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EXPLORING THE RELATIONSHIP BETWEEN GENDER IDENTITY AND THE DEVELOPMENT OF A SHARED UNDERSTANDING BETWEEN DESIGNERS

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ABSTRACT

Prior work has demonstrated that gender identity affects team psychological safety, which is critical to the development of a shared understanding of the task. Further, we know that a shared understanding can increase team cohesion and team performance. Little work has investigated how gender differences affect communicative acts within the context of design, and more specifically how gender differences may affect the development of a shared understanding of the design concept between designers. As a first step towards filling this gap, the current work presents findings from a controlled study conducted at The Pennsylvania State University with 22 design dyads (44 designers). The findings from this study indicate that gender identity within design dyads does not affect participants' shared understanding of a design concept.

Keywords: Human behaviour in design, Teamwork, Design engineering

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1 INTRODUCTION

Engineering design is characterized by complex challenges, ill-formed problems (Schrage, 2010; Simon, 1973, 1996), and uncertainty (Johnson, 2013). Teams are necessary in order to leverage diverse knowledge and skills (Hoegl and Parboteeah, 2007), more broadly explore solution spaces (Gyory et al., 2019), and provide support systems for overworked or under skilled team members (Salas et al., 2005). Many industries view diversity as a competitive advantage; a diversity of skills, backgrounds, knowledge, and perspectives can help design teams remain agile and responsive to the ambiguous and complex nature of design. Minority views "can stimulate consideration of non-obvious alternatives in task groups" (Cox and Blake, 1991), but only if the minority voices are acknowledged and synthesized into a team mental model. A number of factors including workplace culture, team environment, and individual traits, can negate, or worse, reverse the potential benefits of diversity.

Diversity is generally split between surface-level diversity, defined by individual traits that are readily observable (e.g., race), and deep-level diversity, defined by traits that are not readily observable (e.g., cognitive style). In the current work we focus on surface-level diversity, specifically gender diversity, as gender parity remains a pervasive problem within engineering fields. Though greater representation of women in STEM fields has been called for, educational and industry environments in STEM can be unfriendly or even hostile for women (Carnes et al., 2015; Moss-Racusin et al., 2012; Reuben et al., 2014; Settles et al., 2016) especially on sex-dissimilar teams, where feelings of isolation, dissatisfaction, and lack of organizational attachment are reported (Konrad, 1992; Pelled, 1996; Pelled et al., 1999; Price et al., 2006).

Implicit gender bias and stereotyping can emerge as early as three years old (Page, 2005). Due to confirmation bias (Oswald and Grosjean, 2004), humans tend to interpret and process information in ways that conform to deeply held beliefs, such as gender or racial stereotypes. Multiple studies demonstrate that both men and women implicitly associate science and engineering more with men than they do with women, an effect that propagates into educational (Beddoes and Panther, 2018; Cejka and Eagly, 1999) and professional settings (Braun et al., 2017; Régner et al., 2019). On engineering design teams, such biases are guaranteed to emerge and could manifest in a multitude of ways, such as women having fewer opportunities to lead workgroups (Berdahl, 1996), being unconsciously spoken over by men (Babaria et al., 2012), or perceiving ideas produced by women team members as lower quality than those produced by men (Toh et al., 2016).

Research conducted in undergraduate design settings indicates important findings regarding the interaction between gender and design processes. Toh et al. (Toh et al., 2016) found that male students were more likely to show ownership bias during concept selection activities, while women students were prone to the opposite, selecting more of their teammates' ideas over their own. Hirshfield et al. (Hirshfield and Koretsky, 2017) found that while there were no differences in the amount of time men and women spoke in project-based engineering courses, women more frequently discussed less technical topics and were more likely to assume stereotypically "feminine" roles on design teams, such as note-taker, communicator, or planners. These behaviours significantly detract from the inherent benefits of diverse engineering design teams.

