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# Creativity in Design Teams: The Influence of Personality Traits and Risk Attitudes on Creative Concept Selection

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# Creativity in Design Teams: The Influence of Personality Traits and Risk Attitudes on Creative Concept Selection

Christine A. Toh • Scarlett R. Miller

## Abstract

Concept selection is recognized as a crucial component of the design process that largely involves informal group discussions within design teams. However, little is known about what factors affect the selection or filtering of creative ideas during this process. This is problematic because in order for innovation to occur, individuals must first identify and select the creative concepts developed in the early stages of design. However, prior research has shown that individuals tend to select conventional alternatives during this process due to the inherent risk associated with creative concepts. Therefore, the current study was developed to understand how personality traits, risk attitudes, and idea generation abilities impact the promotion or filtering of creative ideas in a team setting. The results from our empirical study with engineering students reveal that teams who have higher levels of conscientiousness, agreeableness and tolerance for ambiguity are more prone to select novel concepts. In addition, the results revealed that the teams' who generate creative ideas did not necessarily select creative ideas during concept selection. These results add to our understanding of team-based decision-making during concept selection and allow us to provide guidelines for increasing the flow of creative ideas through this process.

**Keywords:** Concept selection; design teams; decision-making; personality; risk attitudes; creativity

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## 1 Introduction

The ability to engage in the creative process is an essential component of the engineering profession (Howard, Culley, and Dekoninck 2008) due to the link between innovation and long-term economic success (Ayag, and Ozdemir 2009). As such, engineering research has long since been devoted to increasing the creative abilities of engineering students and professionals through the development and testing of idea generation methods (see for example (Cardin et al. 2013; Chulvi et al. 2012; Oman et al. 2013; Sarkar, and Chakrabarti 2014; Shai et al. 2013; Yang 2009). Despite the recognized importance of creativity *throughout* the engineering design process, there are few studies that have explored the role of creativity during the concept selection process. This is a vital area to explore because in order for innovation to occur, the creative concepts generated during the early phases of design must be recognized and selected during the concept evaluation process (Rietzschel, BA Nijstad, and W. Stroebe 2010).

A variety of formalized concept selection methods are often taught in engineering education (see for example (Ayag, and Ozdemir 2009; Hambali et al. 2009; Jacobs, van de Poel, and Osseweijer 2014; Okudan, and Tauhid 2008). These methods and their merits and disadvantages have received considerable attention from the design community (Frey et al. 2009; Frey et al. 2010; Hazelrigg 2010). Researchers have also noted that these selection methods have been developed from various research strains that each approach the decision-making problem in vastly different manners (Reich 2010). However, research has shown that companies lack a coherent or formal process for selecting ideas (Barczak, Griffin, and Kahn 2009). Instead, the early phases of concept evaluation typically involve a screening process where the ideas generated in the early phases of design are narrowed down to a few key concepts through informal team discussions (Onarheim, and Christensen 2012). While these informal methods can be effective in various contexts, it is often subject to the biases associated with human decision-making (De Martino et al. 2006). For example, factors such as preferences for visually complex designs (Onarheim, and Christensen 2012), development time (Kruglanski, and Webster 1996), organizational culture (Amabile 1996), designer personality traits (Kichuk, and Wiesner 1998) and ownership bias (Onarheim, and Christensen 2012) can influence decision making during informal concept selection.

Research on concept selection in normative brainstorming groups (Delbecq, Van de Ven, and Gustafson 1975) has found that people often perform poorly at selecting creative ideas during the evaluation process (Rietzschel, BA Nijstad, and W. Stroebe 2010) due in part to biases towards self-generated concepts (Nikander, Liikkanen, and Laakso 2014), visually complex designs (Onarheim, and Christensen 2012), and salient ideas (Harvey, and Kou 2013). Similarly, recent research has shown that the type of logical reasoning used during decision-making can affect the selection of creative ideas (Dong, Mounarath, and Lovallo 2012). In addition, research on individual creativity has found that individuals often have a bias towards familiar or conventional ideas during concept selection because of the risk associated with creative ideas (Ford, and Gioia 2000; Rietzschel, BA Nijstad, and W. Stroebe 2010), demonstrating a close link between risk attitudes and perceptions of creativity (Mueller, Melwani, and Goncalo 2011; Nicholson et al. 2005; Zuckerman, and Kuhlman 2000). Although not studied in the context of concept selection, personality, which is closely related to risk (Eysenck, and Eysenck 1977; Whiteside, and Lynam 2000; Zuckerman et al. 1993), has also been linked to creative performance in idea generation tasks (Baer et al. 2007). While these studies identify attributes that may impact creative concept selection, they focus on individual concept selection tasks leaving to question how these factors influence decision making in a team setting. Without this knowledge it is impossible to know what team-based factors impact the selection or filtering of creative concepts. This is important because design is being recognized and taught as a team process in engineering (Dym 2003).

Therefore, the purpose of this study is to investigate the impact of team risk attitudes and personality traits on the selection of creative concepts during team-based concept selection practices in engineering education. In order to accomplish this, an empirical study was conducted with 37 engineering students in order to understand the impact of team personality, risk attitudes, and creative abilities on a team's propensity towards creative concepts. The results of this study add to our understanding of team-based decision-making during concept selection and allow us to provide guidelines for developing and training design teams to identify and select creative ideas. The following sections provide background and motivation for studying the factors that can affect creative concept selection in teams, and starts with a section that explores the role of personality traits and creativity in the design process. Next, research that has investigated the impact of risk attitudes in the creative process are discussed, and lastly, the research questions that are investigated in this paper are presented.

## 101 2 Background & Motivation

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### 103 2.1 Personality Traits and Team Creativity

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105 Design is increasingly being recognized and taught as a team process in engineering (Dym 2003), in part because  
106 products developed by teams have been shown to be of higher quality than those produced solely by an individual  
107 (Gibbs 1995), and in part because teams foster a wider range of knowledge and expertise which aids in the  
108 development of ideas (Dunne 2000). In addition, teamwork has been shown to increase classroom performance  
109 (Hsiung 2012) and encourage more creative analysis and design (Stone, Moroney, and Wortham 2006). Therefore,  
110 researchers have focused their efforts on identifying the factors that impact team-based creativity.

