21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

LITERATURE BASED REVIEW OF A COLLABORATIVE DESIGN TAXONOMY

Righter, James; Chickarello, Doug; Stidham, Hallie; O'Shields, Steven; Patel, Apurva; Summers, Joshua
Clemson University, United States of America

Abstract

A 2003 paper at ICED established a collaborative design taxonomy that can be used to breakdown and categorize engineering design teams. This collaborative design taxonomy was evaluated to determine its usefulness, consistency, and applicability. The taxonomy was used to evaluate 24 papers presenting studies on engineering design teams. Results of this literature review provided insight into what has been recently studied in collaborative engineering design and identified that open-ended responses describing design teams need improvement. The group composition merits further review based on its high frequency of occurrence and the need to better characterize complex teams. The distribution branch requires reconsideration of its organization while temporal criteria require additional details to increase its objectivity. These results provide a direction for future work to apply the taxonomy to real time collaborative design scenarios.

Keywords: Collaborative design, Teamwork, Ontologies, Design theory

Contact:
Prof. Joshua Summers
Clemson University
United States of America
jsummer@clemson.edu

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 8: Human Behaviour in Design, Vancouver, Canada, 21.-25.08.2017.

1 MOTIVATION FOR RESEARCHING THE COLLABORATIVE DESIGN TAXONOMY

The collaborative design taxonomy was originally proposed in 2003 and further refined in 2009 to classify and model collaborative design situations (Ostergaard and Summers, 2009; 2003). This taxonomy contains six top level attributes, three tiers, and 44 taxa. Since this taxonomy was described to assist in classifying design situations, the lack of specific parameters for users to select from can increase its subjectivity and thus lessen the effectiveness of the taxonomy. By using the taxonomy in a review of the literature, it is apparent that the taxonomy assists in evaluating collaborative design situations. The taxonomy is not meant to create specific design teams, although factors presented in the taxonomy can be used to identify what aspects may aid or inhibit a design team. The collaborative design taxonomy can be better applied if advancements were implemented to increase its objectivity, and thus this research aims to assist with that development.

2 BACKGROUND ON COLLABORATIVE DESIGN

The engineering design process is described as problem solving to develop a product for a customer or client through the use of a systematic approach (Pahl et al., 2007; Ullman, 2010). The systematic approach consists of the problem definition, concept generation, embodiment, and detailed design phases. Engineering design often deals with complex problems or product architectures and requires teams of engineers with different backgrounds working under project managers to solve the problems (Pahl et al., 2007; Monell and Piland, 2000).

Team behaviors have been researched and studied by engineers and psychologists for years in order to identify methods for improving project and team success rates. One aspect that has been studied in depth is which factors influence the creativity of design teams (Kim, 2007; Kratzer et al., 2010). These studies have found that engineers generate a larger number of solutions when exposed to scenarios including teamwork. Additionally, diversity's impact on team success has also been the focus of multiple studies. These studies include investigating the impact of leadership styles and gender diversity on teams (Kress and Schar, 2011; Hanus and Russell, 2007). Cultural diversity has also been reviewed to determine its impact on team success (Ibn-E-Hassan et al., 2014). Research on leadership within teams has led to studies published on various leadership styles such as functional and authentic leadership and how the different styles increase a team's likelihood of success (Derue et al., 2011; Morgeson et al., 2010). Another study revealed that engineering student design teams demonstrated task oriented functional leadership behaviors more often than interpersonal leadership behaviors (Palmer and Summers, 2011). Further, functional team behaviors are observed in a capstone project setting and demonstrate how the behaviors of the team evolve as the design project matures (Born and Schmidt, 2016). These topics collectively influence many different aspects on project team performance and effectiveness. Organizing these topics is critical for clear communication and comparison of results, and there is currently no encompassing classification system for all aspects of a group design project.