A critical study recently published by (Cole et al., 2022) demonstrated a fundamental link between perceptions of psychological safety and gender in engineering design. Their work found that females typically perceived higher levels of psychological safety with other female team members, and perceived lower levels of psychological safety with male team members. Interestingly, male team members tended to overestimate their psychological safety with female counterparts. Willingness to share knowledge or ideas, openly communicate, and a belief that team members are working towards a common goal depend on the formation and maintenance of trust and psychological safety within teams. Psychological safety, or the shared belief that the team is safe for interpersonal risk taking (Edmondson, 1999; Miller et al., 2019), facilitates the sharing of ideas and solutions to some common goal or objective. Psychological safety is critical to the formation of a shared understanding amongst team members and higher levels of team cohesion. Building from this previous work we hypothesize that mixed-gender design dyads may have lower levels of shared understanding during communicative acts within design processes. It is critical that we understand how gender identity differences might affect the development of a shared understanding within design teams.

2 RESEARCH APPROACH AND OBJECTIVES

The aim of this study is to investigate the relationship between gender identity and shared understanding of design concepts of a design task within dyads. The following research question was proposed to explore this relationship:

RQ: How does gender identity within design dyads affect the understanding of design concepts?

To answer our research question, we conducted a controlled study at Penn State University. 44 participants were recruited and paired in dyads. This work was part of a broader study to investigate differences in design communication using sketches and low-fidelity prototypes. A condition, either a sketch or prototype, was assigned to each participant to complete a design task. The participants were then instructed to verbally explain their design problem, solution, and the solution's functions to the other participant in their dyad. We asked participants to provide a written account of their own design solution and the solution presented to them through surveys. This was used as the basis for calculating shared understanding. A more detailed description of the experimental procedure is reviewed below.

2.1 Participants

44 participants (22 men and 22 women) completed this study, all of whom were enrolled in the College of Engineering. Participants were recruited through purposeful sampling methods, such as reaching out to students enrolled in undergraduate design classes through mass emails and flyers, and snowball sampling methods, where each participant was asked to inform their peers about the study. 14 participants were graduate students, and 30 participants were junior- or senior-level undergraduate students. 28 participants identified as White, 10 identified as Asian, 2 identified as Hispanic, Latino, or of Spanish origin, 1 identified as Black or African American, 1 identified as White and Asian, 1 identified as Middle Eastern or North African, and 1 identified as White and Hispanic, Latino, or of Spanish origin.

2.2 Procedure

Participants were randomly distributed into pairs. This distribution resulted in twenty-eight participants assigned to a homogeneous pairing and sixteen participants were assigned to a heterogeneous pair to complete the experiment. Figure 1 depicts the experiment groups and procedure. Each pair was randomly assigned to one of two groups: prototyping and sketching; this pairing was done in pursuit of a larger research endeavour and results will not be broken out by condition (prototyping or sketching) in the current work. In previous work we found no statistically significant differences in shared understanding across conditions, and for the remainder of this work we focus on differences in shared understanding developed between heterogeneous and homogeneous gender pairs during communicative acts. At the beginning of the study participants in accordance with Institutional Review Board Guidelines, a summary of the study was provided to participants and all participants were informed that their participation was voluntary and that they may quit at any time. Participants then took a short pre-survey; at the start of the pre-survey all participants generated a unique ID to maintain anonymity.

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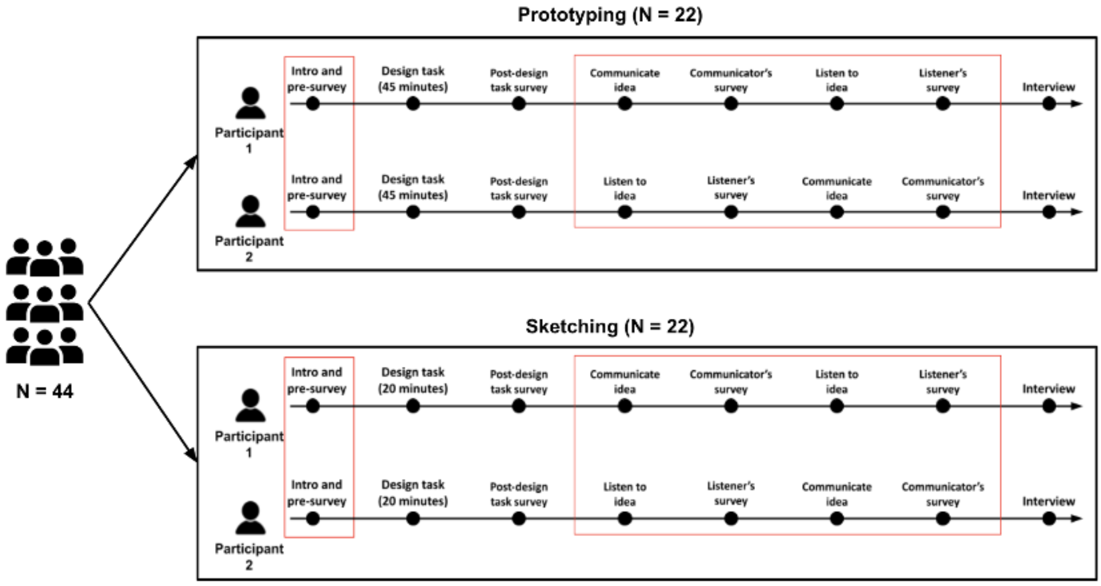

