QUESTIONING IN DISTRIBUTED PRODUCT DEVELOPMENT TEAMS: SUPPORTING SHARED UNDERSTANDING

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ABSTRACT

Distributed teams are an increasingly common feature of New Product Development (NPD). Key to the success of these teams is the development of both short and longer-term shared understanding. Lack of shared understanding has been recognized as a significant challenge, particularly in the context globally distributed NPD activities. Poor shared understanding can ultimately result in delays and rework. One major antecedent of shared understanding development is question asking. This work uses a quasi-experimental study to test the impact of questioning support on different types of distributed teams, both homogeneous and heterogeneous. This extends theoretical insight into the development of shared understanding and contributes one of few empirical studies directly comparing the response characteristics of different team types. From a managerial perspective this work has implications for how distributed NPD teams can be more effectively supported, as well as how shared understanding development can be facilitated in the NPD process.

INTRODUCTION

Communication in New Product Development (NPD) is an important element in both long and short-term performance (Eris et al., 2014; Tang et al., 2011). It is especially critical for distributed teams where there is a high level of reliance on communication support tools (Hinds & Mortensen, 2005; Maznevski & Chudoba, 2000). As such, this has formed the focus of numerous studies including, for example, Eris et al.'s (2014) work on multi-modal interaction and its role in facilitating team development and performance. A key element of communication and essential for developing effective NPD teams is the realization of shared understanding between the team members (Johnson & O'Connor, 2008; Preston, et al., 2006). This links to performance in both the short-term e.g. more cohesive understating of outputs and plans (Humayun & Gang, 2013), and long-term e.g. reduced rework (Johnson & O'Connor, 2008).

Key antecedents of *long-term* shared understanding development are social interaction (Chiu, Hsu, & Wang, 2006), shared context (Humayun & Gang, 2013), and communication quality (Maznevski & Chudoba, 2000); all of which link to overall performance improvement (Johnson & O'Connor, 2008; Preston et al., 2006). This long-term relationship between shared understanding and project performance is well established by theories such as, organizational information processing (Hult etal., 2004). This links information acquisition, knowladge exchange, and shared understanding with project performance at an organisation level.

Short-term development of shared understanding is less fully described in theory. However, key antecedents are intensity of interaction and questioning/feedback activities (Jacobs & Heracleous, 2006; Qu & Hansen, 2008). There are few works exploring this development in the context of NPD or in detail at the team level. This has given rise to questions regarding how best to technically support shared understanding development at

the team level, as well as how to best manage distributed teams with differing characteristics (Johnson et al., 2007). In particular Johnson et al. (2007) highlight the need for tools that support both heterogeneous and homogeneous teams due to studies typically focusing on one or the other. This raises the need for empirical comparison of the two types.

This paper addresses these two gaps using a quasi-experimental study to examine the impact of questioning support on the development of shared understanding in different team types. A review is used to outline the key elements underpinning this work. This forms the basis for the research framework and empirical studies. Next, the methodology is described, followed by the results. These are used to distil both managerial and theoretical implications, which are balanced against the work's limitations.

REVIEW AND RESEARCH FRAMEWORK

In order to theoretically ground the study this section describes three topics: shared understanding development, question asking support, and team heterogeneity. These are then brought together in a research framework.

Shared understanding development

The development of shared understanding is a core component of communication and an important area for communication support tools and management (Humayun & Gang, 2013; Johnson & O'Connor, 2008).

Shared understanding has been recognized as important in a number of domains and has been linked to overall process performance by Organizational Information Processing theory (Carson et al., 2007; Hult et al., 2004). Here, shared understanding is a mediator between information acquisition and knowledge exchange. However, this model does not deal with the development of shared understanding in terms of teams and their interaction. Central to this long-term development of shared understanding are social interaction (Chiu et al., 2006), communication quality (Maznevski & Chudoba, 2000), and shared context (Hinds & Mortensen, 2005; Humayun & Gang, 2013). Again, these have been explored at the organizational level in frameworks such as that of Lawson et al. (2009) linking socialization and knowledge sharing with financial performance.

Despite recognition of shared understanding's high level importance less work has focused on its development at the team level (Badke-Schaub et al., 2007). Instead works have focused on more specific constructs including shared vision (Chiu et al., 2006), shared solution understanding (Preston et al., 2006), and understanding of role distribution (Badke-Schaub et al., 2007). These have all been linked to overall shared understanding and team performance. Specifically they affect performance, trust, and cohesion, particularly when team heterogeneity is high (Bittner & Leimeister, 2013). For example, Hinds and Mortensen (2005) describe how shared identity contributes to reduced conflict in distributed teams. This makes shared understanding a key area when seeking to support improved performance in NPD teams, especially those facing issues such as globally distributed work and cultural diversity (Hansen et al., 2013).