111 Studies conducted in these areas show that factors such as organizational culture, individual abilities, group  
112 diversity, and resources can greatly influence overall team creative performance (Agrell, and Gustafon 1996;  
113 Woodman, Sawyer, and Griffin 1993). While these factors are important in determining overall group performance,  
114 researchers have argued that the composition of team member personality and disposition is one of the most  
115 important factors in determining team performance and (Wilde 1997) creativity (Somech, and Drach-Zahavy 2011).  
116 In fact, the Big Five Factors of Personality (Five Factor Model) framework (Costa, and McCrea 1992) has been  
117 shown to be strongly linked to creativity (Feist 2006).

118 The Five Factor Model states that personality has five dimensions: neuroticism, extraversion, openness to  
119 experience, agreeableness, and conscientiousness. Researchers have linked the extraversion, openness to experience,  
120 and agreeableness personality traits to creativity at the individual level (Batey, and Furnham 2006). Specifically,  
121 studies have shown that creative achievement is closely related to high levels of extraversion (Stafford et al. 2010)  
122 and openness to experience (McCrae 1987; Steel, T, and J 2012). Results on agreeableness, on the other hand, have  
123 had mixed findings; Some studies have reported that high levels of agreeableness relate positively to creative ability  
124 (Feist 1998), while others have found that creative individuals have low levels of agreeableness and “do not adapt to  
125 others, but go their own way” (p. 254) (Hoff, Carlsson, and Smith 2012). Factors that influence individual creativity  
126 are important for group creativity because the creative process starts with individuals conceptualizing ideas and then  
127 deciding whether or not to share them with the team (Gilson, and Shalley 2004).

128 At the team level, where aggregate scores of team-member personality attributes are analyzed (Mohammed,  
129 and Angell 2003; Reilly, Lynn, and Aronson 2001), researchers have found that high levels of extraversion,  
130 openness to experience, and low conscientiousness tend lead to the creation of more creative ideas in design teams  
131 (Baer et al. 2007). However, the results on the personality traits that impact this higher level of creative concept  
132 generation have been mixed. Specifically, researchers have argued that teams with high conscientiousness and  
133 agreeableness levels are more motivated to achieve goals (Bell 2007) and thus, tend to be more creative (Woodman,  
134 Sawyer, and Griffin 1993) while others still have argued that agreeableness and neuroticism are required for group  
135 creativity (Goncalo, and Staw 2006). However, there has been limited research on the role of team personality  
136 attributes and creative concept selection.

137 These studies highlight the impact of individual personality traits on team-level creativity, but also show  
138 conflicting findings on which personality traits significantly impact team creativity. In addition, most research  
139 conducted in this area investigates the impact of personality traits on a team’s ability to *generate* creative ideas,  
140 leaving little data on how personality traits affect a team’s tendency to *select* creative concepts. Therefore, the  
141 current study was developed to respond to this research void.

142

### 143 2.2 Risk-taking and Team Creativity

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145 In addition to personality traits, it’s also important to study the role of risk attitude in creative concept selection as  
146 prior work has shown that risk attitudes impact an individuals’ perception of creativity (Rubenson, and Runco 1995)  
147 and their creative abilities (Dewett 2007; El-Murad, and West 2003). In the context of creativity, risk can be used to  
148 describe the extent to which there is uncertainty about whether potentially significant or disappointing outcomes will  
149 be realized given creative effort (Sitkin, and Pablo 1992). Researchers have argued that risk-taking is an essential  
150 element of creativity since it encourages the individual to push boundaries and explore new territories (Kleiman  
151 2008). However, it has been shown that individuals often select conventional or previously successful options during  
152 the concept selection process (Ford, and Gioia 2000) due to their inadvertent bias against creativity (Rietzschel, BA  
153 Nijstad, and W. Stroebe 2010). Recent research conducted in this space has found that student design teams  
154 typically base decisions on the technical feasibility of ideas (Toh, and Miller In Press). Because people have a deep-  
155 seated desire to maintain a sense of certainty and preserve the familiar (Sorrentino, and Roney 2000), individuals  
156 may prematurely filter out novel ideas during the concept selection process regardless of merit in order to reduce

157 risk. Risk not only impacts and individuals' creative level, but it also impacts their larger role in the social structure.  
158 Specifically, Perry-Smith (2006) showed that individuals who play a central role in the team and who have fewer  
159 external ties are more likely to take risks in group settings and score higher on supervisor-rated creativity. Therefore,  
160 it is essential that we understand the impact of risk-taking during team concept selection activities in order to  
161 promote the flow of creative ideas throughout the design process.

162 In addition to risk aversion, ambiguity aversion has also been studied in the context of creativity. While risk  
163 aversion is often calculated using situations where outcomes have a *fixed* probability of occurring, ambiguity  
164 aversion is calculated in situations that are more uncertain, or where outcomes have an *unknown* probability of  
165 occurring (Moore, and Eckel 2003). Ambiguity is significant to the study of decision making since many realistic  
166 situations involve both risk and ambiguity (Heath, and Tversky 1991). Therefore, researchers have focused on  
167 studying the link between ambiguity aversion and creativity. Studies such as those done by Charness and Greico  
168 (2013) have shown that an individual's tolerance for ambiguity is linked to creativity in problem solving tasks.  
169 Similarly, other studies reveal that an individual's tolerance for ambiguity is positively correlated with creative  
170 performance (Sternberg, and Lubart 1991; Zenasni, Besancon, and Lubart 2008) and is often a requirement for  
171 creativity, especially in scientific domains (Csermelv, and Lederman 2003). While it is clear that both risk and  
172 ambiguity aversion are important factors that impact creativity, little research has been conducted regarding the  
173 possible effects that these factors may have on the creative concept selection.