This work focuses on collaborative design situations and improving the way engineers currently analyze design that occurs in teams. The collaborative design taxonomy was developed with the intent of systematically classifying the unique properties of collaborative design scenarios (Ostergaard et al., 2007; Ostergaard and Summers, 2009). The taxonomy consists of the following six top level attributes: Team Composition, Communications, Distribution, Nature of the Problem, Information, and Design Approach. These attributes are then expanded upon to a detailed level of individual taxa that can be evaluated for specific design projects and teams, and are divided into three distinct levels (Figure 1). The taxonomy was used to establish a model of collaborative design based on the metaphor of an electric circuit (Ostergaard and Summers, 2004). The theory has three basic concepts: passive knowledge, active knowledge, and circuit resistance. Passive knowledge, such as the engineers experience or lessons learned on previous projects, is modelled as the voltage of the circuit. Active knowledge is considered the rate at which specific knowledge regarding the project grows. Specifically, active knowledge is an example of the rate at which the requirements documents grow, the generation of new function structures, or the evolution of prototypes. The growth of active knowledge acts as the systems' electrical current. Finally, the resistance of the circuit is modelled by the taxa of the collaborative design taxonomy (Ostergaard and Summers, 2009).

This work aims to identify potential areas of the taxonomy that require additional clarification and improvement. The identified portions of the taxonomy needing improvement will be modified in future work. The purpose of creating a more complete taxonomy is so that it can be utilized in academia and industry in order to accurately characterize collaborative design activities. Having the ability to classify all types of teams will allow others to differentiate between what has worked well and poorly, and use this information to make improvements in the future.

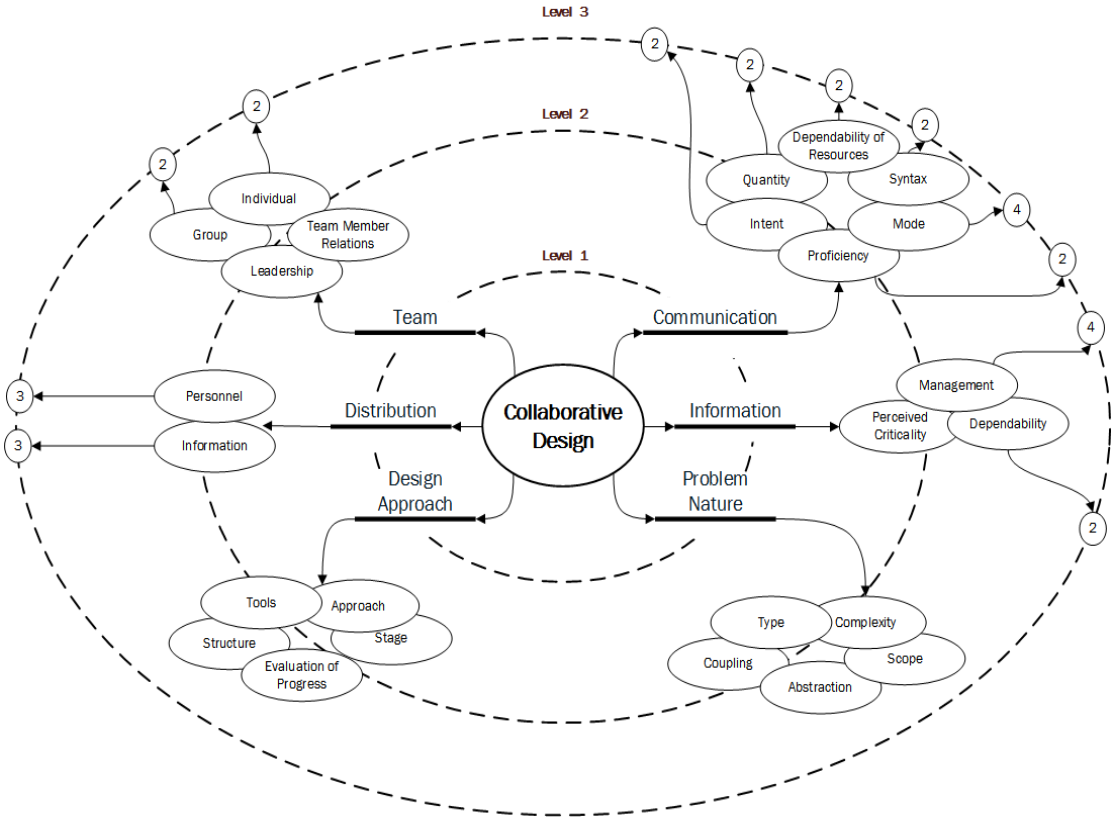

Figure 1. Recreated representation of Ostergaard's collaborative design taxonomy (Ostergaard and Summers 2009)

3 METHODS

An analysis of the taxonomy was performed in the form of a literature review, using the taxonomy to characterize the design teams found in the literature. Three papers were chosen for individual review by four reviewers (Born and Schmidt, 2016; Kratzer et al., 2010; Linsey et al., 2011). These initial papers were specifically identified as representing a broad range of research methods and team compositions, two were case studies and one was an experiment. The teams studied ranged from small sizes of 4-6 members to large multinational product teams. These papers were selected in order to determine the applicability and consistency of the taxonomy matrix across a range of scenarios. An inter-rater reliability test was performed to evaluate the agreement among reviewers regarding the categories that were addressed.

