INITIAL CONDITIONS: THE STRUCTURE AND COMPOSITION OF EFFECTIVE DESIGN TEAMS

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ABSTRACT

Nearly all design work is collaborative work. The phenomenon of the multidisciplinary design team is increasingly common in both industry and project-based education. Existing research has shown that team diversity has mixed and often negative effects, especially when measured by demographic factors. However, relatively little research has been done on the cognitive style of team members, or "team cognitive diversity." Our research team is conducting a study examining several measures of cognitive style as they impact project performance for 15 collaborative student design teams. Though our full analysis is ongoing, a few noteworthy trends have emerged during our preliminary analysis. We believe that these trends, separate though they are from our central argument of cognitive diversity, have strong implications in understanding design teams and, ultimately, building teams for design success. In particular, trends relating to leadership, gender ratio and the peculiar influence of a cognitive factor called "Extraverted Feeling" will be discussed. We expand upon these findings and how they might be applied in multidisciplinary teamwork in design engineering education and practice.

Keywords: Design teams, cognitive diversity, extraverted feeling, social sensitivity

1 INTRODUCTION

As teams engage in the practice of design, there is a growing awareness among educators, managers and researchers that team diversity may play a significant role in the quality of the design output. However, there is a significant body of research that indicates team diversity has both a positive and a negative impact on team performance. (1) On the positive side, team diversity can provide a variety of perspectives and problem-solving approaches, which can lead to greater creativity and quality of team performance. However, most research on diversity and team performance of the evidence favors a more pessimistic view: that diversity creates social divisions, which in turn create negative performance outcomes for the group.

When demographic measures of diversity have been used to predict team outcomes the results of team diversity have been non-existent to negative. We believe that team members benefit not from each others' demographic variation, but rather by means of a "team cognitive diversity" in thinking styles and problem-solving approaches. Though some have focused on the impact of cognitive style on team dynamics, the need for examining the underlying psychological and cognitive mechanisms linking diversity directly to team outcomes has been emphasized by several researchers and provides motivation for our ongoing study. (2) (3) (4)

We examined fifteen Masters-level student design teams over the course of a year-long design engineering project for evidence of the effects of cognitive diversity. However, our model and investigation of team cognitive diversity will not be the central focus of this paper. Rather, we discuss a few interesting and relevant trends that surfaced during our preliminary analysis. In particular, we will discuss team performance outcomes as influenced by leadership style, gender balance, and a cognitive preference called "Extraverted Feeling." Significantly, we find that a team's overall cognitive preference for Extraverted Feeling, as well as its proportion of females, can positively impact performance. We also discuss a trend that suggests a benefit to adopting a balanced leadership style within the team.

2 METHODOLOGY

2.1 Background

This study examines 15 independent project teams within the context of a project-based global engineering design innovation course. The course spanned a full academic year and was hosted simultaneously at nine international universities. Most of the project teams included students from two different universities; though the students have a handful of opportunities to meet face-to-face during the project, the majority of their work is conducted in a state of distributed collaboration. A few of the teams were "local-only" and did not have any international counterpart. The teams ranged in size from 3 to 9 individuals (predominantly first-year Masters-level engineers, but also some students of industrial design, business and marketing, and information technology). All students were graded and evaluated as part of a team.

A corporate "client" sponsors each team and provides a brief project prompt at the beginning of the course. The prompts vary in scope, subject matter and difficulty and provide a rough outline for the project work. The prompt is likely to be revisited, refined and redefined through subsequent meetings between the team members and a corporate liaison. The students had approximately eight months to develop a solution and deliver a functional proof-of-concept prototype. The design process, though undoubtedly implemented differently on each team, combines exploration, need-finding, iterative prototyping and user testing. The teams had no appointed leader or project manager, providing the potential for emergent leadership within the teams. Their work was guided by feedback from teaching team members as well as industry coaches and corporate liaisons.

There were notable differences in how the program was set up at each of the different universities. While one of the universities hosted ten projects (32 students total), six others hosted two or fewer (with a total of 8 students or less). Teaching teams (including professors and teaching assistants) varied in size from zero to seven members, and conducted varying amounts of weekly lecture/feedback sessions. However, all students had access to lecture videos from other universities and the course content was largely standardized. Though the major milestones and deadlines were largely shared across universities, grading policies were different in some cases. Not all universities assigned independent industry coaches to their teams. Each team was provided an unrestricted research and development budget of approximately equal size.