Figure 1. Experimental procedure of the study

Following the pre-survey, participants were asked to complete a design challenge. As physical model is known to be more time consuming than sketching (Viswanathan & Linsey, 2010), participants in the prototyping condition were provided with 45 minutes to accomplish the design task. Participants in the sketching condition were provided with 20 minutes to accomplish the design task. The participants received the following prompt corresponding to their assigned condition:

"You will now be given a design task to complete. You can use as many materials as possible that are given to you and you have forty-five minutes to complete the task. You can feel free to sketch out as many ideas as you want, but you will only be allowed to bring your final prototype with you when explaining your design solution. Your final design can be a single idea, or a combination of your ideas generated." (Prototyping condition)

"You will now be given a design task to complete. You have twenty minutes to complete the task. You can feel free to sketch out as many ideas as you want, but you will only be allowed to bring your final sketch with you when explaining your design solution. Your final design can be a single idea, or a combination of your ideas generated." (Sketching condition)

After being provided with the design prompt, participants were led to separate rooms to ensure the participants would not see each other's design solution prior to the explanation phase of the study. To ensure distinct solutions, each participant was provided with a design prompt different from their partner. The two prompts were selected from prior work that validated their similarity in terms of their structure, complexity, and solvability (Patel et al., 2019). The design prompts given to participants were:

"Design an automatic clothes-ironing machine for use in hotels. The purpose of the device is to press wrinkled clothes as obtained from clothes dryers and fold them suitably for the garment type. You are free to choose the degree of automation. At this stage of the project, there is no restriction on the types and quantity of resources consumed or emitted. However, an estimated 5 minutes per garment is desirable."

"Design an automatic recycling machine for household use. The device should sort plastic bottles, glass containers, aluminium cans, and tin cans. The sorted materials should be compressed and stored in separate containers. The amount of resources consumed by the device and the amount of space occupied are not limited. However, an estimated 15 seconds of recycling time per item is desirable."

Participants in the sketching condition were provided with pencils, papers, and a ruler. Participants in the prototyping condition were provided with foam-core, cardboard, popsicle sticks, rubber bands, wire, thread, utility knife, scissors, tape, cotton balls, tube cleaners, and hot glue.

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Once participants completed the design task, they were asked to provide a written description of their design problem, the solution and how it works. The participants then reconvened with their partner once both completed the written description. They were instructed to bring the final sketch(es) and prototype with them. All subsequent interactions between the participants were audio and video recorded. The participants were instructed to present their design solution to each other with the following prompt:

"You will both now present your design solution to each other, and you can use your design representation to do so. Please remember to go over your design problem, solution, how it works, and how you arrived at it, and keep the explanation of your solution consistent with your written explanation in the survey you just completed."

Before the interaction began, one participant was assigned as the communicator and the other as the listener. The communicator was given 5 minutes to explain their design problem and solution to the listener. The listener then had 3 minutes to ask the communicator any clarifying questions. Once the communicative act was complete, the listener was asked to describe the design concept that was presented to them: "In as much detail as possible, please recall the solution that was presented to you, and describe what the solution is, the problem it solves, and how it works in your own words.". Following this, the participants switched roles, i.e., the participant who was previously the listener became the communicator and followed the same protocol. All sketches and prototypes were photographed and stored, and written descriptions were again collected from the listener, following the procedure outlined above.

3 ANALYSIS

3.1 Metrics

3.1.1 Shared understanding

Shared understanding in design is the similarity between different individuals' conceptualizations of a design concept (Kleinsmann et al., 2007) . Fu et al. in their work compared the written explanations of designers' conceptualizations of design concepts and used this as the basis for calculating shared understanding (Fu et al., 2010). We use a similar approach in this work.

