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HOW DESIGN EDUCATION CAN SUPPORT COLLABORATION IN TEAMS

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ABSTRACT
Design education has moved towards a collaborative practice where designers work in teams and with other disciplines to solve unstructured problems. Along with the cognitive skills involved in the execution of the design process, designers also need skills to work in teams, share information, negotiate common ground and reach consensus. The aim of this research is to understand the cognitive processes used during the interactions of design teams to reach consensus during the design process. Four cases were studied across different design domains during the problem definition, ideation and concept development phases of the design process. The cases involved two bio-medical fellowship programs, an undergraduate product design project and a user experience design consultancy. The team's conversations were recorded and a discourse analysis (DA) was used as the main method to analyse the data. The findings show that during team interactions design teams alternate between four main cognitive processes to execute the design task and reach consensus throughout the process. Recommendations are proposed that can guide design educators to support students during team interactions when solving design problems.

Keywords: Consensus, teams, cognitive processes.

1 INTRODUCTION

Many problems in industry faced by designers are ill defined and require techniques beyond what is achievable by one discipline [1-3]. While interdisciplinary team work is common place in industry it is less so in education where the curricular structure and requirement for assessment make it difficult to implement [4]. Understanding how educators can better support the skills of collaboration can help to advance the adoption of team practice in design schools. Design problems are complicated as there may be many ways of solving them [5, 6]. This poses difficulties for design teams and highlights the requirement to reach consensus on a variety of matters. Arriving at consensus can be challenging for teams and is affected by cognitive diversity [7-9]. In addition many teams fail to optimally use their distributed information due to a poor understanding of each other, their task, and an overemphasis of agreement seeking at the expense of information elaboration [10]. To understand groups' effective use of distributed information there is need to identify factors that are conducive to the elaboration, exchange, discussion and integration of information and perspectives [11]. There is a need to explore how teams reach agreement during complex design and innovation problems to better inform how design educators can engage students in teams.

2 METHOD

This research uses case studies to identify the cognitive activity of design teams working on real projects in their working environment. "Case studies are the preferred strategy when "how" or "why" questions are being posed. The focus was to explore in detail small samples within a real-life context. [12]. Observations were conducted of the interactions between team members during work sessions and meetings. The raw data was audio recorded and transcribed, Table 1 provides detail of the cases and the data collected per phase of the design process. Three phases are covered: problem definition, ideation and concept development. The problem definition phase is concerned with understanding the problem and identifying user needs. The ideation phase is where solutions are explored and created. This phase requires divergent thinking through brainstorming, exploration and the consideration of alternative options. The concept development phase is about the development of ideas.

Table 1. Case description

Case	Project	Data per stage in design process
Bio-innovate 1 Medical device innovation. No of participants: 8 (2 teams of 4)	To uncover opportunities for innovation.	**Problem definition** Team A: 1Hr 40min Team B: 1hr 52min
Undergraduate case No of participants: 14 (2 teams of 7)	Design of a user-centred crew rest for flight attendants.	**Problem definition:** Team A: 40 min Team B: 46 min. **Ideation:** Team A: 30min Team B: 1Hr
Professional Practice case User experience design. No of participants: 4 (1 team)	Redevelopment of a software program with a user-centred approach,	**Problem definition / Ideation:** 1.5hrs
Bio-innovate 2 Medical device innovation. No of participants: 4 (1 team)	To uncover opportunities for innovation and design of a device	**Problem definition:** 3hrs **Ideation:** 1hrs 25min **Concept development:**50min

Discourse analysis (DA) was the main method used to analyse the data. The analysis of discourse is the analysis of language in use and what that language is used for [13]. DA requires detailed analysis of sequences of talk in order to discern the strategies adopted by participants in furtherance of their ends [14]. The first step in managing the data was to divide it into manageable chunks through the identification of topics. Topic shifts and changes were considered to be appropriate means of dividing segments for the purpose of analysing consensus as they tend to come about through cooperation, the maintainment of common ground and agreement [15].

2.1 Coding of the data

Four cognitive processes used by design teams were identified from the literature to guide the empirical research: *knowledge processing [16], critical thinking[17], creative thinking[18] and meta-cognition[19].* Four steps of the coding process are described as follows:

Open coding which involved open coding of the data to inductively allow categories to emerge.