Location	Students	Project Teams	Teaching Team Size	Weekly Sessions	Coaches Assigned
United States	32	10	6	2	Yes
Finland	23	6	6	2	Yes
France	13	3	3	0	Yes
Mexico	8	2	7	2	No
Northern Germany	6	2	3	1	Yes*
Colombia	6	2	6	-	-
Japan	4	1	0	0	No
Southern Germany	4	1	3	1	No
Switzerland	4	1	2	1	No

*Shared coach

Figure 1.3 – *Student Breakdown by Location*

2.2 Psychometric Assessment of Individuals

As part of our investigation into cognitive diversity, psychometric and ethnographic survey instruments were administered to the students during the early phases of the course. The psychometric instruments included the Kirton Adaption-Innovation Index (KAI), the NEO-Five Factor Personality Inventory (NEO-FFI) as assessed by the Ten-Item Personality Instrument (TIPI), the Herrmann Brain Dominance Inventory (HBDI) and the Wilde-Type "Teamology" method. (5) (6) (7) (8) These four instruments were selected from a much larger pool of potential psychometric instruments; our selection was based on relevance of the instruments to our construct of cognitive diversity, personal experience with the instruments, extent of scientific support in the literature and variability across

instruments for a multi-faceted approach. Though the instruments had some common language, we did not make any claims about construct validity at the outset and treated all output variables as functionally independent. All four of these instruments are in the self-reported survey format. In the interest of brevity, we will only expand upon one of these instruments here.

Instrument Name	Output Variables	Survey Items	Survey Instrument
NEO-FFI	5	10	TIPI
HBDI	4	120	HBDI
Wilde-Type "Teamology"	4	20	Modified MBTI
KAI	1	32	KAI

Figure 1.4 – *Psychometric Instruments*

The "Wilde-Type Teamology" method was developed by Dr. Douglass J. Wilde using Jung's original construct theory of psychological types. (9) By means of a 20-item instrument, this method seeks to establish cognitive style preferences on four continua (introversion/extraversion, thinking/feeling, sensing/intuition and judgment/perception). These preferences are then algebraically combined to score each individual on eight different cognitive modes (comprised of four mutually exclusive pairs). According to Dr. Wilde, these modes correspond to different problem solving styles and perhaps even to specific team roles and activities. For example, an individual with a high score in the Extroverted Sensing (ES) mode would be expected to prefer physical prototyping and experimentation as a problem-solving strategy, and may be the first on the team to undertake such activities. (8) Dr. Wilde's theory on team formation posits that a strong team has all cognitive modes fairly represented, so as to possess a complete "tool kit" of problem-solving strategies.

2.3 Measures of Team Diversity

A large portion of our theoretical work on this project has been in developing a model of cognitive diversity that aggregates individual-level cognitive style data on multiple instruments into a team-level numerical representation of overall cognitive diversity. However, we will not expand on that model here as it is not immediately relevant to this paper. A full treatment of that model, and the results of our search to find its effects in our sample population, will appear in subsequent publications. As part of our analysis, we computed team mean scores for each cognitive variable. This allowed us to observe relationships between our dependent measures and cognitive variables themselves (not as a measure of diversity), and this is the analysis we refer to here.

Since the majority of existing diversity research has focused on ethnographic diversity (measured by outward characteristics such as race, gender and age), we decided to collect this information in addition to the psychometric assessments. While our main intention was to test the hypothesis that cognitive diversity is independent of ethnographic diversity, this data also gave us a window into how certain ethnographic characteristics themselves, such as gender, may have impacted team performance. In total, nine points of standard ethnographic data were captured in addition to the fourteen psychometric variables. These 25 data points for each individual, as well as fixed team parameters (team size, project difficulty, etc.) comprised our independent variable data set.

2.4 Assessing Team Effectiveness

Overall "team effectiveness" was defined as a combination of the team's output quality (project performance) and a measure of team members' self-reported satisfaction. As a whole, this represents our primary dependent variable; considering its elements independently, we are also able to observe the relationships between items such as leadership style and project performance.