174 One of the main obstacles to overcome when exploring the relationship between risk and creative concept  
175 selection is identifying a method for appropriately measuring individual risk attitudes in creative design tasks  
176 (Weber, Blais, and Betz 2002). While there are a variety of ways to measure risk attitudes such as through the  
177 calculation of risk propensity (Dewett 2006), engineering-domain-specific risk-taking (Bossuyt et al. 2013; Bossuyt  
178 et al. 2012), and preference of ambiguity to risk (Charness, and Grieco 2013), their relationship to risk in a creative  
179 task is largely unknown. Due to the fact that no measure exists that assesses risk-taking in the context of creative  
180 concept selection, and since risk behavior has been shown to vary greatly across situations and domains (Weber  
181 2010; Weber, Blais, and Betz 2002), it is unclear how existing measures of risk can be used to measure risk-taking  
182 in a creative domain. A common method of studying risk behavior is through the use of traditional behavioral  
183 economics measures such as utility theory (Boyle et al. 2012; Boyle et al. 2011; Han et al. 2012) or variants such as  
184 prospect theory (Kahneman, and Tversky 1979) that use financial lotteries to determine risk and ambiguity attitudes  
185 since these measures have a high adoption rate and familiarity of in existing design research. However, these  
186 measures have not been tested for their relationship to risk-taking in creative tasks. Other measures such as  
187 psychometric domain-specific risk taking should also be explored for their role in creative concept selection since  
188 researchers have shown that the *perception* of what constitutes a risky situation can be context dependent (Weber  
189 1999). Risk behaviors in the financial, ethical, and social domain are of particular interest to the study of risk in  
190 engineering design since much of design occurs in team-based project settings. Therefore, work is needed that  
191 explores the relationship between traditional behavioral economics and psychometric domain-specific measures of  
192 risk attitudes on risk-taking in a creative context in order to bridge the gap between risk attitudes in these different  
193 domains.

#### 194 2.4 Research Objectives

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197 The goal of this study is to identify factors that impact creative concept selection in engineering design teams  
198 through an empirical study. Specifically, the following research hypotheses are addressed:  
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200 Hypothesis 1: The creativity of an idea has no impact on its likelihood of being selected during concept  
201 selection. We anticipate this result since prior research has shown that individuals often select conventional  
202 or previously successful options during the concept selection process (Ford, and Gioia 2000).  
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204 Hypothesis 2: Creative idea generation ability affects team propensity for creative concept selection. We  
205 anticipate that teams who generate creative ideas (a combination of novelty and quality) will have a higher  
206 propensity for selecting creative ideas since prior research in psychology has shown that *individuals* who  
207 generate ideas with higher novelty are more likely to select novel ideas during group discussions (Putman,  
208 and Paulus 2009).  
209

210 Hypothesis 3: Team risk-taking attitudes affect team propensity for creative concept selection. We  
211 anticipate that teams who are more risk prone will have a higher propensity for selecting creative ideas  
212 since prior research has shown that individual risk attitudes affect one's perception of creativity (Rubenson,  
213 and Runco 1995).

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215 Hypothesis 4: Team personality traits (specifically agreeableness, conscientiousness, and neuroticism)  
216 affect team propensity for creative concept selection. This hypothesis is based on prior research that  
217 showed that teams with high conscientiousness and agreeableness levels are more motivated to achieve  
218 goals (Bell 2007) while agreeableness and neuroticism are required for group creativity (Goncalo, and Staw  
219 2006).

220  
221 These hypotheses are built on our previous research that found that individual-level risk attitudes can affect creative  
222 concept selection and generation in design (Blank for review).

### 223 224 225 **3 Methodology**

226  
227 To address our research questions, a controlled study was conducted with engineering design students at a large  
228 northeastern university. During the study, participants were tasked with completing an idea generation activity and a  
229 concept selection activity in design teams. The details of this study are provided in the following sections.

#### 230 231 **3.1 Participants**

232  
233 Thirty-seven engineering students (25 males, 11 females) participated in this study. Nineteen of the participants  
234 were recruited from a first-year introduction to engineering design course, while the remaining 18 participants were  
235 recruited from a third-year mechanical engineering design methodology course. Participants in each course were in  
236 3 and 4-member design teams that were assigned by the instructors at the start of the course based on prior expertise  
237 and knowledge of engineering design (four 4-member teams, seven 3-member teams). This team formation strategy  
238 was used to balance the *a priori* advantage of the teams through questionnaires given at the start of the semester that  
239 asked about student proficiencies in 2D and 3D modeling, sketching and the engineering design process. Thus,  
240 design teams were formed in such a manner that no single team was significantly more proficient at these design  
241 skills.

#### 242 243 **3.2 Procedure**

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245 One-week before the study, participants were introduced to the purpose and procedure of the study and  
246 were given an informed consent form to complete. Participants were given brief information regarding the purpose  
247 and procedure of the study, but no specific details about the design task, purpose of risk and personality measures, or  
248 research hypotheses were disclosed to participants. Therefore, participants were not given any information that  
249 could enable them to prepare for the design task in any meaningful way. Once informed consent was obtained,  
250 participants were asked to complete an online survey that assessed individual risk aversion and ambiguity aversion  
251 using a set of 20 lottery questions (10 each for risk and ambiguity aversion), see the metrics section of this paper for  
252 a description of the questions. The lottery questions were developed and utilized according to established measures  
253 used in standard behavioral economics (Boyle et al. 2012; Boyle et al. 2011; Han et al. 2012) in order to capture  
254 each individual's level of risk aversion and ambiguity aversion. In addition, personality measures for each  
255 participant were captured using the Short Form for the IPIP-NEO (International Personality Item Pool  
256 Representation of the NEO PI-R™) online questionnaire (Johnson 2014). Participants were assigned unique  
257 participant identification code for use in the online surveys and subsequent design tasks in order to maintain  
258 participant anonymity.

