holder", while the designer's role is that of "knowledge demander" and provider of "innovative concepts triggers".

Other elements identified by the authors which were also used to analyse the experimental results are:

7. "Verbal communication and language use" investigates the words used by agents. In particular this element highlights if the languages used by agents are different and if there are misunderstanding among agents.

8. "Use of drawing" inquires into the use of drawing as a design tool and as a communication tool among agents [5,7,10,17 18, 19]. In particular this analysis highlights if agents use drawing in the same way and if their design activity is carried out using drawing as the main tool to communicate.

These analyses have highlighted that the use of drawing is one of the most important tools used by design team agents due to its role as a communication tool during a design session, in particular it's ability to assist with the explanation of an agents' knowledge and in the development of new ideas. This is particularly important within multidisciplinary team design, because the differences and attainment of a shared understanding of the current design problem among team agents are easier and quicker to resolve graphically.

V. IMPLICATIONS FOR DESIGN EDUCATION

Industry demands for more creative engineers with better team skills poses a serious question for educators as they consider the development of new courseware to meet these needs. In Australia, growing student to teacher ratios accompanied by reduced educational funding may suggest a strategy of rationalising academic resources through the development of combined 'multidisciplinary' courses as an effective response. But is the strategy of providing industrial design students with more technology courses and engineering students with more creative courses the right way to go?

The observations of this experiment lend weight to the contention that the differences in knowledge between agents in collective design motivates learning and in particular supports the suggestion by Minneman that more emphasis be given to supporting the communication skills within design teams [20]. Bucciarelli suggests that each agent possesses an ingrained set of technical values and representations that act as a filter during the design process [21]. One pathway through this filter may be through increasing the graphical representation skills of engineering students. Rather than increasing the breadth of knowledge between the disciplines, a more focused set of outcomes and supporting activities may more effectively leverage the existing didactic framework. These might include:

1. Developing an improved student awareness of the individual roles within the design process and the development of skills to leverage this understanding within a collective design process.

2. Development of activities that are more process focused, in particular, interpersonal skills.

3. Increased focus on communication skills such as graphical representation (talking sketches)

4. Increased exposure to the historical development of engineering and industrial design.

VI. CONCLUSIONS

The aim of this paper was to explore the hypothesis that learning occurs during a design activity carried out within a multidisciplinary team more effectively than in a design activity carried out by a mono-disciplinary team.

The authors, in the introduction, have discussed the background motivations and elements that have produced the diffusion of the multidisciplinary approach within team design activities.

The authors have, then, presented the "Collective Learning in Design" theory, that is applicable within the analysis of a multidisciplinary team design to demonstrate the core hypothesis.

Then, the authors have presented the experimental session and the results of its analysis: in particular, the authors have identified all elements of the "Collective Learning in Design" model and have introduced new elements useful for the analysis of team design activity, and in particular for multidisciplinary team design.

Finally, the authors have suggested that these results may be useful in improving the design education of engineers and industrial designers.

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