In the context of team level NPD Badke-Schaub et al. (2007) describe *'agreement actions'* as indicators of sharedness. These link to four antecedents of shared understanding development at this level: *problem definition/analysis and explanation*, *planning procedure and reflection*, *task allocation and team skills*, and *appreciation and*

confirmatory informal conversation. Further, Johnson et al. (2007) conclude that shared understanding is important for both team and task related communication. This links to the social elements identified at the organizational level, where team focused shared understanding is developed.
In terms of assessment Humayun and Gang (2013) review four major approaches: pair wise rating, causal mapping, repertory grid, and concept mapping. Of these, concept maps have been shown to be particularly relevant and robust in a number of recent works, described in the method section.

Question asking support

Shared understanding development is underpinned by effective communication (Ko et al., 2005) and more specifically the process of structuring, evaluating, interpreting, and transforming information into knowledge (Swaab et al., 2002). This supports teams in creating shared mental models of e.g. problems and solutions. Decomposing this further, question asking and feedback are core elements in this process. For example, Mulder et al. (2002, 2004) describe how questioning and feedback drives the development of shared understanding in mixed design teams. In particular, they link reflective behavior and shared understanding via questioning and feedback. A different perspective is provided by Qu and Hansen (2008) who characterize negotiation as one of the key activities underpinning close collaboration and shared understanding development. Finally, Lanaj et al. (2012) highlight how poor coordination and feedback result in individuals ignoring the bigger operational picture, instead basing decisions on their own experience.
Previous works in NPD have highlighted the significance of question asking in problem solving and in the application of different design strategies (Ahmed et al., 2003; Aurisicchio et al., 2006; Eris, 2002). In this context design engineers progress their tasks by asking questions at both reasoning and strategic levels (Aurisicchio et al., 2007). Further, Dym et al. (2005) identified the benefits of a question centric thinking process when exploring the concept domain. Decomposing this Eris (2002) identified 22 question classes, divided into two groups: *Deep Reasoning Questions* and *Generative Design Questions*. Deep reasoning questions focus on understanding facts, while generative questions focus on creating possibilities. These studies all highlight the importance of question asking in design, however, they focus on question asking as an aspect of problem solving and information gathering activities, rather than in the context of shared understanding. Subsequently these studies have typically focused on the types of design situation predominantly associated with problem solving e.g. individual design work (Ahmed et al., 2003). Thus there is a need to extend this understanding of question asking to include its role in shared understanding development. Further, this is coupled with a need to extend the empirical context to situations more closely associated with shared understanding development e.g. process planning and team work tasks. However, one aspect is consistent across these studies – the importance of structure in the question asking and information search activities.
The need for structure in the shared understanding, question asking context is illustrated by Earley and Mosakowski (2000) in their observations of long-term shared understanding development. They highlight the systematic elicitation and evaluation of all team members' views as a key success factor. This has also been discussed by Mulder et al. (2004) who link conceptual learning, feedback, questioning, and expression of

affect as mediators of shared understanding. There are three key gaps in current work on questioning support and shared understanding in this context. First, studies have either focused on areas outside of NPD or on more traditional problem solving design tasks. However, as highlighted by Hansen et al. (2013), the main issues associated with distributed NPD teams propagate from clarification and planning type tasks. Second, few studies have examined shared understanding support in both homogeneous and heterogeneous teams. This is in contrast to the situation in NPD where teams fall across the spectrum of heterogeneity (Earley & Mosakowski, 2000). Finally, there has been relatively little use of direct measures of shared understanding in this context e.g. Constructed Shared Mental Models (O'Connor, 2004).

Team heterogeneity

Team heterogeneity has a number of aspects that affect team performance including, culture (Matveev & Nelson, 2004), demographics (Lau & Murnighan, 1998), and education (Humayun & Gang, 2013). In this context, communication support tools have typically focused on developing new techniques to support heterogeneous teams (Johnson et al., 2007), based on the assumption that any tool that works in this context will also work for more homogeneous teams. However, this relationship has not been directly examined, particularly with respect to team cohesion and shared understanding – key correlates of team performance (Hinds & Mortensen, 2005; Lawler & Yoon, 1996). Johnson et al. (2007) explicitly state that further study is needed to directly compare the differing characteristics of homogeneous and heterogeneous teams. In this context heterogeneity is defined with respect to culture, professional experience, education, age, and sex, in line with Steinfield et al. (2001) and others (Matveev & Nelson, 2004; Humayun & Gang, 2013).