259 One week after the online surveys were completed, participants attended a design session where they were  
260 asked to develop a novel device to froth milk. While the design session took place at the same time and location of  
261 the participant's design course, the activities were led by the research team and were independent of required class  
262 related activities. The design task used in this study was selected to represent a typical project in an engineering  
263 design course. Students in these courses typically redesign small, electro-mechanical consumer products that require  
264 minimal engineering knowledge or expertise (Simpson, and Thevenot 2007; Simpson et al. 2007). In order to make  
265 sure that our task fit within this spectrum, the design task went through a round of pilot testing with other  
266 undergraduate students in order to identify a task that most engineering undergraduate students were neither familiar  
267 nor unfamiliar with. In order to ensure our participants were equally familiar with the product being explored, our  
268 design task went through pilot testing with first-year students prior to deployment. Specifically, the design task  
269 provided to participants in the current study was:

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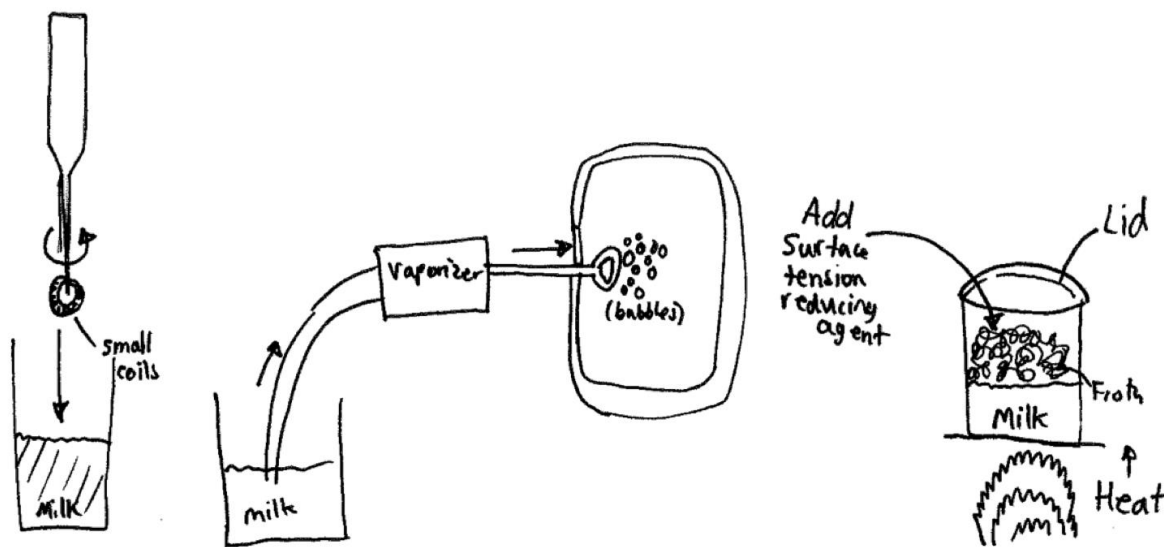
"Your task is to develop concepts for a new, innovative, product that can froth milk in a short amount of time. This product should be able to be used by the consumer with minimal instruction. Focus on developing ideas relating to both the form and function of the product."

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Participants were informed that the goal of the design task was to generate creative early-phase ideas to satisfy the design goal.

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Each participant was then provided with sheets of papers and asked to generate as many concepts as possible for a novel milk frother. Participants were given 20 minutes for this brainstorming activity and were asked to stop generating ideas at the 20-minute mark. This brainstorming activity was conducted individually in order to facilitate the free-flow of ideas without judgment and to avoid distractions that can occur in group brainstorming activities (Diehl, and Stroebe 1987). Participants were instructed to sketch only one idea per sheet of paper and write notes on each sketch such that an outsider would be able to understand the concepts upon isolated inspection, see Figure 1. It should be noted that no financial compensation was offered for participation; participants were motivated, perhaps, by the grade received in the course that was based on the novelty and feasibility of the final design concepts.



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Fig. 1 Example concepts sketched by participant N03AX.

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Following the idea-generation session, participants were given a three-hour break. Next, the second design session was completed where participants were asked to individually review and assess all concepts that their design team had generated in the previous session. Participants then formed their design teams that were assigned by the course instructor at the start of the semester and were asked to categorize each concept as follows:

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**Consider:** Concepts in this category are the concepts that will most likely satisfy the design goals; you want to prototype and test these ideas immediately. It may be the entire design that you want to develop, or only 1 or 2 specific elements of the design that you think are valuable for prototyping or testing.

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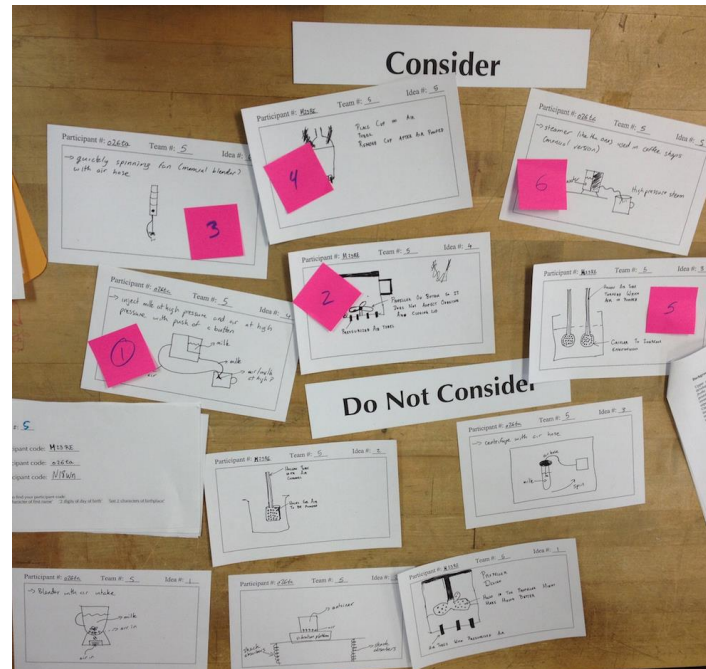
**Do Not Consider:** Concepts in this category have little to no likelihood of satisfying the design goals and you find minimal value in these ideas. These designs will not be prototyped or tested in the later stages of design because there are no elements in these concepts that you would consider implementing in future designs.