Following the inter-rater reliability test, a total of twenty-one additional sources were analyzed among the team members using this taxonomy to determine what aspects of collaborative design team activities are frequently addressed in design research literature (Capra and Moreira, 2013; Chiu, 2002; Cross et al., 1995; Denton, 1997; Détienne et al., 2004; Doumit et al., 2015; Ensici and Badke-Schaub, 2011; Garner, 2001; Jung and Leifer, 2011; Man et al., 2013; Mathieson et al., 2011; Ovesen, 2015; G Palmer and Summers, 2011; Sonnenwald, 1996; Stempfie and Badke-sehaub, 2002; Taylor and Ahmed-Kristensen, 2015; Van der Loos and Ostafichuk, 2009). Of the twenty-one sources, fourteen were case studies, six were protocol studies, and one was a user study. The raters identified instances where each category was addressed in each paper. For example, the design problem could be defined as a variant or novel design. The type of problem could also be implicitly detailed by the fact that the designed artefact

has not been previously attempted such as the design of a non-pneumatic wheel for use in a lunar environment (Gary Palmer and Summers, 2011). Through this analysis, we hope to identify the most used taxa, as well as identify which taxa need to be further defined or removed.

4 ANALYSIS OF TAXONOMY FOR CONSISTENCY

Cohen's Kappa statistic was used to determine the level of agreement between the four raters for the three initial papers chosen for individual review. The Kappa values calculated for each pair of raters for all three sources evaluated are shown in Table 1. Sixteen of the eighteen kappa values fall between 0.510 and 0.800. These values suggest that there is a moderate to substantial level of agreement between the raters. As a result, it was concluded that the different sources evaluated by these raters are equivalent for the purpose of identifying whether these sources address specific categories in the taxonomy.

Table 1. Kappa Values for Each Pair of Raters (note that higher values indicate greater rater agreement)

Source	Rater Pairs					
	1&2	1&3	1&4	2&3	2&4	3&4
(Born & Schmidt 2016)	0.609	0.524	0.697	0.652	0.696	0.653
(Kratzer et al. 2010)	0.661	0.704	0.601	0.670	0.380	0.413
(Linsey et al. 2011)	0.697	0.697	0.650	0.827	0.777	0.633

5 RESULTS OF TAXONOMY USE ANALYSIS

Twenty-one additional papers were reviewed by the raters. These papers were identified from a search of journal papers and ICED conference papers focused on collaborative design, design teams, and collaborative design activities (Table 2). The frequency of occurrence is calculated as the percent of papers that address a particular aspect of collaborative design. Level 1 contains the top level attributes and Level's 2 and 3 contain the individual taxa.

Table 2. The Frequency of Occurrences for Papers that Address a Described Aspect of Collaborative Design

Level 1	Occur.	Level 2	Occur.	Level 3	Occur.
Team Composition	100%	Group	95%	Size	86%
				Culture	76%
		Individual	100%	Personality	19%
				Expertise	95%
		Team Member Relations	19%		
		Leadership Styles	48%		
Nature of Problem	81%	Type	67%		
		Concurrency	29%		
		Coupling	5%		
		Abstraction	5%		
		Scope	29%		
		Complexity	43%		
Information	52%	Form	33%		
		Management	33%	Ownership	14%
				Permission to Change	14%
				Security	10%
				Change Propagation	0%
		Perceived Criticality	14%		
		Dependability	10%	Reliability	0%
				Completeness	10%
Communication	100%	Mode	95%		
		Quantity	67%	Frequency	67%
				Duration	57%
		Syntax	52%	Language	52%
				Translators	10%
		Proficiency of Team	0%	Techniques	0%
				Technology	0%
		Dependability of Resources	0%	Resource Reliability	0%
				Resource Availability	0%
		Intent	10%		
Distribution	100%	People	100%	Geographic	95%
				Organizational	90%
				Temporal	86%
		Information	86%	Geographic	86%
				Organizational	86%
				Temporal	81%
Design Approach	76%	Tools	33%		
		Evaluation of Progress	29%		
		Degree of Structure	48%		
		Process Approach	29%		
		Stage	57%		