Consolidated coding was the next step where categories were merged and reduced.

Axial coding which involved linking the conversation activities to the cognitive processes within each utterance. The data was then examined to see if a conversation activity was used as, *knowledge processing critical thinking, creative thinking* or *meta-cognition.*

3 FINDINGS

The next step in the analyses was to identify how these cognitive processes and conversation activities led to consensus. Table 2 summarises the analysis of the data. In addition to the four cognitive processes identified in the literature six conversation activities were inductively uncovered which supported each of the cognitive processes.

Table 2. Analyses of the data

Cognitive processes	Description
Knowledge processing	Elaborating/ explaining clarifying and exchanging information
Critical thinking	Analysing, judging, evaluating, inferring, interpreting
Creative thinking	Idea generating, lateral thinking, imaginative and divergent thinking
Meta-cognition	Planning, monitoring and evaluating
Conversation activities	
Domain knowledge	Specialist and expert knowledge of a particular domain including reference to prior experience, or a particular case.
Analogies	Transferring information or meaning from a particular subject (the analogue or source) to another subject (the target). e.g.: Comparing the shape of a car to a fish.

Arguing	Give reasons for or against an idea, action, or theory, usually with the aim of persuading others to share one's view.
Mental simulation	Where a sequence of interdependent events is consciously enacted or run through mentally to determine cause and affect relationships.
Scenarios	Creating a mental picture of how someone would behave or feel in a certain situation. Imagining and predicting a situation.
Building on	Building on another's thoughts and ideas.

3.1 How the activities enabled consensus

Table 3 provides an account of how the cognitive processes and conversation activities were effective at bringing about consensus. The findings found that the teams engaged in mainly *critical thinking* (40%) followed by *knowledge processing (34%)*, *metacognition (27%) and creative thinking (7%)*. In support of this the teams applied conversation activities that were defined as: *arguing (22%), building on (17%) domain knowledge (14%)*, *scenarios (12%) analogies (7%)* and *mental simulations (5%).*

Table 3. Example of coded data

Examples	**Cognitive processes**	**Conversation activities**
Harry: This stuff here again it's all very rough. This is a classic example of unbelievably inefficient space use. You'd get all of this in here and it would still read properly if you designed it properly. You could have all of this in here and the rolled up stuff and not have this presentation at all. Because this is an amalgamated part of this. So when you click on this; it pops out that. It asks all the questions and rolls up the figure and you can have all of these states in there as well. It's no problem there's not that much information there.	KP, CT, CRT	Domain knowledge, scenario, mental simulation, arguing
Faye: The only problem we have there is if you look at initial use right. What does the user see on the screen when they haven't filled in the questions?	CT	Scenario, arguing,
Harry: The questions? You fill them out and then roll them up.	KP	Mental simulation,
Faye: Each one of these would be almost like headers.	CRT	Analogy, building on
Harry: Yeah **CONSENSUS**	KP	
Faye: Expand and contract questions.	CRT	Building on
Harry: Yeah and you do the questions and it roll ups and when you close it, it reconfigures the header and that gets them away from having to do this save thing which is counter intuitive	KP,CT CRT	Domain knowledge, mental simulation, arguing, building on,
Faye: Yeah, ok that makes sense. **CONSENSUS**	CT	
Harry: you would have to design it obviously.	KP, CT	

KP: knowledge processing, CT: Critical thinking, CRT: Creative thinking, MC: meta-cognition

Individuals using *domain knowledge* were better at applying the other conversation activities. They were better able to *build on* another's utterance. They made better *arguments* and were in turn better able to apply a *scenario, mental simulation* or an *analogy* to support a contribution.

3.2 How the activities were used at the different stages of the process

Knowledge processing increased across the design phases to show that the requirement to agree on new information continues throughout the process. *Critical thinking* was at high levels across all phases of the design process dropping only slightly at the ideation phase. *Creative thinking* was at low levels across all phases rising significantly only at the ideation phase. *Meta-cognition* was at high levels at the problem definition phase. When *critical thinking* and *metacognition* (convergent in nature) levels were high, *creative thinking* (divergent in nature) was at low levels, see Figure 1. *Analogies, mental simulations* and *scenarios* were linked to *creative thinking* and increased significantly at the ideation phase, *Arguing* was linked to *critical thinking* and featured strongly at the problem definition and concept development phases see Figure 2. The number of times a cognitive process and conversation activity was used per utterance was counted to give the frequency of use.