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These two categories were chosen to simulate the rapid filtering of ideas that occur in the concept selection process in industry (Rietzchel, Nijstad, and Stroebe 2006). The design teams were asked to discuss each concept with their team members and come to a team consensus on which concepts best addressed the design goal. During this discussion session, the teams were asked to physically sort the generated concepts into these two categories and rank the ideas in the 'consider' category using post-it notes (1 being the best), see Figure 2.

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**Fig. 2** The sorting of team generated concepts into the ‘Consider’ category and ‘Do Not Consider’ category by Team 5.

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### 3.4 Metrics

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#### 3.4.1 Creativity Metrics

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*Idea Novelty,  $D_j$* : This metric was developed to capture the amount of novelty in each of the generated ideas.

Novelty is the “measure of how unusual or unexpected an idea is compared to other ideas” (Shah, Vargas-Hernandez, and Smith 2003) and was calculated for each generated design using the feature tree approach developed by Shah, Vargas-Hernandez and Smith (2003). In order to accomplish this, the novelty of each



feature was first calculated. This feature novelty is defined as the novelty of each feature,  $i$ , as it compares to all other features addressed by all the generated designs. The more frequently a feature is addressed, the lower the feature novelty score. Thus, feature novelty,  $f_i$ , can then vary from 0 to 1, with 1 indicating that the feature is very novel compared to other features. The method of computing  $f_i$ , is shown in Equation 1.

$$f_i = \frac{T - C_i}{T} \quad (1)$$

Where  $T$  is the total number of designs generated by all participants and  $C$  is the total number of designs that addressed feature  $f_i$ . The novelty of each design,  $j$ , is then determined by the combined effect of the Feature Novelty,  $f_i$ , of all the features that the design addresses. Because  $D_j$  is computed for all the features addressed by a design, the novelty per design,  $D_j$ , is computed as an average of feature novelty, as seen in Equation 2.

$$D_j = \frac{\sum f_i}{\sum i} \quad (2)$$

Where  $f_i$  is the feature novelty of a feature that was addressed in the design and  $\sum i$  is the number of features addressed by the design.

*Task-Related Novelty*: This metric was developed to capture the level of creativity present in each design team. In order to accomplish this, participant novelty metric was first calculated as the average design novelty of all the designs each participant generated (Shah, Kulkarni, and Vargas-Hernandez 2000; Shah, Vargas-Hernandez, and Smith 2003), as seen in Equation 3.

$$\text{Task - Related Novelty} = \frac{\sum D_j}{N} \quad (3)$$

Where  $N$  is the total number of ideas generated by the participant. Team novelty was then computed as the average of the design novelty scores for all concepts generated within each design team.

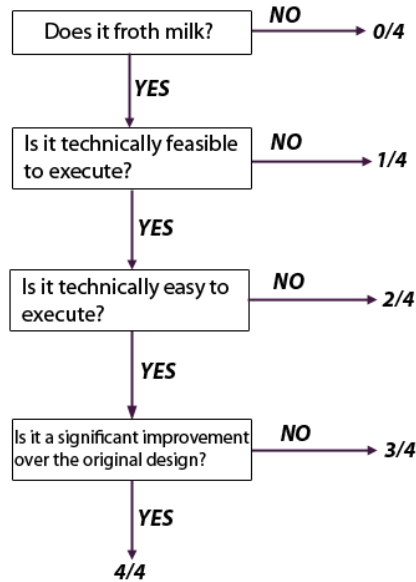
*Propensity Towards Novel Concept Selection,  $P_N$* : This metric was developed by the authors in previous studies to assess each team's tendency towards selecting or filtering creative concepts during concept selection (Blank for Review). In order to calculate this metric, first the average novelty of the concepts selected by the team during concept selection is computed. Next, the average novelty of all concepts available to choose from is computed. Lastly, the quantity from step 1 is divided by the quantity in step 2. This metric is shown in detail in Equation 4.

$$P_N = \frac{\sum_{j=1}^k (D_j \times C_j)}{k} \times \frac{l}{\sum_{j=1}^l D_j} \quad (4)$$

Where  $P_N$  is the team's propensity for selecting novel ideas during concept selection,  $k$  is the number of ideas selected by the team,  $l$  is the number of ideas in their set, and  $C_j = 1$  if the idea is selected and 0 if the idea is not selected.

In essence,  $P_N$  measures the proportion of novel idea selection out of the total novelty of the ideas that were developed by the design team. This metric has a value greater than 1 if the average novelty of the selected ideas is higher than the average novelty of all the generated ideas, indicating a propensity for novel concept selection. In contrast,  $P_N$  can achieve a value less than 1, indicating an aversion for creative concept selection. A score of 1 indicates that the team chose a set of ideas that, on average, had the same level of novelty as the ideas that was generated, indicating no propensity towards novel concept selection.

*Idea Quality,  $Q_j$* : Quality is defined as a measure of a concept's feasibility and how well it meets the design specifications (Shah, and Vargas-Hernandez 2003). Similar to Linsey et al. (Linsey et al. 2011), we measured quality on an anchored multi-point scale. However, we included an additional question to the quality scale in order to capture the improvement of the generated concept over the original design. The quality metric was calculated using the raters' answers to the final 4 questions on the 24-question survey, see Figure 3.



**Figure 3:** Quality scores assessed using the 4-point scale.

The design quality,  $Q_j$ , of each design was then computed using Eqn. 5, where  $q_k$  is the answer to the  $k^{\text{th}}$  quality question.  $q_k = 1$  when the quality question is answered with a 'yes', and  $q_k = 0$  when the quality question is answered with a 'no'.

$$Q_j = \frac{\sum_{k=1}^3 q_k}{3} \quad (5)$$

The quality score for each participant is then obtained by computing the average quality scores of all designs that the participant generated.