In terms of shared understanding it is generally accepted that homogeneous teams have a higher level of base shared understanding (Shokef & Erez, 2006; Cronin &Weingart, 2006). However, the comparative difference in how the two types of teams develop shared understanding over time has not been fully explored.

Research framework

Bringing the elements highlighted in this section together the following research framework is proposed. This links communication support, team composition, and the development of shared understanding as illustrated in Figure 1. Based on this framework, and the extant literature two hypotheses were formulated. The first focuses on the idea that heterogeneous teams are typically supposed to be more affected by communication support (Mulder et al., 2004). The second focuses on the fundamental nature of communication and shared understanding development, and thus proposes that effective support should benefit both types of team (Ko et al., 2005).

H1: *Heterogeneous teams will perceive a greater improvement in shared understanding than homogeneous teams when given similar support.*

H2: *Both heterogeneous and homogeneous teams will experience improved shared understanding when given communication support.*

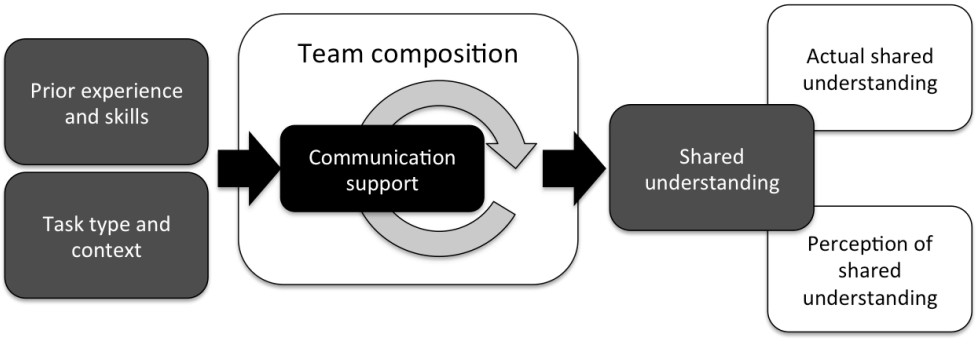

Figure 1: Research framework relating communication support, team composition, and the development of shared understanding

METHODOLOGY

In order to compare the development of shared understanding in both heterogeneous and homogeneous teams two studies were undertaken, focusing on the different team types respectively. In all other aspects the studies were identical, using a quasi-experimental approach to explore the impact of questioning support on the development of shared understanding. The overall progression of the studies is summarized in Figure 2. The 'barriers' denoted in Figure 2 represent the participants being moved to individual offices – completely isolated from each other.