2.4.1 Project Performance – Due to the variability of scope, content and complexity in the initial project prompts, it was necessary to establish a difficulty rating that could be used to adjust the final project performance scores. Adjusting by overall difficulty allowed us to make more valid performance comparisons across the different projects. Project difficulty was rated by assessing the technical complexity, breadth of scope, extent of ambiguity and overall difficulty of each project judging from the initial project prompts.

The assessment was conducted by a sampling of 32 design professionals with an average of 12 years' experience in the field. The inter-rater agreement was ($\alpha = .81$). Two additional projects were inserted into the rating, one deemed easy and one hard by the researchers, to check the validity of the ranking. The ratings had an internal consistency ($\alpha = .84$), so we used to the mean of the four measures as the numerical difficultly rating for each project. The overall project difficulty ratings were proportionately adjusted so that the easiest project had a rating of 1.00, while the most difficult project had a rating of 1.41, reflecting a 41% difference in difficulty ratings between the easiest and hardest projects.

Project performance was then assessed according to four performance variables and three process variables. The performance variables were: proposed solution effectiveness at addressing the stated need; usability of the solution were it to be implemented as a real product; technical feasibility of the solution to be implemented as a real product; and originality of the proposed solution. The process variables examined whether the team redefined the problem statement as given by the prompt, whether their final prototype successfully demonstrated the proposed solution, and whether the stated need was compelling.

The researchers reviewed all project materials and were trained in rating and rating agreement. After rating, the internal consistency among the performance variables was .639. As a result we opted to use the sum of all four-performance variables as the raw project performance score. Process variables were tracked but not immediately included in the analysis. Prior to adjusting for difficulty, the range of scores obtained was 2.0 to 8.0 (of a possible 0.0-8.0 integer range). Project performance ratings were multiplied by the project difficulty scores to produce the final adjusted performance rating. These ratings ranged from a low of 2.07 to a high of 10.85.

2.4.2Team Satisfaction & Emergent Leadership – At the conclusion of the projects, students were asked to complete a ten-item satisfaction survey (that would not be seen by their teammates or teaching teams). This survey contained Likert-style questions exploring conflicts and conflict resolution within the team, shared goals, liking of team members, teamwork skills and general satisfaction with the team's performance. In addition, the survey contained a question in the style of the Aron Scale of Closeness (10) and two open-response questions about leadership. Specifically, students were asked to name a team member who had emerged as leader, if any, and also to describe his or her leadership style. These descriptions allowed us to make qualitative assessments of the leadership style within the team. The condition for "emergent leadership," by our definition, was the case in which two thirds or more of all team members identified the same individual as leader.

3 RESULTS

Of the fourteen cognitive variables under our observation, one exhibited a particularly strong and significant correlation with project performance. That variable was one of the eight "cognitive modes" of the Wilde-Type Teamology method: Extraverted Feeling (EF). Teams exhibiting a more pronounced preference for this thinking style overall tended to perform better to a very high level of significance ($r = 0.74, p = 0.00$). Note that this is measured as a team mean, and is therefore not a diversity measure. This was supported by a similar (though less pronounced at $r = 0.42, p = 0.11$) finding for the "communication" variable of the Herrmann Brain Dominance Indicator (HBDI). EF and HDBI-C share similar language in their descriptions, particularly regarding social behavior and communication. The alignment in these results suggests construct validity and provides some confidence in our understanding of their effects.

Overall, our population sample was approximately 67% male. The gender ratio on teams ranged from 50% to 87% male, with most teams having only one female member. The percentage of males on the team was moderately negatively correlated with project performance ($r = -0.42, p = 0.09$) at the 10% level of significance (fairly strong considering the small sample size of teams). In other words, teams with more females tended to perform better, and our data in no way indicates that this effect diminishes even at the maximum observed 50% female ratio. Though it is often suggested that EF-

type behaviors are evidenced more strongly in females, perhaps contributing to their positive impact, we did not find evidence to support that claim in our subject pool.