*Propensity Towards Quality Concept Selection,  $P_Q$ :* This metric was developed by the authors to assess each team's tendency towards selecting or filtering high-quality concepts during concept selection. In order to calculate this metric, first the average quality of the selected concepts is computed. Next, the average quality of all concepts available to choose from is computed. Lastly, the quantity from step 1 is divided by the quantity in step 2. This metric is shown in detail in Equation 6.

$$P_Q = \frac{\sum_{j=1}^k (Q_j \times C_j)}{k} \times \frac{l}{\sum_{j=1}^l Q_j} \quad (6)$$

Where  $P_Q$  is the team's propensity for selecting quality ideas during concept selection,  $k$  is the number of ideas selected by the team,  $l$  is the number of ideas in their set, and  $C_j = 1$  if the idea is selected and 0 if the idea is not selected.

*Task-Related Quality:* This metric was developed to capture the level of creativity present in each design team. In order to accomplish this, participant quality metric was first calculated as the average design quality of all the designs each participant generated (Shah, Kulkarni, and Vargas-Hernandez 2000; Shah, Vargas-Hernandez, and Smith 2003), as seen in Equation 7.

$$\text{Task - Related Quality} = \frac{\sum Q_j}{N} \quad (7)$$

Where  $N$  is the total number of ideas generated by the participant. Team quality was then computed as the average of the design quality scores for all concepts generated within each design team.

### 433 3.4.2 Risk and Ambiguity Aversion Metrics

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435 In addition to measuring the creativity of the ideas generated and selected by each team, the team's risk attitudes  
436 were also measured. Since no measure exists that assesses risk-taking in the context of creative concept selection,  
437 and since risk behavior has been shown to vary greatly across situations and domains (Weber 2010; Weber, Blais,  
438 and Betz 2002), it was unclear if, or how well, existing measures of risk could be used to measure risk-taking in a  
439 creative domain. Therefore, our work sought to understand the relationship between these existing approaches for  
440 measuring risk taking in a creative task by measuring participants' risk attitudes according to 2 existing approaches:  
441 traditional behavioral economics measures of risk (risk aversion and ambiguity aversion), and psychometric domain-  
442 specific measures of risk (financial risk behavior, ethical risk behavior, and social risk behavior). While 5 domain-  
443 specific measures of risk were originally developed using this psychometric approach, the Financial, Ethical, and  
444 Social domains of risk were used in this study due to their relevance to the social and risk-reward nature of team-  
445 based design tasks. On the other hand, the Health/Safety and Recreational domains of risk were not used in this  
446 study since they do not capture relevant aspects of creative concept selection in a small team setting. Specifically, in  
447 order to calculate combined risk attitude scores for each team, the following methods were used:  
448

449 *Risk Aversion:* An individual's risk aversion was measured using the 10 lottery questions (Chronbach's  $\alpha = 0.91$ )  
450 from the risk aversion online survey taken from research in standard behavioral economics (Boyle et al.  
451 2012; Boyle et al. 2011; Han et al. 2012). An example question is "Which would you prefer? \$15 for sure,  
452 or a coin flip in which you get \$ [an amount greater than \$15] if it is heads, or \$0 if it is tails?" Potential  
453 gamble gains vary randomly within the interval of \$20.00 to \$300.00, where monetary increments were  
454 determined through a series of pilot tests with engineering students. The team's combined risk aversion  
455 score was calculated as the mean of each team member's risk aversion score, as is typically done when  
456 calculating aggregate attribute scores from individual attribute scores (Mohammed, and Angell 2003;  
457 Reilly, Lynn, and Aronson 2001).  
458

459 *Ambiguity aversion:* In addition to risk aversion, ambiguity aversion was also measured due to its significance in the  
460 study of decision making since many realistic situations involve both risk and ambiguity (Heath, and  
461 Tversky 1991). It is important to investigate the role of ambiguity aversion in creative tasks since prior  
462 research conducted on ambiguity aversion has shown that an individual's tolerance for ambiguity is linked  
463 to creativity in problem solving tasks (Charness, and Grieco 2013), and creative performance (Sternberg,  
464 and Lubart 1991; Zenasni, Besancon, and Lubart 2008). Ambiguity aversion was measured using 10 lottery  
465 questions (Chronbach's  $\alpha = 0.85$ ) from the ambiguity aversion online survey. The goal of the assessment  
466 was to identify the point at which an individual would take the gamble given *unknown* odds of winning the  
467 gamble (i.e., make the 'uncertain' choice). An example question is "Which would you prefer? \$15 for sure,  
468 or \$20 if you win the gamble with unknown probability and \$0 if you do not?" Ambiguity Aversion was  
469 then calculated according to Borghans et al. (2009). Similar to risk aversion, the team's combined  
470 ambiguity aversion score was calculated as the mean of each team member's ambiguity aversion score.  
471

472 *Financial Risk Behavior Score:* In addition to participants' financial risk aversion measured using lottery questions,  
473 participants' financial risk behavior was measured from a psychometric perspective using 8 survey  
474 questions (Chronbach's  $\alpha = 0.70$ ) that assessed each participant's self-reported likelihood of participating in  
475 behaviors that are risky in a financial context on 5-point verbally anchored Likert scale (Weber, Blais, and  
476 Betz 2002) through the online survey, see example in Figure 4. While new 7-point scales have been  
477 developed for Weber's psychometric assessment, the use of the 5-point scale strikes a balance between  
478 validity and increases in variability that may arise from a larger number of points on a Likert scale  
479 (Friedman, and Amoo 1999).  
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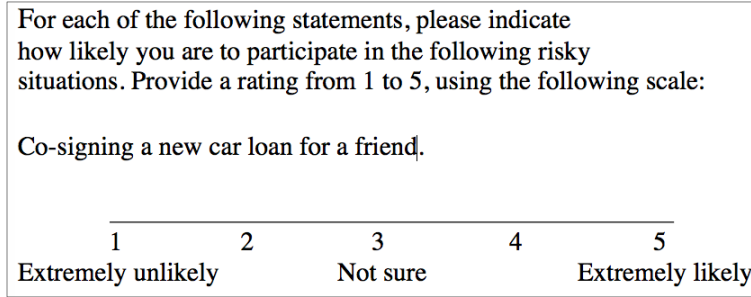


Fig. 4 Example financial risk behavior question from Weber, Blais and Betz (2002).