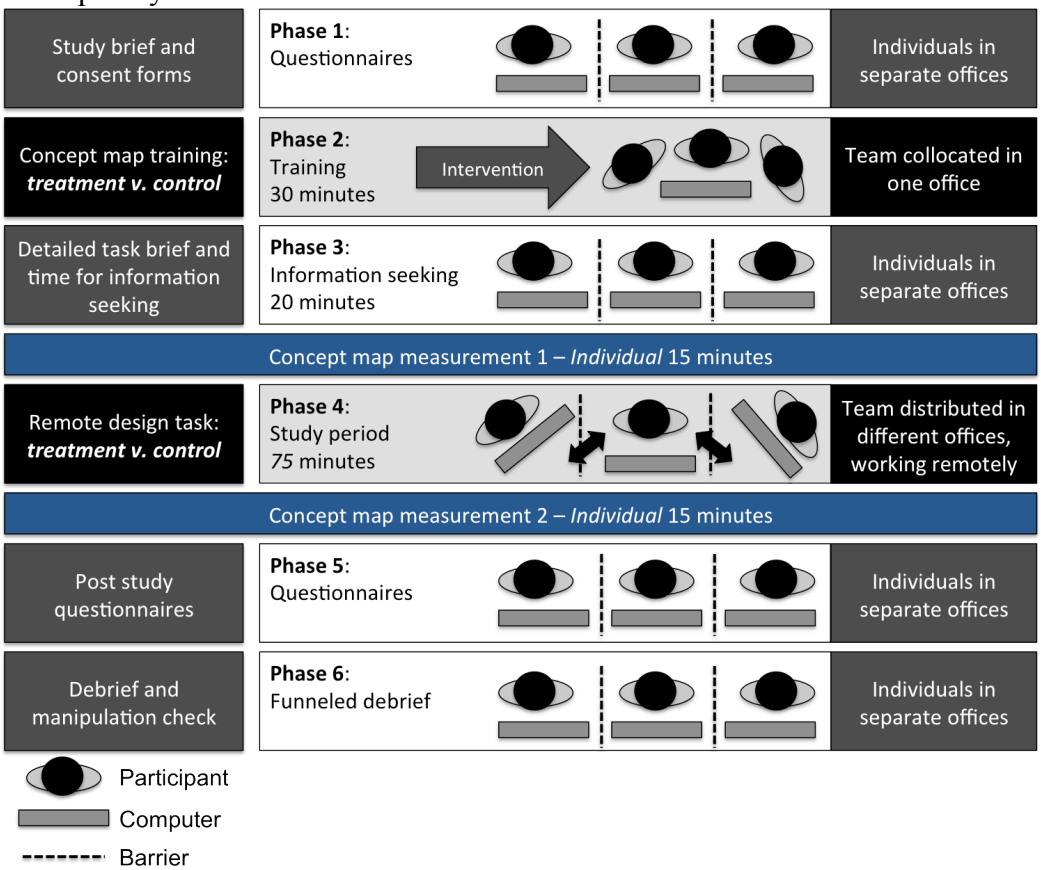

Figure 2: Experimental plan

Study 1: heterogeneous postgraduate teams

In the first study a population of 18 (11 male and 7 female) postgraduates with NPD experience was used. These formed a highly heterogeneous population, which was randomly allocated to six three-person teams. Random allocation was used to reduce systemic bias (Robson, 2002; Torgerson & Torgerson, 2003).

Study 2: homogeneous student teams

In the second study a population of 24 (11 male and 13 female) students was used. These formed a highly homogeneous population, which was again randomly allocated to eight three-person teams.

The two populations are compared in Table 1. Note the difference between the teams with respect to each of the aspects highlighted in the review of heterogeneity.

Table 1: population characteristics for the two studies

Demographic information	**Study 1**	**Study 2**
Age	Mean = 30 SD = 3.1	Mean = 24.5 SD = 2.2
Nationalities	10 countries (all teams were of mixed nationality)	5 countries (all teams had at least two members from one country)
Education	PhD level management or design, various masters degrees (all teams were of mixed educational background)	Masters level education in design, engineering, and innovation in a single program
Experience	Mean = 11 months Range of companies (all teams were of mixed experience areas)	Mean = 10 months (although these typically are internships or part time roles in parallel with study) Design companies

Setup and task

The overall task was as follows: "*The idea is to provide a universal camera mount, which can be attached to a range of remotely controlled aerial vehicles. The mount will also give the option for remote orientation, and control of the camera. The overall objective of this meeting is to produce a detailed plan for the collaborative design, and manufacture of the product, maximizing the skills of each company*." This was adapted from the previously validated work of Cash et al. (2013). It was selected because it has previously been used in a similar comparative context and was easily adapted to focus on scoping/planning type activities, whilst retaining the link to more traditional NPD design tasks.

Both studies followed the six-phase structure outlined in Figure 2. The two phases related to the intervention were 2 and 4. In Phase 2 the treatment/control interventions were introduced in the form of communication support training. In Phase 4 the teams used the provided communication support to complete the design task. The specific difference between the conditions was the inclusion of a questioning support element.

During the study participants were randomly allocated information on one of three company profiles, to provide them with a basis for their contribution to the teamwork. Each participant had different task related information better reflecting typical distributed NPD work (Hansen et al., 2013). The company profiles gave information on aerial vehicles (blimps/balloons specifically), camera mountings, and actuators, and were based

on similarly sized real world companies in order to help improve the realism of the task. Both studies used the same equipment and setup.

Treatment and control

In both studies teams were either exposed to a treatment of control intervention. The treatment intervention consisted of targeted communication support in the form of a question asking/feedback protocol. This was explained with regard to the importance of gathering opinion and highlighting important questions for agreement in the team. All participants were provided with a bell in Phase 4, which they were asked to use to initiate the protocol as summarized in Figure 3. This aimed to provided the treatment teams with a structured means for taking decisions, interpreting information, and fostering agreement – all linked to shared understanding (Mamykina et al., 2002; Spee & Jarzabkowski, 2009). The protocol also encouraged shared understanding by asking participants to consider all aspects of the question e.g. what, when, where etc. (Oppl & Stary, 2013).