Our satisfaction surveys at the end of the projects asked students to identify a team member who had emerged as leader, and to describe that leader's style in an open format. Though nearly every student did identify a leader, there was remarkably little agreement among members of the same team as to who the leader was. In only four cases was our condition for emergent leadership satisfied (that two thirds or more of the team identify the same individual as leader). In two of those cases, the leadership style descriptions were qualitatively negative; the other two cases were qualitatively positive. There was a noticeable difference that the group of teams with leaders (both positive and negative) had a mean performance score nearly a full point lower than those teams without leaders (4.85 to 5.83, respectively), or a differential of about 17%. This represented a moderate but not significant statistical difference (probably due to the small sample size of teams with sufficient leadership data, $n = 13$). Though most teams were without "single point leaders" by this definition, those teams all had multiple leaders named on the survey.

4 DISCUSSION

4.1 The Impact of Extraverted Feeling

We were not necessarily surprised to find that one cognitive variable tracked well with performance on its own. After all, with fourteen cognitive variables, it is expected just by statistical variation that some will track more strongly than others. However, the result linking the Extraverted Feeling (EF) variable with performance was undeniably strong and significant. One might have expected that the several measures with names like "Innovation" might have been the ones to stand out in this context, but that was not the case. Knowing that these instruments are reliable (in that subjects will reliably tend to score similarly when taking the instrument at different times), it is promising just to have possibly established a testable cognitive variable that could predict team effectiveness. Beyond that, we can begin to really understand the effects of EF on a team, particularly with construct validity as indicated by the similar result for HBDI-C "Communication."

The Wilde-Type Teamology method identifies eight distinct cognitive modes of which EF is one. From personal experience, a typical population of individuals will possess about two mode preferences on average. Given that there are eight modes, and assuming those modes are more or less equally frequent in our sample, that means we would expect each mode to be represented in about 25% of the population. We have no reason necessarily to believe (or not to believe) that any of those assumptions are inaccurate, as there is limited access to general population data for this instrument; nevertheless, a significant preference for EF (as defined by the instrument) was expressed in precisely 25% of the population. In that sense, it was not overly scarce, and therefore we do not expect that the effect is being exaggerated statistically.

4.1.1 Defining Extraverted Feeling – According to Dr. Wilde, the EF mode corresponds to a problem-solving style that relies on "Communication" as its essential element. The extraversion portion indicates an outward direction of energy for the individual, and the feeling portion indicates a preference for interpreting experiences emotionally (rather than rationally). These individuals are characterized as being quick to sense and address conflict, and often being the ones responsible for keeping the lines of communication open. It is important to note that the EF variable, as defined by the Teamology method, is mathematically distinct from any of the types defined by the Myers-Briggs Type Indicator (MBTI).

Jung describes extraversion as the psychological condition to orient ones understanding on objective experience, often translating into a communicative or open disposition. Extraverted feeling types, specifically, tend to interpret experiences through genuine objective feeling. As such, they are "always in harmony with objective values," and the first to proactively create "a pleasant feeling atmosphere, for which purpose everything must be felt as agreeable." Furthermore, Jung states that extraverted feeling "proves itself a creative factor. Without it, a harmonious social life would be impossible. To

that extent extraverted feeling is … beneficial and sweetly reasonable in its effects." (8) It is not hard to see how these kinds of cognitive preferences could be beneficial for long-term team performance.

4.1.2Extraverted Feeling in Design Education – In fact, there are several specific examples of beneficial actions and practices within teams that represent precisely this type of behavior. Many of these practices are intentionally worked into the curriculum of the course, though not always explicitly. Teams are frequently encouraged to perform "debrief" sessions where they share their feelings and impressions of the work so far, as well as address directly interpersonal dynamics issues in a positive and productive manner. These sessions lend a supportive, open air to the team dynamic and prevent conflict from growing worse due to neglect. This is the sort of role that a strong EF-type person might be expected to play. Furthermore, teaching assistants, coaches and other course members are routinely selected for exhibiting this type of behavior.

In general, the course atmosphere encourages the notion that failure is a natural (and essential) part of learning, not something to hide or to be ashamed of. This is one example of deliberately "re-branding" an ordinarily negative experience into something characteristically positive and productive. Similarly, encouraging outlandish (even infeasible) ideas during brainstorms and "deferring judgment" of one another's ideas is a learned practice specifically aimed at maintaining a positive atmosphere of open communication. Feedback from instructors is structured as collaborative guidance (rather than critique or grades-based evaluation), and this feedback may or may not be incorporated into the final product at the team's discretion. Many of these intentional or unintentional curricular elements, particularly at the higher-performing universities, seem to be modeled on a platform of openness and communication that encourages EF-type interactions and behaviors in the course at large, including actively fostering a strong sense of community among students.