6 DISCUSSION ON LEVEL 1 TAXONS

6.1 Team Composition

Team size and member expertise are the most frequently characterized areas in team composition. Expertise is addressed in 95% of the papers whereas, size is addressed in 86% of the papers. Team

culture is also commonly addressed (76%) although other characteristics are less frequently noted. Leadership style, member personality, and team relations are all addressed less than 50% of the time. While team composition is frequently addressed, areas such as leadership may require further research and decomposition beyond just leadership styles.

6.2 Distribution

There are trends in the aspects of collaborative design activities that are addressed in the papers selected for this literature review. The geographic and organizational distribution of the design team's members are some of the most frequently addressed categories in these papers at frequencies of 95% and 90%, respectively. Further, all aspects of distribution are addressed in at least 81% of the papers surveyed. Geographic distribution is either categorized as collocated or distributed while organizational distribution is selected as within or outside of organizational boundaries. Temporal distribution was identified in the taxonomy as being within the same or different time zone. In some cases, authors addressed temporal distribution as synchronous or asynchronous rather than addressing differences in time zones. The placement of *distribution* in the taxonomy, and the lowest tier of *temporal distribution* require further review.

6.3 Nature of the Problem

The nature of the design problem is most frequently addressed (67%) in terms of the novelty of the problem. This was often explicitly addressed by categorizing the problem as variant or novel, while in other cases it was implicitly addressed by a clear definition of the design problem itself. The complexity of the problem was the next most commonly addressed aspect of the nature of the problem; however, there was not a consistent definition or metric for complexity in the selected papers.

6.4 Information

The form of the information transmission (verbal, textual, or graphic) was most frequently addressed in selected literature for information descriptions. Detailed components of information management such as permissions to view, obtain, or change information were less frequently addressed. The trustworthiness and completeness of information were not commonly addressed.

6.5 Communication

Communication was one of the most frequently described aspects of collaborative design activities in the literature surveyed. Specifics of the mode (90%), frequency (67%), and duration (57%) of communication had the highest occurrence in the literature. Language was addressed in a majority of cases (52%). The proficiency of the team at communicating with each other and using necessary communication technologies was seldom addressed. The dependability of communication resources was not addressed in the selected papers. The significance of including this designation in the taxonomy should be reviewed.

6.6 Design Approach

The design approach addresses the methodology and tools employed by the team in the design process. It also involves the degree of freedom the team has to select those methods, and the source of evaluations. The most commonly specified aspect of this branch of the taxonomy was the design stage. The design stage was stated in a majority of the papers (58%). The degree of freedom granted to the team to determine its design approach was frequently addressed (48%). All aspects of design approach are addressed in at least 29% of the papers reviewed.

7 CONSISTENCY IN CATEGORY DESIGNATION

Three papers were read by all four reviewers to determine how consistently they could use the taxonomy to describe the same collaborative design scenarios as described in literature. The results of the reviewers were then compiled and compared using a joint probability of agreement. While the raters' reliability regarding which categories were addressed in the specific paper was sufficient, the degree of consistency in how they described or defined the scenario was not sufficient. By considering the probability of agreement for each taxon description, areas for further discussion or exploration were identified.

For example, on the first paper evaluated, 3 of 4 reviewers agreed that culture was specified by the author. However, one reviewer described the culture as “flat/participative” while one described it as a student culture, one did not rate it as described, and two rated it as university or student culture. In this particular case, there is not a further breakdown of culture in the taxonomy. Without a further breakdown of this category in the taxonomy, the raters were unable to consistently characterize each collaborative design team or activity.
Expertise was another area with a challenging likelihood of agreement. Some reviewers would evaluate team members as “experienced” or “novice” while others would characterize expertise in terms of years of experience. Likewise, complexity level does not have a specific metric or further division identified in the taxonomy.

8 DISCUSSION

The reviewers' attempts to apply the taxonomy to characterize design teams as described in design research literature revealed challenges that require further exploration. Some of these were manifested by challenges in applying the taxonomy consistently, while others were revealed by the frequency of occurrence of some of the branches and taxa. Finally, others continued to be highlighted by discussion amongst the reviewers on the facility of characterizing the design teams using the taxonomy and the arrangement of its upper levels, which shows concern over the descriptions provided by the taxonomy.