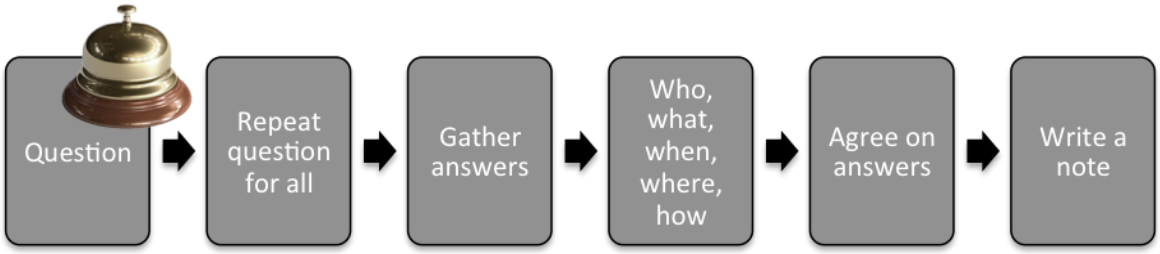

Figure 3: The question asking protocol used in the treatment intervention

The control intervention built on placebo control logic (Adair et al., 1989), delivering generic training related to the communication tool to be used by the participants. This also consisted of close attention from the facilitator and the appearance of important training as part of the study. This disguised the fact that no structured support was given for facilitating questioning. As such, attention and other possible bias vectors were equivalent in both conditions, reducing possible experimental bias (Gephart & Antonoplos, 1969). A hypothesis awareness check was also built into the funneled debrief in Phase 6, to confirm the effectiveness of the control measures.

Measurement

With respect to the research framework (Figure 1) the intervention addressed the questioning support, while the differing study populations addressed the team composition aspect. Measurement focused on the development of shared understanding in relation to the team's overall performance in the task.

Perception of shared understanding

Previous studies have used 7-point Likert scale questionnaires to assess perception of shared understanding (Badke-Schaub et al., 2007; Preston et al., 2006). Thus this previously validated approach was also used here. These questions address several aspects of perception. The different assessment elements are outlined in Table 2 together with related studies where similar measures have been used. A control measure was also used to check the quality of the communication in the teams, after Chiu et al. (2006). In total 23 questions were distributed across the different measures. All questions were

delivered in a random order and assigned positive/negative phrasings to mitigate structural bias (Robson, 2002).

Table 2: Measures for perception of shared understanding development

Measures	**Assessment**
Shared understanding	Shared problem definitions, and requirements (Badke-Schaub et al., 2007; Mulder et al., 2004)
Shared vision	Aim, scope, and timeline (Badke-Schaub et al., 2007; Chiu et al., 2006)
Solution understanding	Details of the proposed plan and execution approach (Preston et al., 2006)
Role distribution understanding	Role and task distribution details (Badke-Schaub et al., 2007; Preston et al., 2006)
Critical issue understanding	Scope, magnitude, and nature of potential issues (Ahmed, 2005)
Control measure	
Knowledge quality	Ease and relevance of information exchanges (Chiu et al., 2006)

Actual shared understanding

In terms of the systematic assessment of actual shared understanding development Constructed Shared Mental Models (CSMM) have been validated in a number of studies (Johnson & O'Connor, 2008; Johnson et al., 2007; O'Connor, 2004). Concept maps have also been previously used in the NPD context by Badke-Schaub et al. (2007).

For this study participants were asked to create individual concept maps representing their understanding of the design plan (the final output from Phase 4). This task was repeated before and after Phase 4 in order to isolate understanding changes stemming from the team's interaction in this phase (see Figure 2).

A list of inspirational concepts was provided to support the participants. These were synthesized from the lists of fundamental design concepts described by Ahmed (2005), Ahmed and Storga (2009), and Badke-Schaub et al. (2007). Using such a list is in line with CSMM methods and is described as semiconstrained. This is particularly relevant where participants might not be previously familiar with CSMM's (Johnson & O'Connor, 2008). Sharedness was then assessed with regard to the five standard measures of similarity summarized in Table 3. This produced a score (1 point for each measure in Table 3) for each round of mapping. Before and after scores could thus be compared at the team and individual levels to assess change in shared understanding.

In addition, the total number of concepts used by the team was considered as an indicator of focus and allowed for normalization across the teams. This reduced the impact of factors such as participants' writing speed or language fluency – important given the mix of cultural and educational backgrounds.