Specifically, the explanations of an idea from each participant in a dyad was used to create a functional structure of the idea, using the functional structure taxonomy by Stone & Wood (Stone and Wood, 1999). These functional structures were then validated by the research team. Next, this functional structure was converted to a weighted network, and a network-based similarity measure was used to calculate shared understanding. Specifically, both participants in a dyad had to provide written explanations of a particular design concept – the communicator provided this after generating the idea, and the listener provided their explanation after the communicator presented their idea. These explanations were then converted to functional structures, and then to networks to be able to quantify similarity. This is similar to the approach followed by Nandy et al. (2021) in their work. In each network, each function, flow, and component are represented as a node, with the connections between each being represented as edges. A network approach was chosen since specific components could also be accounted for. Edges were weighted in each network to account for repeated functions, flows, and components.

To calculate similarity between two weighted networks, we used a weighted Jaccard Similarity approach. This approach starts with the creation of a union vector that contains all of the connections in the two networks being compared. Next, the weighted Jaccard Similarity is calculated per equation (1), procured from work by Ioffe (2010) For two networks G and H, in equation (1), Gk and Hk is the associated weight of the element in the network. If one of the networks does not have an element, the weight is 0. Next, the minimum and maximum of corresponding weights for each element is identified, and the sums of the minima and maxima are then divided to quantify the similarity. In this work, the networks represent the mental models of a communicator and listener in the dyad, and the weighted Jaccard similarity is representative of the shared understanding.

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$$J(G,H) = \frac{\Sigma_k \min(G_k,H_k)}{\Sigma_k max(G_k,H_k)} \quad (1)$$

3.1.2 Idea complexity

It is possible that the complexity of the idea being communicated may also affect shared understanding – a more complex idea would mean a person would have to remember more information, leading to more chances for errors in their mental model. Hence, idea complexity, or the amount of information being communicated, was controlled for. After validating the composed functional structures, the size complexity of each functional structure was calculated using the method described by Ameri et al. (2008). The number of functions and flows in a given functional structure were used to calculate size complexity through equation (2).

$$Cx_{size\_func} = (D_v + D_r) \times \ln(r+n) \quad (2)$$

where,
D_v = Number of instances of functions blocks and I/O types
D_r = Number of instances of primitive relations
r = The number of primitive modules (operands) available within the representation (35, as there are 35 possible functions in the taxonomy)
n = The number of primitive relationships (operators) available between all available modules (3, as there are 3 I/O types, namely material, energy, and information)

4 RESULTS

In pursuit of our research question, how does gender identity within design dyads affect the understanding of design concepts, an ANCOVA was performed with gender pairing as the independent variable, shared understanding as the dependent variable, and idea complexity as the covariate. All statistical analyses were performed on R version 4.1.1. One dyad was removed from the dataset due to a participant not interpreting the design prompt correctly. An ANCOVA was performed to determine the difference between FF and MM homogeneous pairs. A statistically significant difference was not found; thus, FF and MM pairs were included as a larger homogeneous group. As previously stated, prior work demonstrated that condition had no significant effect on shared understanding, thus the sketching and prototyping conditions were not included in analysis. Prior work did identify that idea complexity had a significant negative correlation with shared understanding ($\rho = -0.428$, $p < 0.005$), implying that more complex ideas were associated with lower shared understanding. As a result, the complexity was included as a confounding variable in the analysis. The result of the ANCOVA analysis was not significant; gender pairing did not significantly affect shared understanding ($F(1,40) = 0.505$, $p = 0.48$), and a negligible effect size was noted (Partial $\omega 2 = 0.008$). In other words, our findings suggest that gender differences in engineering dyads did not affect the formation of shared understanding during communicative acts. Figure 2 visualizes these results.