4.1.3 Extraverted Feeling in Design Practice – Several successful design consultancies and innovative technical companies in general have adopted a similar model of an understated hierarchy and open communication among employees who previously may have had little or no interaction. They invest considerable resources in creating a positive atmosphere and use processes labeled "user-centric" and "empathetic." All of these practices may also indicate a focus on EF-type interactions, though I admit that I have neglected to define that to a high degree of specificity at this point. All of these practices suggest that it is possible to "coach" or otherwise educate people in EF-type behaviors regardless of their cognitive disposition; understanding the real effects of these exercises could help us to characterize what role EF-type behaviors really play on a team. Even so, it appears that the prevalence of the EF disposition still provides a noticeable advantage in the long run; in that sense, it may be a useful indicator (or even predictor) of team performance.

4.1.4 Beyond Extraverted Feeling – We do not suggest that EF is the only factor at work here, or that it is necessarily the best description or indicator of what I have loosely labeled "EF-type" behaviors. Wooley et al., in searching for a measure of collective group intelligence, found instead that the team's overall score in "social sensitivity" seemed to provide the best explanation for performance. (11) Such a definition may be more practical and meaningful than the label extraverted feeling, especially since there appears to be a commonality between the two (though they are measured quite differently). Indeed, it appears that the definition lies somewhere in the overlap between communication, openness, sensitivity and empathy. Understanding precisely what the mechanism is, and what is the best way to measure it, is certainly worth addressing in the future. At present, it is encouraging that there may be several varied ways of observing this phenomenon at work within teams, and that EF appears to be one of those.

4.2 Emergent vs. Balanced Leadership

Based on the responses, it is clear that most students did not perceive an absence of leadership on their teams. Therefore, we can infer that any performance discrepancy is not one due to "leadership" versus "no leadership." Rather, it appears that there may be three distinct leadership styles at work on these teams. First there is a style that we will call the "natural leader:" solo emergent leadership on the team that is rated qualitatively positive by teammates (this occurred twice). Second, the "reluctant leader" is

an individual who felt pressured to take control because of missed deadlines, etc. and is rated qualitatively negative by teammates (this also occurred twice). Lastly, there is a quite different leadership style, which is characterized by different teammates reporting different individuals as leaders (this happened nine times). We believe that this may be evidence of a "balanced leadership" style. In our study, there is some indication that natural leaders and reluctant leaders may dampen their teams' performance. A style of balanced leadership, on the other hand, may be a superior team structure.

4.2.1 Emergent Leadership - Only four of thirteen teams achieved two-thirds agreement or more (the condition for "emergent leadership"). Note that two teams were removed from the analysis at this point for an insufficient response rate to the closing survey. On average, though this result is not statistically significant, teams with emergent leaders performed about 17% worse than their peers. This is not necessarily because emergent leadership in itself is a bad thing, but perhaps because in this context emergent leadership tended to occur in response to other persistent team dynamics problems. As such, emergent leadership may actually indicate underlying problems or shortcomings on a team, and so it tends to coincide with lower performance. This can hold true even in the cases where teammates agree that the leadership is helpful. It may also be that defaulting into a single-leader group dynamic can indeed help to overcome some organizational or dynamics problems, but that it fundamentally limits the productive contribution of other team members by introducing a persistent imbalance into the group dynamic.

4.2.2Balanced Leadership – Of course, it may be that individuals on teams have different definitions of leadership in the context of their team, and therefore select different individuals. In fact, this may be a result of balanced leadership: if there is no overbearing personality on the team, or the personalities are at least evenly balanced, then there is the potential for everyone to be a recognized as a leader in some capacity. To the greater extent that these capacities are known, understood and valued by their teammates, the positive effect of the balanced leadership strategy is likely to be enhanced. Decision-making is more likely to be shared and handled openly. Communication is more balanced. We might also expect this to coincide with mutual feelings of respect and perhaps, subsequently, better listening and deeper understanding. Teams who can all identify the same leader have been forced to accept, for better or worse, that that individual is in charge; therefore, in both the qualitatively positive and negative cases, it still has the effect of undermining the balanced leadership strategy. The potential benefits of this strategy are then lost to the team. There are associated interpersonal dynamics (such as turn-taking in conversation) which are likely also to be affected for the worse.