Table 3: Measures for CSMM development

Measure	**Assessment**
Shared concepts	Concepts with the same labeling
Shared sequences	Strings of concepts with the same ordering
Shared links	Two (or more) concepts with the same labeling and with the same link between them

Shared importance	Concepts with the same priority indication
Shared clusters	Clusters of concepts with the same labeling and links
Additional measure	
Number of concepts	Number of concepts used at team and individual level

Design performance

Design performance was assessed based on the final design plan produced by each team. This was produced at the end of Phase 4 and was recorded on a single sheet of A3 paper. This forced the team members to communicate their thoughts and synthesize them into a single plan able to be produced by one member of the team. The plan was assessed based on the number of elements identified with respect to the various performance measures detailed in Table 4. These areas were defined based on the works of Ahmed (2005), Ahmed and Storga (2009), and Mulder et al. (2004). An overall score was then be used to compare the team's plan documents. These results were again normalized to account for writing speed.

Table 4: Measures for design performance

Measure	**Assessment**
Design process	Task identification, design issues, task distribution, manufacturing plan, distribution plan
Physical product	Component, subassembly, and assembly identification, interfaces, structure and form, manufacturing methods, links to product families
Functions	Functions, plan for lifecycle
Design issues	Identification of critical considerations when completing the design process, critical relationships, key decision gates, potential issues preventing completion

RESULTS

This section outlines the results for the two studies before comparing them in terms of both team heterogeneity and the treatment/control condition.

Perception of shared understanding

Perception was assessed using the Likert questionnaires which are an individual exercise, thus, n = 9 in the heterogeneous study and 12 in the homogenous study. Each participant answered a total of 17 questions distributed across the measures, in addition to six related to the control measure. In order to check for consistency in the answers a Cronbach alpha test was conducted, which found the measures to be consistent across all conditions (Cortina, 1993). The results are summarized in Table 5 together with their significance. A one tailed students T-test for populations with different variance was used to compare the difference between the treatment and control means (Walker, 2010).

Table 5: Perception of shared understanding (**heterogeneous**/homogeneous)

	Mean response (n = **9** / 12)		
Measure	**Treatment**	**Control**	**Significance value**
Shared understanding	**5.22** / 4.75	**5.07** / 5.42	p = **0.34** / 0.02
Shared vision	**4.81** / 4.80	**4.97** / 5.21	p = **0.31** / 0.08

Solution understanding	**4.80** / 4.61	**4.11** / 4.73	p = **0.03** / 0.36
Role distribution understanding	**4.64** / 4.90	**4.58** / 4.79	p = **0.44** / 0.37
Critical issue understanding	**4.22** / 4.13	**3.83** / 4.50	p = **0.22** / 0.23

Shared understanding

Sharedness was assessed at two levels: team and individual.

At the team level (n = 3 heterogeneous/4 homogeneous) this consisted of two measures: the increase in the sharedness score between the first and second concept mapping exercise, and the decrease in the number of concepts used in the same period. These are reported as percentages of the total number of concepts used by each team in order to account for individuals' writing speed. The difference between the two conditions was again tested using a one tailed students T-test for populations with different variance (Walker, 2010). Results are summarized in Table 6.

The second assessment was at the individual level (n = 9/12) and considered increase in the percentage of shared concepts, and the change in the number of overall concepts used. Here a one tailed students T-test was used, but for within populations (Walker, 2010) as the focus was on the change associated with each participant between the first and second concept mapping exercise. Results are summarized in Table 6.

At both levels all conditions showed a general improvement in sharedness. This is to be expected as it is well documented that simple team discussion and interaction help to improve sharedness (Eris et al., 2014) – hence the importance of social factors in team performance and understanding (Lawson, Petersen, Cousins, & Handfield, 2009).

Table 6: Team and individual level shared understanding (**heterogeneous**/homogeneous)

Team level (n = **3** / 4)				
	Mean response			
	Treatment	**Control**	**Significance value**	
Change in sharedness	**54.99**% / 15.00%	**12.08**% / 11.09%	p = **0.10** / 0.44	
Change in number of concepts	**-22.67**% / 0.45%	**-3.41**% / -2.52%	p = **0.12** / 0.38	
Individual level (n = **9** / 12)				
	Mean response		**Significance value**	
	Treatment	**Control**	**Treatment**	**Control**
Change in number of concepts	**-4.78**% / 4.42%	**-1.00**% / 0.33%	p = **0.07** / 0.003	p = **0.45** / 0.43
Change in number of shared concepts	**3.33**% / 2.75%	**1.11**% / 1.58%	p = **0.08** / 0.004	p = **0.26** / 0.09

Design performance

The final assessment measure was the team level design performance (n = 3/4). This resulted in a score for each measure (Table 7), which was then used to generate a mean for the overall performance. Significance was assessed via a one tailed students T-test for populations with different variance (Walker, 2010).