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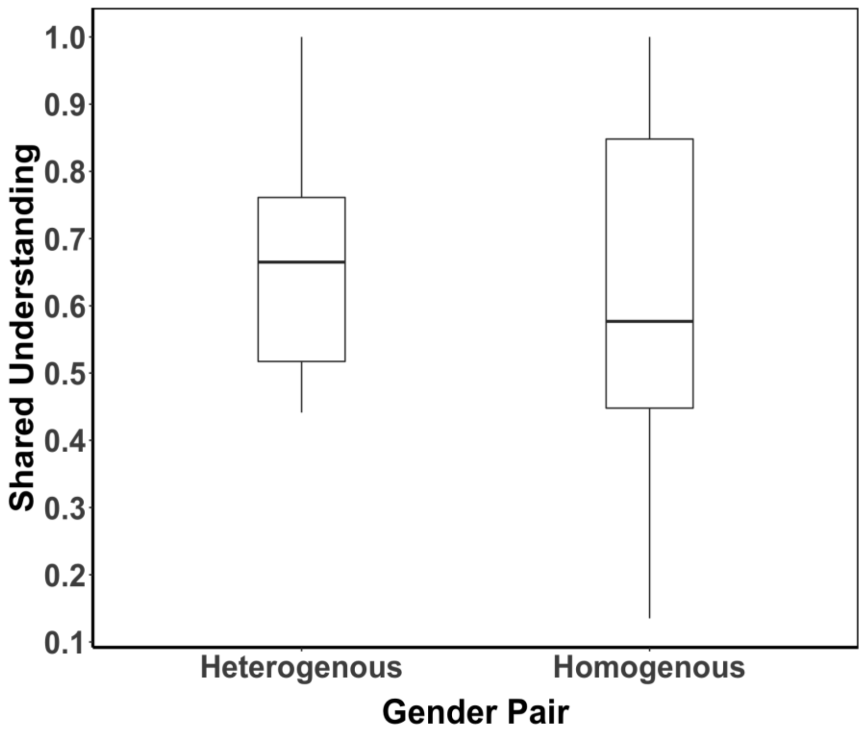

Figure 2. Distribution of shared understanding by gender pairing

5 DISCUSSION

The study investigates shared understanding in terms of sketches and prototyping for design teams. A controlled study paired 44 engineering students from The Pennsylvania State University into dyads. Our goal is to evaluate the relationship between gender pairs to determine if there is a difference in understanding between homogeneous and heterogeneous dyads. We know from prior work that psychological safety is inextricably linked to shared understanding and team performance (Edmondson, 1999). Recent findings from (Cole et al., 2022) suggest that female designers perceive lower levels of psychological safety with male teammates as compared to female teammates. Further, their findings suggest that male teammates overestimated their perceived psychological safety with female teammates. This past work suggests that a discrepancy between psychological safety may exist in heterogeneous gender pairs. Based on these prior studies we hypothesized that shared understanding may be lower in heterogeneous gender pairs. However, our findings do not confirm this hypothesis. Our findings reveal there is not a significant difference in shared understanding between same gender pairs and mixed gender pairs using sketches and prototypes.

6 CONCLUSION AND LIMITATIONS

The main goal of the study is to determine how gender identity affects shared understanding of design concepts using sketches and prototypes. Our findings suggest that these communicative acts do not affect shared understanding between genders in dyads. We highlight that in the current work we did not measure perceptions of psychological safety, and, thus, it is not known if the psychological safety of the heterogenous gender pairs was lower than the psychological safety of the homogenous gender pairs. We underscore that this work focused specifically on communicative acts, and thus the dyads did not operate as teams during the design process, so the measurement of psychological safety was not appropriate given the experimental context. Additionally, we highlight that the current work studies shared understanding in pairs. Shared understanding in multi-person teams was not explored and should be considered in future studies to account for the effect of team dynamics. Future work should explore the intersection between perceptions of psychological safety and shared understanding on mixed gender dyads, working collaboratively.

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REFERENCES

Ameri, F., Summers, J.D., Mocko, G.M. and Porter, M. (2008), "Engineering design complexity: an investigation of methods and measures", Research in Engineering Design, Vol. 19 No. 2, pp. 161–179, https://dx.doi.org/10.1007/s00163-008-0053-2.

Babaria, P., Abedin, S., Berg, D. and Nunez-Smith, M. (2012), "'I'm too used to it': A longitudinal qualitative study of third year female medical students' experiences of gendered encounters in medical education", Social Science & Medicine, Vol. 74 No. 7, pp. 1013–1020.

Beddoes, K. and Panther, G. (2018), "Gender and teamwork: an analysis of professors' perspectives and practices", European Journal of Engineering Education, Vol. 43 No. 3, pp. 330–343, https://dx.doi.org/10.1080/03043797.2017.1367759.