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*Ethical Risk Behavior Score:* Ethical risk behavior was measured using 8 survey questions (Chronbach’s  $\alpha = 0.73$ ) that assessed each participant’s self-reported likelihood of participating in ethically risky behaviors on 5-point verbally anchored Likert scale (Weber, Blais, and Betz 2002) through the same online survey (e.g., Forging someone’s signature).

*Social Risk Behavior Score:* Social risk behavior was measured using 8 survey questions (Chronbach’s  $\alpha = 0.54$ ) that assessed each participant’s self-reported likelihood of participating in risky social behaviors on 5-point verbally anchored Likert scale (Weber, Blais, and Betz 2002) through the online survey (e.g., Speaking your mind about an unpopular issue at a social occasion).

3.4.3 Personality Trait Metrics

Finally, personality scores were measured using the short Five Factor Model (FFM) online questionnaire (Short Form for the IPIP-NEO (International Personality Item Pool Representation of the NEO PI-R™) (Johnson 2014)). The combined personality trait scores of each team were calculated as follows:

*Team Personality Levels:* In order to calculate the combined personality trait scores of each design team, the personality traits of each participant was used. Each participant received a score (ranging from 0 to 100) on every one of the five personality traits: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness. The team’s combined score on each personality trait was then calculated as the average of all the team members’ individual scores, as is typical of team personality research (Mohammed, and Angell 2003; Reilly, Lynn, and Aronson 2001).

4 Results and Discussion

During the study, 22 ideas (SD = 6.4) were generated, on average, by each team and 8 ideas (SD = 3.02) were selected, on average, for further development. Examples of ideas that were categorized in the ‘consider’ and the ‘do not consider’ categories are shown in Table 1.

Table 1: Examples of ideas in the ‘consider’ and ‘do not consider’ categories.

<p>Ideas in ‘Consider’ category</p>	<p>Mean = 8 ideas SD = 3.0 ideas</p>	
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Ideas in 'Do Not Consider' category	Mean = 22 ideas SD = 6.4 ideas	
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520 Before testing our research questions, a post-hoc power analysis was conducted using the software  
521 package, GPower (Faul et al. 2007). Three predictor variables and a sample size of 11 were used for the statistical  
522 power analyses. For moderate to large effect sizes of  $R^2 = 0.70$ , the statistical power for this study was calculated as  
523 0.902. Therefore, it can be concluded that there was adequate power to detect moderate or large effect sizes. Since  
524 this study has the primary goal of exploring any possible effects that behavioral economics measures of risk,  
525 psychometric measures of risk, and personality have on creative concept selection, no interaction effects were  
526 explored in the analysis.

527 In addition, it was also important to conduct some preliminary analysis of our  $P_N$  and  $P_Q$  ratio variables in  
528 order to identify their appropriateness for analysis. Specifically, in order to insure a linear relationship between the  
529 novelty/ quality of the generated ideas and the novelty/ quality of the selected ideas, two linear regression analyses  
530 were conducted. The results revealed that there was in fact a significant positive relationship between the novelty  
531 ( $R^2 = 0.53$ ,  $R^2_{\text{adjusted}} = 0.47$ ,  $p < 0.01$ ) and quality variables ( $R^2 = 0.58$ ,  $R^2_{\text{adjusted}} = 0.54$ ,  $p < 0.01$ ). Since these  
532 relationships were found to be linear, the  $P_N$  and  $P_Q$  ratio variables were found to be appropriate for use in the  
533 remainder of our statistical analysis.

534 In addition, to determine the impact of any confounding variables since prior work has demonstrated  
535 differences between education levels and creativity in engineering design (Genco, Holtta-Otto, and Seepersad 2012),  
536 two ANOVAs were conducted, both using education level as the independent variable. The first ANOVA used team  
537 propensity for novel concept selection  $P_N$  as the dependent variable and the second ANOVA used team propensity  
538 for quality concept selection  $P_Q$  as the dependent variable. The results revealed no significant relationship between  
539 education level and  $P_N$ ,  $F = 2.10$ ,  $p > 0.18$ , and between education level and  $P_Q$ ,  $F = 0.51$ ,  $p > 0.49$ , indicating that  
540 education level did not impact the teams' propensity for selecting novel or quality concepts. Therefore, the data from  
541 both classes are analyzed for our analysis. SPSS v.20 was used to analyze the findings. A significance level of 0.05  
542 was used in all analyses, and ordinary least squares methods were used for all regression analyses. The following  
543 sections present the detailed results of our analyses in the order of our research hypotheses.