Much of this appears to be implicit knowledge in team-based education; many programs seek to teach leadership skills in a team context, and as teachers we often seek to encourage equal participation and sharing of ideas (even if it means dampening some overbearing individuals). Though some classes do (unfortunately) insist on assigning explicit team leaders or project managers, many do not. Modern interdisciplinary design classes and consultancies intentionally bring together individuals from different backgrounds to work on equal footing. The classic example of an entrepreneurial team consists of a small group of equally dedicated yet uniquely skilled individuals operating as a unit with no formal hierarchy. It may be that this balanced leadership style (not as common elsewhere in industry, where managerial hierarchies are often in place) is one of the reasons that these teams are able to innovate so effectively. It is reassuring to find some indication that this model may also be succeeding in our sample population. However, a more in-depth focus on leadership and a larger sample size of teams would be necessary to draw any firm conclusions on the impact of leadership style.

4.3 Gender Diversity

Gender diversity is among the more common and familiar forms of outward (ethnographic) diversity, though previous research has generally been unable to show that it is consistently linked to performance one way or another. In our case, however, there was a fairly clear indication that increased female presence on the team was associated with better overall team performance. To clarify

the real meaning of this, first note that the effect was by no means unilateral; indeed, the team at the minimum 13% female ratio was also a strong performer. Also, the way this statistic was calculated may be somewhat misleading as a team of four with one female will be scored with a higher female proportion than a team of five with one female; in this sense, the effect of increased proportion of females may simply be an artifact of incrementing team size.

In support of the finding, however, there was no overall significant link between performance and team size in the sample, suggesting that the differential may in fact be attributable to the proportion of females. It remains unclear whether it is prudent to represent the gender balance as a ratio or as a whole number of female individuals on the team; it is likely that the positive effect tracks with an increased number of female team members, and so we would (in general) expect teams with more female members to perform better. Of course, this distinction is only meaningful because we had a broad range of team sizes in our sample. Our data does seem to suggest that these design teams stand to benefit as the number of females in the course and on each team increases; Woolley's findings are also consistent as far as the beneficial impact of increasing the proportion of females on a team. (12)

Of course, it is a sensitive issue when one speaks of gender (or of any other outward ethnographic characteristic, such as race) as a basis for evaluating and forming teams. Indeed, teams of all gender compositions have performed well on all sorts of tasks. Furthermore, this is absolutely not to suggest that all females think the same way, act the same way or fill the same role on a team. There is no reason to believe that the females in our sample had even remotely consistent contributions to their respective teams. Nevertheless, for those of us who would like to believe in the power of diversity, it is reassuring to see an indication that the minority gender may be having a positive impact just by being involved in the course and mixed in on the teams. We might also hope to discourage the notion that a "token female" is adequate to tilt the balance (or, said quite differently, a team of five with one female is better off adding another female than dropping a male). It would be interesting to test the limits of this effect in future studies with teams ranging across all gender ratios.

4.4 Future Work

We believe that further developing our understanding of team cognition in a more holistic fashion will help us to understand why certain teams perform better than others and why diversity makes an impact. We also hope to explore the boundaries within which these findings may apply, as we are confined to a very small, non-representational fraction of the population (and a very unusual course) at the moment. A part of establishing the more general applicability of our findings will also come from more standardized evaluations of performance, possibly in the form of repeatable laboratory experiments to measure team effectiveness.

If successful, we expect that this will guide us in how to build teams, how to design team-based education curricula, and how to coach teams for success in academia and in industry. Though this is an extraordinarily broad claim, we do believe that this is the potential for having a better cognitive understanding of teamwork in the context of creative problem-solving. Perhaps, with this understanding, we may also be better able to define what is really meant by "design thinking" at a cognitive level. Our future work and subsequent publications will expand upon this broader framework of team cognitive diversity, while understanding it in the context of very real and present factors such as gender and social atmosphere.

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