Table 7: Design performance (**heterogeneous**/homogeneous)

	Mean response (n = **3** / 4)	

Measure	Treatment	Control	Significance value
Design process	**53.70**% / 66.33%	**51.75**% / 74.73%	p = **0.11** / 0.34
Physical product	**10.00**% / 20.64%	**33.23**% / 12.43%	p = **0.07** / 0.42
Functions	**0.00**% / 0.00%	**10.00**% / 1.04%	p = **0.21** / 0.20
Issues	**36.30**% / 13.03%	**5.03**% / 11.81%	p = **0.25** / 0.46
Combined			
Overall design performance	**11.58**% / 11.11%	**12.65**% / 11.11%	p = **0.06** / 0.34

Control variables

All check variables (background information, baseline variables, and knowledge quality) showed no significant difference between the treatment and control conditions in both studies. This included both prior expectations for the study and post-test assessments of performance. The one exception to this was that the treatment condition in the heterogeneous study reported significantly greater experience with the type of task than the control. The Cronbach alpha for the knowledge quality questions was again found to be good for both studies (Cortina, 1993). The final hypothesis awareness check built into the funneled debrief also showed no awareness of the study conditions or hypotheses in any group.

DISCUSSION

In this section the various comparison dimensions are outlined before they are more fully explored in relation to the presented literature and research framework.

Baseline comparison

The first comparison of note is between the baseline shared understanding measurement in the two populations. Here, there were no significant differences between the populations either in terms of mean number of concepts used or in the number of concepts shared between team members. This gives a good basis for comparing the differing responses of the populations to the questioning support intervention.

Homogeneous response

In terms of perception, the results trended towards a greater positive perception in the control compared to the treatment in all but one case (role distribution). However, of the various measures only overall '*shared understanding*' was significant.

In contrast there were more mixed results in the actual development of shared understanding. All measures trended towards a greater improvement in the treatment condition, although only the individual measures were significant. At this individual level a slight increase was observed in the average number of concepts produced by each individual. Despite this there was a decrease at the team level. This is explained by a general increase in the homogeneity of the team's concept map responses, with participants in the treatment teams moving towards a team average (those who initially wrote more reduced significantly, while those who wrote less increased slightly). As such, despite this increase at the individual level the results still strongly support improved shared understanding. In contrast the control teams showed no significant improvements and no increase the team homogeneity. However, it is important to note

that all results showed a slight positive trend in line with the natural increase in understanding expected from simple interaction. Thus, the overall trend indicated a net improvement in the treatment condition compared to the control. This strongly suggests that shared understanding is significantly improved in the treatment team due to the increased proportion of shared concepts and homogeneity of response.
The mixed findings in this context – perceived v. actual improvement – point to the need for further analysis but do suggest that overall the intervention still had a positive impact.
In terms of design performance there were no obvious trends, with the different categories showing improvement for both populations. Further, there were no significant differences in any category or common trends across categories.

Heterogeneous response

In all but one instance (shared vision) the treatment condition showed a higher perception of shared understanding development, although only '*solution understanding'* was significant.
Similarly, all measures for actual shared understanding development (both team and individual level) showed a positive trend towards the treatment condition. At all levels the trend was large but only weakly significant. However, the agreement across measures suggests that greater significance would be expected in a larger sample. This is supported by combing the two measures in a meta-analysis that gives $p < 0.05$. This is further supported by the fact that the treatment teams showed a substantial reduction in the distribution of the concepts used within each team, as in the homogeneous response.
The fact that these variables agree and all trend in the same direction thus suggests that the treatment condition developed a better overall shared understanding than the control, and importantly, that this improvement was perceived by the team.
In terms of design performance results, these are again inconclusive with mixed trend direction and no significant differences. This is in line with the homogeneous population findings.