8.1 Taxonomy Layers

The first challenge was clear from the results of the initial inter-rater for specific categories. Discussions between the raters revealed a possible need for an additional layer to the taxonomy in some categories. As discussed, the reviewers were not able to obtain consistent characterizations of culture. The raters were also unable to consistently evaluate complexity. Culture and complexity are both characterizations that may need further subdivision or a suggestion of appropriate metrics in order to consistently apply the taxonomy. The results imply that cultural characteristics may include elements of organizational, and possibly other social cultural aspects. A review of literature concerning culture within design teams should be conducted for relevant aspects and to suggest a further layer of taxa.
Complexity of the problem has a broad range of possible interpretations including number of components and degrees of interaction with others. A review of literature on design complexity is required to evaluate the need for further definition of this taxon (Summers and Shah, 2010; Suh, 2005). Finally, expertise was an area with broad agreement that the area had been addressed, however, lesser agreement was seen in the actual categorization itself. Some literature revealed that multiple levels of expertise were present among a team, thus adding another level of complexity to this taxon. A further layer with an accepted hierarchy of expertise and method for identifying teams with multiple levels of expertise could be a useful addition to the collaborative design taxonomy.

8.2 Teams and Systems of Teams

The reviewers were particularly challenged to achieve agreement in characterization of the team composition by Kratzer et al. (2010). The product development teams in this paper are complex multinational systems of teams. They were also multi-tiered. While the taxonomy provides the means to clearly define the composition of simple individual teams, it does not appear to provide sufficient means to characterize these complex teams. The study of Multiteam Systems (MTS) or systems of interdependent teams sharing common goals provide a promising means to analyze and characterize these more complex systems of teams (Shuffler et al., 2015). This opens the aperture of team composition and characteristics, which can be used to consider the position of the team and its relation to other teams in the system. The team composition branch should be re-evaluated to consider these further complexities of teams and systems of teams. This will increase its applicability and usefulness within research and practical settings of the increasingly common and complex systems of design teams.

8.3 Temporal Aspects

The temporal aspects of the collaborative design activity are addressed indirectly; however, this is an area that may require further exploration. Some teams have a relatively permanent structure while others exist only for the completion of an individual task or goal. This status as a standing team or project oriented design team could impact the complete description of the team. While the design stage is

addressed in the nature of the problem, the current longevity of the team is not addressed. The time that the team has been together may be a defining characteristic beyond just its competency at applying communication tools. Consideration should be given to including this as a portion of the taxonomy.

8.4 Distribution

Distribution is included as a distinct upper level in the taxonomy. It is further subdivided into sections of people and information. A more natural arrangement may be to include distribution as a subdivision of team composition and of information since these are already elements of the taxonomy. Post-activity discussion amongst the raters concluded that this warrants further consideration. This may become a more significant consideration as the complexity of a system of teams increases.

Additionally, further consideration should be given to the distribution of information. The form of information clearly impacts the availability of information. When information is textual or graphic, and is available via internet connected systems, the relevance of time zone or geography, to the distribution of that information may be questioned. Information that is available only in hard copy would be impacted by geographic distribution. However, organizational distribution could be more significant. As such, the definition of information distribution requires further consideration.

8.5 Team vs. Activity

The collaborative design taxonomy was designed to form the basis for a model of collaborative design. Some aspects of the taxonomy are clearly associated to the team and the design problem, while others are more clearly associated to individual activities of the team. This would imply that some are more permanent characteristics of the team, while others are more temporal. It may be useful to delineate in the taxonomy which aspects fall into these two categories. Further consideration is required to define and delineate these activities.

8.6 Items Not Commonly Characterized

The frequency of occurrence revealed that the information management and communication proficiency taxa were not commonly characterized in the literature. Information management changes throughout a project, as was identified in the taxonomy, which makes it difficult to define for an entire project. Thus, it would be helpful to revisit this taxon to identify its importance in the taxonomy and whether it can be excluded in future iterations of the taxonomy. Similarly, communication proficiency is rarely reported in the literature and should be examined for its importance to the taxonomy.