Berdahl, J.L. (1996), "Gender and leadership in work groups: Six alternative models", The Leadership Quarterly, Vol. 7 No. 1, pp. 21–40.

Braun, S., Stegmann, S., Hernandez Bark, A.S., Junker, N.M. and van Dick, R. (2017), "Think manager-think male, think follower-think female: Gender bias in implicit followership theories: BRAUN et al.", Journal of Applied Social Psychology, Vol. 47 No. 7, pp. 377–388, https://dx.doi.org/10.1111/jasp.12445.

Carnes, M., Bartels, C.M., Kaatz, A. and Kolehmainen, C. (2015), "Why is John More Likely to Become Department Chair Than Jennifer?", Transactions of the American Clinical and Climatological Association, Vol. 126, pp. 197–214.

Cejka, M.A. and Eagly, A.H. (1999), "Gender-Stereotypic Images of Occupations Correspond to the Sex Segregation of Employment", Personality and Social Psychology Bulletin, Vol. 25 No. 4, pp. 413–423, https://dx.doi.org/10.1177/0146167299025004002.

Cole, C., Jablokow, K., Mohammed, S. and Miller, S. (2022), "The Impact of Gender on Individual Perceptions and Team Psychological Safety in Engineering Design Teams", IDETC-CIE2022, Volume 6: 34th International Conference on Design Theory and Methodology (DTM), https://dx.doi.org/10.1115/DETC2022-89910.

Cox, T.H. and Blake, S. (1991), "Managing cultural diversity: Implications for organizational competitiveness", Academy of Management Perspectives, Vol. 5 No. 3, pp. 45–56.

Edmondson, A. (1999), "Psychological Safety and Learning Behavior in Work Teams", Administrative Science Quarterly, [Sage Publications, Inc., Johnson Graduate School of Management, Cornell University], Vol. 44 No. 2, pp. 350–383, https://dx.doi.org/10.2307/2666999.

Fu, K., Cagan, J. and Kotovsky, K. (2010), "Design Team Convergence: The Influence of Example Solution Quality", Journal of Mechanical Design, Vol. 132 No. 11, https://dx.doi.org/10.1115/1.4002202.

Gyory, J.T., Cagan, J. and Kotovsky, K. (2019), "Are you better off alone? Mitigating the underperformance of engineering teams during conceptual design through adaptive process management", Research in Engineering Design, Vol. 30 No. 1, pp. 85–102, https://dx.doi.org/10.1007/s00163-018-00303-3.

Hirshfield, L. and Koretsky, M.D. (2017), "Gender and Participation in an Engineering Problem-Based Learning Environment", Interdisciplinary Journal of Problem-Based Learning, Vol. 12 No. 1, https://dx.doi.org/10.7771/1541-5015.1651.

Hoegl, M. and Parboteeah, K.P. (2007), "Creativity in innovative projects: How teamwork matters", Journal of Engineering and Technology Management, Vol. 24 No. 1–2, pp. 148–166, https://dx.doi.org/10.1016/j.jengtecman.2007.01.008.

Ioffe, S. (2010), "Improved Consistent Sampling, Weighted Minhash and L1 Sketching", 2010 IEEE International Conference on Data Mining, presented at the 2010 IEEE International Conference on Data Mining, pp. 246–255, https://dx.doi.org/10.1109/ICDM.2010.80.

Johnson, B.D. (2013), "Engineering Uncertainty: The role of uncertainty in the design of complex technological and business systems", Futures, Vol. 50, pp. 56–65, https://dx.doi.org/10.1016/j.futures.2013.03.011.

Kleinsmann, M., Valkenburg, R. and Buijs, J. (2007), "Why do(n't) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design", CoDesign, Taylor & Francis, Vol. 3 No. 1, pp. 59–73, https://dx.doi.org/10.1080/15710880601170875.

Konrad, A. (1992), "Diversity In Work Group Sex Composition: Implications for Majority and Minority Members", Research in the Sociology of Organizations.

Miller, S., Marhefka, J., Heininger, K., Jablokow, K., Mohammed, S. and Ritter, S. (2019), "The trajectory of psychological safety in engineering teams: A longitudinal exploration in engineering design education", International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Vol. 59278, American Society of Mechanical Engineers, p. V007T06A026.