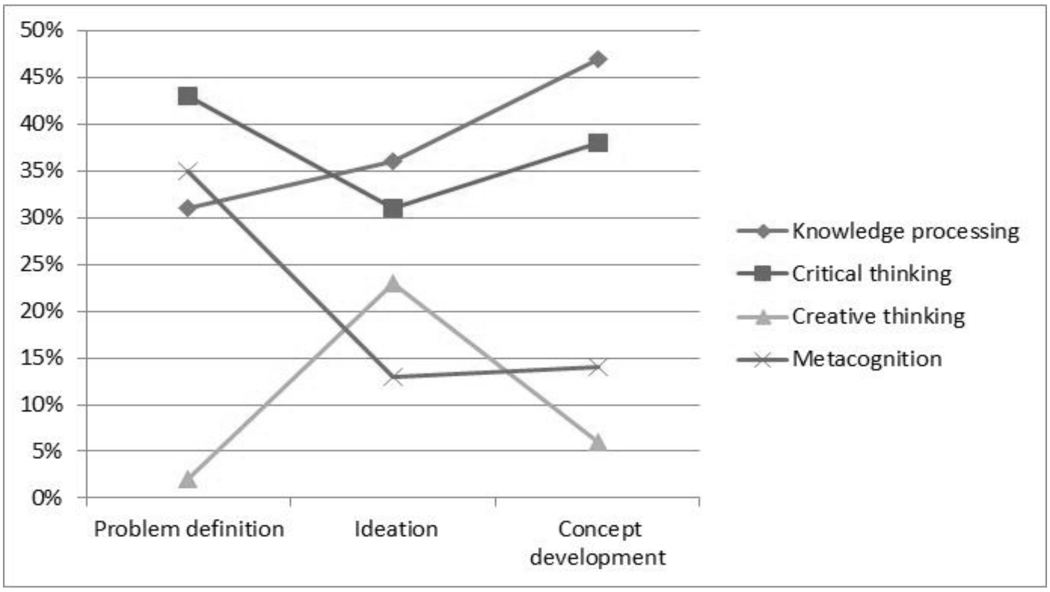

Figure 1. The cognitive processes used per design phase

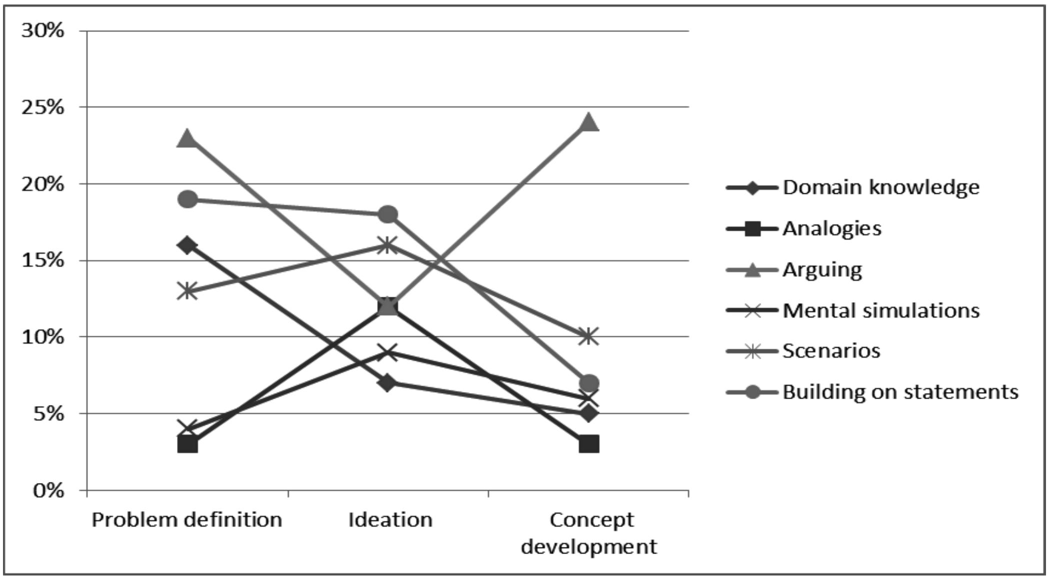

Figure 2. The conversation activities used per design phase

4 DISCUSSION AND CONCLUSIONS

This research has shown that the four cognitive processes of: *knowledge processing, critical thinking, creative thinking and meta-cognition* were instrumental in facilitating teams to share knowledge and beliefs, negotiate and elaborate on that knowledge to reach common ground and consensus. What was surprising was the proportion used. The teams were found to use mainly *critical thinking* while *creative thinking* accounted for only 7% of cognitive activity yet much of the literature in design emphasizes creativity. The ability to apply the conversation activity of *domain knowledge* was critical to the effective application of the cognitive processes and other conversation activities. Those with strong *domain knowledge* were better critical thinkers and better able to justify arguments. *Domain knowledge* helped team members to use *mental simulations* to convey to others a step by step account of the process of using a product or service and *analogies* to make comparisons to other applications and products. *Arguing* was strongly associated with *critical thinking* and students can be encouraged to create arguments to force the necessary negotiation of information that is required to reach consensus based on common ground amongst design teams. As *scenarios* can depict vivid examples of cause and effect this makes them a forceful tool to explain, persuade and convince others to a different position. *Scenarios*, *analogies* and *mental simulations* were also linked to *creative thinking* and helped individuals to imagine new possibilities during ideation and communicate them to others. *Building on* was a conversation activity that can be encouraged to get team members to build on both the arguments and ideas of others.

What the findings also show is that the steps to reaching consensus can vary depending on the phases of the design process and call for different emphasis on the cognitive processes and conversation activities. *Knowledge processing* increases across each phase to show that new information must be processed and agreed upon throughout the process and not just at the beginning of a project. *Critical thinking* is at high levels at the problem definition phase and concept development phase dropping at the ideation phase. This shows that negotiation is mainly required at certain phases and that the ideation phase requires more collaborative behaviour through *building on* others ideas. *Critical thinking* may be used at the ideation phase but only to further analyse the problem rather than to critique