9 CONCLUSIONS AND FUTURE WORK

The collaborative design taxonomy was applied to a total of 24 sources to determine the consistency of the taxonomy's application across these pieces of literature. Results showed that nineteen of the collaborative design characteristics provided in the taxonomy were used less than twenty percent in the reviewed literature. This can be explained due to the undue need of providing this for classifying collaborative design since this is not heavily emphasized in the literature. Moreover, the ambiguity of the taxonomy caused the raters to not properly input the data as intended by the taxonomy's original authors.

Further, instances were observed where the reviewers did not consistently review the literature to each other. This can be explained by the lack of clear definitions for the taxonomy that allows for each user to have their own opinion of the taxonomy's terminology. Although this was described as an initial attempt at developing a collaborative design taxonomy, further development is needed to consistently and accurately apply this to literature reviews, design team analysis, or for potential design team creation.

After performing the literature review and applying the taxonomy, it is evident that changes can be implemented to improve the taxonomy. The literature review, and frequency analysis of taxa revealed that while some taxa were commonly reported, the reviewers were unable to consistently identify the information to characterize in the taxon. Similarly, some taxa were not commonly characterized and thus could be left as a reference category only or omitted from the taxonomy completely.

In order to further justify making changes to the taxonomy, future work includes performing a case study on design teams in a capstone design class. Over the course of the semester teams of 4-5 students will be characterized at least twice using the taxonomy. By addressing which characteristics are commonly

used or not and how the teams are characterized differently throughout the semester it will provide evidence for modification or removal or certain taxa. Changes will be made to the taxonomy, then a subsequent literature review will be performed. Following the literature review the changes will be evaluated for effectiveness of characterizing design teams in the literature as well as through a case study. This will provide validation for changes made.

REFERENCES

Born, W. & Schmidt, L., (2016), An Observational Study on Functional Behavior in Team Design. *IDETC/CIE*, pp.1–10.

Capra, A. & Moreira, M., (2013), Investigation of Internal and External Design Teams During the Product Development Process in Footwear. *19th International Conference on Engineering Design (ICED13)*, (August), pp.1–10.

Chiu, M.-L., (2002), An organizational view of design communication in design collaboration. *Design studies*, 23(2), pp.187–210.

Cross, N., Cross, A.C. & Discipline, D., (1995), Observations of teamwork and social processes in design. *Design Studies*, 16, pp.143–170.

Denton, H.G., (1997), Multidisciplinary team-based project work: planning factors. , 18, pp.155–170.

Derue, D.S. et al., (2011), Trait and Behavioral Theories of Leadership : an Integration and Meta-Analytic Test of Their Relative Validity. , pp.7–52.

Détienne, F., Boujut, J.-F. & Hohmann, B., (2004), Characterization of collaborative design and interaction management activities in a distant engineering design situation. *Cooperative systems design*, pp.83–98.

Doumit, N., Fortin, C. & Huet, G., (2015), Study of the Efficiency of Product Development Teams Through Combined Virtual Communities of Practice , Plm and Social Media Technologies. In *20th International Conference on Engineering Design (ICED 15)*. Milano, Italy, pp. 1–10.

Ensici, A. & Badke-Schaub, P., (2011), Information Behavior in Multidisciplinary Design Teams. In *International Conference on Engineering Design (ICED11), Impacting Society through Engineering Design*. ICED.

Garner, S., (2001), Comparing graphic actions between remote and proximal design teams. *Design Studies*, 22(4), pp.365–376.

Hanus, J. & Russell, J.S., (2007), Integrating The Development Of Teamwork, Diversity, Leadership, And Communication Skills Into A Capstone Design Course. In *ASEE Annual Conference and Exposition*.

Ibn-E-Hassan et al., (2014), Influence of national and engineering culture on team role selection. *International Journal of Technology and Design Education*, 24(1), pp.91–105.

Jung, M. & Leifer, L., (2011), A Method to Study Affective Dynamics and Performance in Engineering Design Teams. *International Conference on Engineering Design, ICED11*, (August), pp.244–253.

Kim, M.S., (2007), Analysis of team interaction and team creativity of student design teams based on personal creativity modes. In *Proceedings of the ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*. Las Vegas, pp. 1–13.

Kratzer, J., Leenders, R.T.A.J. & Van Engelen, J.M.L., (2010), The social network among engineering design teams and their creativity: A case study among teams in two product development programs. *International Journal of Project Management*, 28(5), pp.428–436.