Discussion of findings

The results from this study indicate two major findings. First, that questioning support can be targeted to successfully improve the development of shared understanding in distributed design teams. Second, that despite positive actual responses to the intervention the populations showed mixed perception of improvement. As such, study hypotheses have been fulfilled as follows:
H1: *Heterogeneous teams will perceive a greater improvement in shared understanding than homogeneous teams when given similar support.* ***Confirmed***
H2: *Both heterogeneous and homogeneous teams will experience improved shared understanding when given communication support.* ***Confirmation***
With respect to H1 the studies show a substantial difference between the perceptions of the two populations. This is in contrast to the actual improvement in shared understanding found across both studies. This links to Johnson et al.'s (2007) call for further research in this area, as it is clear from this study that perception of, and actual, effect have quite different characteristics in the two populations. This poses issues for the deployment and management of team support tools in mixed population companies or in

the effective management of team level morale. If a tool is not perceived to be useful it is not likely to be utilized or positively received by a team.
In the context of H2 both populations showed a positive trend in shared understanding development supporting the hypothesis. Although the individual measures were weakly significant the fact that the treatment effect was consistently positive across all measures and approaches provides good evidence to support the claim. However, there were indications that the populations reacted to the intervention differently, with less consistency in the homogeneous populations results. This is interesting, as the homogeneous population was not significantly more aligned pre-test than the heterogeneous population. This highlights the need for further research to explore these smaller scale effects, although these do not detract from the overall improvement seen in both team types. This can be linked to the larger body of work where shared understanding is closely associated with team cohesion and trust (Panteli & Sockalingam, 2005), and thus to communication behavior and awareness of team member's needs (Lawson et al., 2009). It should be highlighted that a strength of this framework, and questioning support in general, is that it serves to enhance communication and social interaction, which have been shown to be critical to team success (Lawson et al., 2009). Together these findings have a number of implications for practice and research, as well as some specific limitations, addressed in the following sections.

Implications

First, this study supports the key role of shared understanding and its relationship with questioning in NPD. In this case, in the difficult project scoping/planning situations common to globally distributed design projects.
Second, the alignment between the populations in terms of actual improvement in shared understanding highlights the utility of semi-structured question asking and feedback on the short-term development of shared understanding, which also links to the long term project success factors described by Hult et al. (2004).
Third, the differences between the two populations highlights the need for careful management of team support to best align actual improvement and team perception. As such, further work is needed to explore this difference in other situations and with other support tools.
Finally, this study feeds into the wider work on team behavior in the distributed NPD context and highlights the possibility for small interventions having a significant impact on team cohesion via their integration with everyday tasks. In particular, there is scope for exploring the use of questioning support and CSMM's in other NPD situations in line with other works in this domain (Ariff et al., 2013).

Limitations

There are three limitations of note with respect to this study. First, the size of both populations is small. Although this does limit the statistical power of the results it is partially mitigated by the use of multiple measures. Further, the rich characterization of the sample did not highlight any obvious systemic biases, which further supports validity.
Second, the results are only weakly significant, partially due to the small sample. However, the coherence of the results mitigates this substantially. In particular the fact that all the measures trend in the same confirmatory direction is highly supportive of the

findings. Further, as the results from this study align with other studies in this area and the logic outlined in the research framework the confidence in their reliability is increased.
Finally, the study focuses on questioning support. Although this limits the scope of the target behavior the applicability is wide, due to the importance of question asking and feedback in NPD. Further, the focus on shared understanding links this work to the wider literature and is well correlated with improved performance on the organizational level (Hult et al., 2004). As such, this work is in line with these larger scale phenomena increasing the applicability of the study.

CONCLUSIONS

This paper reports two quasi-experimental studies examining the development of shared understanding in distributed design teams. In particular it focused on the impact of questioning support in heterogeneous and homogeneous teams.
From the results reported here there is good support for question asking support as a key facilitator of shared understanding, and thus cohesion and ultimately long term project performance in design teams. This advances research understanding substantially beyond traditional characterizations of question asking as a simple problem solving activity in the design context. Further this links to the long-term development of shared understanding via the works of Mulder et al. (2004) and Hult et al. (2004), who both highlight its importance in overall project performance.
A second key conclusion is that despite the relatively minimal intervention and short study duration, significant changes in shared understanding were still observed across both populations. This points to possible new approaches for NPD support in the question asking and communication facilitation areas. In particular, the development of integrated tools to support these activities, coupled with 'real time' shared understanding assessment could prove significant for design practitioners in a globally distributed context (Hansen et al., 2013). However, this should be balanced against the differing perception findings where the homogeneous population did not perceive an effect in line with the actual influence of the intervention. Thus careful consideration should be given to tool performance in the context of companies, where a wide range of team compositions is common. In particular, this work highlights that despite positive effect there is not necessarily a common perception across populations.
Based on these conclusions there are two main areas requiring further work. First, examining other design populations and situations. In particular it would be relevant to explore the development of shared understanding across a more systematically varied range of team types. This would extend understanding of the differences between perceived and actual effects and help tailor tools and management support. Second, there is a need to expand the scope of situations covered and the time frame considered.

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