ideas. As this is about divergent thinking consensus is suspended but the aim is to reach a shared understanding of ideas. *Meta-cognition* is required most frequently at the problem definition phase to manage the uncertainty and diversity in perspectives at this phase. This is the most unstructured phase of a project and teams may only be recently formed. Teams must monitor and evaluate their approach and representations in order to identify gaps or misrepresentations. This is the phase where the teams must also plan and strategize their approach. Any oversights or misunderstandings at this phase will have a detrimental knock on effect to subsequent solution phases. Many design processes do not make a significant distinction between the phases particularly the ideation and concept development phases and see these two phases as one generative phase. Therefore by recognizing the phase in the process and the objectives of the team interactions it is possible to guide the focus of cognitive activity.

4.1 Implications for design pedagogy

These findings have implications for design education. There is much effort to advance design education with a move towards more student-centred activity based learning approaches focusing on self-directed learning, collaborative learning and learning related to practice [17, 20]. Collaboration is believed however to be encouraged more in practice than in education, where individual competition prevails [21]. Design education must focus on teaching designers to function in multidisciplinary teams emphasizing the complex process of enquiry, learning and decision-making through working collaboratively [17]. This entails the facilitation of the cognitive skills not just in the execution of the design process, but also skills, such as, the elaboration of information, negotiation, and consensus reaching. This may be achieved by encouraging the use of the four main cognitive processes as outlined in this paper. This can be supported by facilitating the use of the six conversation activities outlined. Attention should also be given to the purpose of the phase for example an emphasis of *metacognition* at the early phase and the encouragement of *creative thinking* at the ideation phase. While all of the conversation activities can be applied across the cognitive process certain ones have been shown to support specific cognitive process. Supporting effective discourse within design teams in education may be achieved by adopting a problem-based learning (PBL) model where the focus is on real-world problems and students learn transferable skills through collaborative problem-solving with other disciplines. Tutors can act as facilitators to guide conversation amongst teams.

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