Kress, G. & Schar, M., (2011), Initial Conditions: The Structure and Composition of Effective Design Teams. In *International Conference on Engineering Design, ICED'11*. Copenhagen.

Linsey, J.S. et al., (2011), An Experimental Study of Group Idea Generation Techniques: Understanding the Roles of Idea Representation and Viewing Methods. *Journal of Mechanical Design*, 133(3), p.31008.

van der Loos, H.F.M. & Ostafichuk, P.M., (2009), Case Study: Application of Team-Based Learning to a Mechanical Engineering Design Course Traditionally Taught in Lecture Format. In *DS 58-10: Proceedings of ICED 09, the 17th International Conference on Engineering Design, Vol. 10, Design Education and Lifelong Learning, Palo Alto, CA, USA, 24.-27.08. 2009*.

Man, J., Lu, Y. & Brombacher, A., (2013), Design teamwork in distributed cross-cultural teams. *ICED13, International Conference on Engineering Design*, (August), pp.1–10.

Mathieson, J.L., Miller, M. & Summers, J.D., (2011), A Protocol for Connective Complexity Tracking in the Engineering Design Process. In *International Conference on Engineering Design 2011, Copenhagen, Denmark*. p. No--657.

Monell, D.W. & Piland, W.M., (2000), Aerospace systems design in NASA's collaborative engineering environment. *Acta Astronautica*, 47(2), pp.255–264.

Morgeson, F.P., DeRue, D.S. & Karam, E.P., (2010), *Leadership in Teams: A Functional Approach to Understanding Leadership Structures and Processes*.

Ostergaard, K.J. et al., (2007), An experimental methodology for investigating communication in collaborative design review meetings. *International Journal of CoCreation in Design and the Arts*, 1(December 2012), pp.37–41.
Ostergaard, K.J. & Summers, J.D., (2003), A taxonomic classification of collaborative design. In *Proceedings of the 14th International Conference on Engineering Design ICED03*. pp. 617–618.
Ostergaard, K.J. & Summers, J.D., (2009), Development of a systematic classification and taxonomy of collaborative design activities. *Journal of Engineering Design*, 20(1), pp.57–81.
Ostergaard, K.J. & Summers, J.D., (2004), Resistance Based Modeling of Collaborative Design. In *Concurrent Engineering*. p. DAC--57076.
Ovesen, N., (2015), Pragmatic Team Compositions in Scrum-Based DEVELOPMENT PROJECTS. In *20th International Conference on Engineering Design (ICED 15)*. Milano, Italy, pp. 1–10.
Pahl, G. et al., (2007), *Engineering Design: A Systematic Approach* 3rd ed., London: Springer-Verlag London Limited.
Palmer, G. & Summers, J.D., (2011), Characisterization of Leadership within Undergraduate Engineering Design Teams through Case Study Analys. In *International Conference on Engineering Design 2011, Copenhagen, Denmark*. p. No--204.
Palmer, G. & Summers, J.D., (2011), Characterization of Leadership Within Undergraduate Engineering Design Teams Through Case Study Analysis. In *International Conference on Engineering Design 2011, Copenhagen, Denmark*. p. 204.
Shuffler, M.L., Jimenez-Rodriguez, M. & Kramer, W.S., (2015), The Science of Multiteam Systems: A Review and Future Research Agenda. *Small Group Research*, 46(6), pp.659–699.
Sonnenwald, D.H., (1996), Communication roles that support collabortaion during the design process. *Design Studies*, 17, pp.277–301.
Stempfie, J. & Badke-sehaub, P., (2002), Analysis of Team Communication. *Design Studies*, 23, pp.473–496.
Suh, N.P., (2005), Complexity in Engineering. *CIRP Annals - Manufacturing Technology*, 54(2), pp.46–63.
Summers, J.D. & Shah, J.J., (2010), Mechanical Engineering Design Complexity Metrics: Size, Coupling, and Solvability. *Journal of Mechanical Design*, 132(2), p.21004.
Taylor, T.P. & Ahmed-Kristensen, S., (2015), A Longitudinal Study of Globally Distributed Design Teams : The Impacts on Product Development . In *20th International Conference on Engineering Design (ICED 15)*. Milano, Italy, pp. 1–10.
Ullman, D.G., (2010), *The Mechanical Design Process* 4th ed., New York, NY: McGraw-Hill.