Moss-Racusin, C.A., Dovidio, J.F., Brescoll, V.L., Graham, M.J. and Handelsman, J. (2012), "Science faculty's subtle gender biases favor male students", Proceedings of the National Academy of Sciences, Vol. 109 No. 41, pp. 16474–16479, https://dx.doi.org/10.1073/pnas.1211286109.

Nandy, A., Dong, A. and Goucher-Lambert, K. (2021), "Evaluating Quantitative Measures for Assessing Functional Similarity in Engineering Design", Journal of Mechanical Design, Vol. 144 No. 3, https://dx.doi.org/10.1115/1.4052302.

Oswald, M.E. and Grosjean, S. (2004), “Confirmation bias”, Cognitive Illusions: A Handbook on Fallacies and Biases in Thinking, Judgement and Memory, Vol. 79.
Page, A. (2005), “Batson’s blind-spot: Unconscious stereotyping and the peremptory challenge”, BUL Rev., Vol. 85, p. 155.
Pelled, L.H. (1996), “Demographic Diversity, Conflict, and Work Group Outcomes: An Intervening Process Theory”, Organization Science, Vol. 7 No. 6, pp. 615–631, https://dx.doi.org/10.1287/orsc.7.6.615.
Pelled, L.H., Eisenhardt, K.M. and Xin, K.R. (1999), “Exploring the Black Box: An Analysis of Work Group Diversity, Conflict, and Performance”, Administrative Science Quarterly, Vol. 44 No. 1, p. 1, https://dx.doi.org/10.2307/2667029.
Price, K.H., Harrison, D.A. and Gavin, J.H. (2006), “Withholding inputs in team contexts: Member composition, interaction processes, evaluation structure, and social loafing.”, Journal of Applied Psychology, Vol. 91 No. 6, pp. 1375–1384, https://dx.doi.org/10.1037/0021-9010.91.6.1375.
Régner, I., Thinus-Blanc, C., Netter, A., Schmader, T. and Huguet, P. (2019), “Committees with implicit biases promote fewer women when they do not believe gender bias exists”, Nature Human Behaviour, Vol. 3 No. 11, pp. 1171–1179, https://dx.doi.org/10.1038/s41562-019-0686-3.
Reuben, E., Sapienza, P. and Zingales, L. (2014), “How stereotypes impair women’s careers in science”, Proceedings of the National Academy of Sciences, Vol. 111 No. 12, pp. 4403–4408, https://dx.doi.org/10.1073/pnas.1314788111.
Salas, E., Sims, D.E. and Burke, C.S. (2005), “Is there a ‘Big Five’ in Teamwork?”, Small Group Research, Vol. 36 No. 5, pp. 555–599, https://dx.doi.org/10.1177/1046496405277134.
Schrage, M. (2010), “The Culture(s) of PROTOTYPING”, Design Management Journal (Former Series), Vol. 4 No. 1, pp. 55–65, https://dx.doi.org/10.1111/j.1948-7169.1993.tb00128.x.
Settles, I.H., O’Connor, R.C. and Yap, S.C.Y. (2016), “Climate Perceptions and Identity Interference Among Undergraduate Women in STEM: The Protective Role of Gender Identity”, Psychology of Women Quarterly, Vol. 40 No. 4, pp. 488–503, https://dx.doi.org/10.1177/0361684316655806.
Simon, H.A. (1973), “The structure of ill structured problems”, Artificial Intelligence, Vol. 4 No. 3–4, pp. 181–201, https://dx.doi.org/10.1016/0004-3702(73)90011-8.
Simon, H.A. (1996), The Sciences of the Artificial, 3. ed., [Nachdr.]., MIT Press, Cambridge, Mass.
Stone, R.B. and Wood, K.L. (1999), “Development of a Functional Basis for Design”, DETC99, Volume 3: 11th International Conference on Design Theory and Methodology, pp. 261–275, https://dx.doi.org/10.1115/DETC99/DTM-8765.
Toh, C.A., Strohmetz, A.A. and Miller, S.R. (2016), “The Effects of Gender and Idea Goodness on Ownership Bias in Engineering Design Education”, Journal of Mechanical Design, Vol. 138 No. 10, p. 101105, https://dx.doi.org/10.1115/1.4034107.

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