544

#### 545 4.1 Hypothesis 1: Creative ideas do not have a higher likelihood of being selected during concept selection

546

547 Our first research hypothesis sought to determine if idea creativity, conceptualized as a combination of novelty and  
548 quality, would affect the likelihood of an idea being selected by team members during group concept selection  
549 activities. Since the dependent variable of this analysis is discrete (selected or not selected), a multiple logistic  
550 regression analysis was conducted on all the generated ideas, with the dependent variable being whether the idea  
551 was selected by the team or not. In addition, since creativity is operationalized as the combination of design novelty  
552 and quality, the independent variables used in this analysis were idea novelty and idea quality. The results of this  
553 analysis revealed that idea novelty and quality did not significantly affect the likelihood of the idea being selected  
554 during concept selection,  $\chi^2(2) = 3.72$ ,  $p > 0.16$ . This result indicates that idea creativity did not significantly affect  
555 the selection of ideas during the team concept selection activity. This finding suggests that even if a highly creative  
556 design is generated during the early phases of design, it may not be selected during the concept selection process.  
557 This result demonstrates that design teams do not show any preference for creative ideas during the selection  
558 process, even though creativity is touted as an important element of the design process (Howard, Culley, and  
559 Dekoninck 2008). Since feasibility is an important element of creativity in this study, this result is contrary to prior  
560 work that has found that individuals tend to select ideas based on feasibility, rather than originality (Ford, and Gioia  
561 2000; Rietzschel, BA Nijstad, and W. Stroebe 2010). However, unlike previous studies, the selection activity was  
562 conducted in design teams, and involved typical engineering design problems. Nevertheless, the results of the study  
563 show that individuals did not show a preference for creative ideas even though creativity is regarded as an important

564 element of successful engineering design. That is, despite the fact that design educators and practitioners recognize  
 565 the importance of creativity in design, the mere awareness of its importance does not guarantee creative idea  
 566 generation and selection. Therefore, more focused and directed efforts aimed at highlighting the importance of  
 567 creativity and encouraging creative activities are needed to increase awareness of creativity throughout the design  
 568 process.

#### 570 4.2 Hypothesis 2: Creative idea generation ability is related to the teams' propensity for creative concept selection 571

572 Our second research hypothesis sought to determine the effect of team task-related creativity on team propensity for  
 573 selecting creative ideas during concept selection. In order to address this, a multivariate linear regression analysis  
 574 was conducted using team propensity for novel concept selection,  $P_N$  and team propensity for quality concept  
 575 selection  $P_Q$  as dependent variables, while team task-related novelty and quality scores were used as independent  
 576 variables. The multivariate regression analysis revealed no significant relationship between the dependent variables  
 577 and task-related novelty (Wilk's  $\lambda = 0.86$ ,  $F = 0.57$ ,  $p > 0.59$ ), and task-related quality (Wilk's  $\lambda = 0.84$ ,  $F = 0.65$ ,  $p$   
 578  $> 0.55$ ). These results indicate that task-related creativity is not predictive of the teams' propensity for selecting  
 579 creative ideas. In other words, a team's ability to generate creative ideas has no significant impact on their ability to  
 580 identify and select creative concepts during the later stages of the design process.

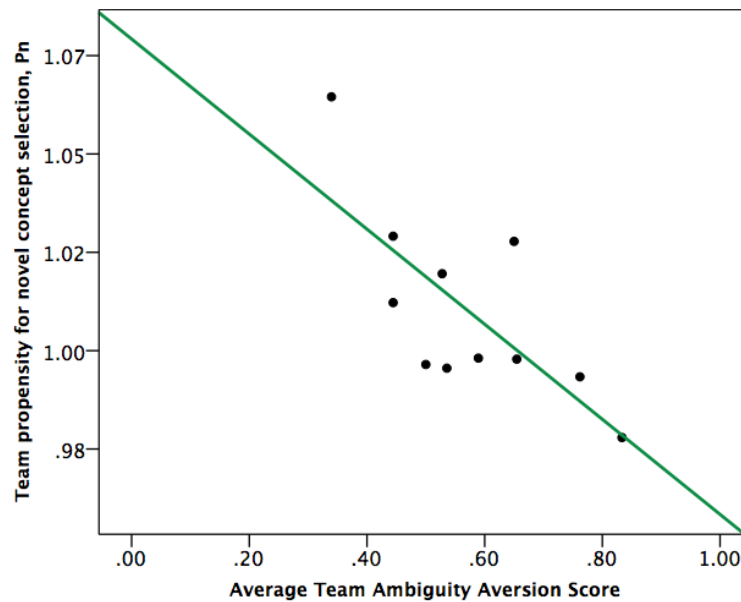
581 This finding suggests that even if a design team generates highly creative ideas, they may not necessarily  
 582 select these creative ideas during the concept selection process. However, this result is promising because it  
 583 demonstrates that even if a team does not generate a high number of creative ideas, it does not mean they cannot  
 584 identify and select the most creative concepts out of their set, and thus contribute significantly to the overall  
 585 creativity of the design process. Thus, students and practicing engineers who are expected to be creative during the  
 586 design process should focus on creativity during concept generation *and* selection in order to truly innovate and  
 587 break convention. While adoption rates of formalized methods in engineering practice remain relatively low  
 588 (Birkhofer, Jansch, and Kloverdanz 2005), the development and study of new methods and techniques for  
 589 encouraging creativity during the selection phase is essential for increasing design creativity, since prior research  
 590 has shown that many existing selection techniques discourage the selection of innovative ideas (Dong, Lovallo, and  
 591 Mounarath 2015). Research efforts aimed at developing and studying these new creativity methods can also help add  
 592 to our knowledge of the concept selection process in design.

#### 594 4.3 Hypothesis 3: Teams who are more risk prone will select more creative ideas during concept selection. 595

596 Our third research hypothesis sought to determine the effects of team risk attitudes on team propensity for selecting  
 597 creative concepts. To address this research hypothesis, traditional behavioral economics measures of risk (risk  
 598 aversion and ambiguity aversion) and psychometric domain-specific measures of risk (financial risk, ethical risk,  
 599 and social risk) were investigated for their effects on the teams' propensity for creative concept selection. First, a  
 600 multivariate linear regression was conducted with the independent variables being team risk aversion and ambiguity  
 601 aversion and the dependent variables being team propensity for novel concept selection,  $P_N$  and team propensity for  
 602 quality concept selection  $P_Q$  scores. This analysis revealed that risk aversion (Wilk's  $\lambda = 0.98$ ,  $F = 0.08$ ,  $p > 0.93$ )  
 603 and ambiguity aversion (Wilk's  $\lambda = 0.49$ ,  $F = 3.71$ ,  $p > 0.08$ ) could not predict the combination of team  $P_N$  and  $P_Q$   
 604 scores, see Table 2 for summary. However, team ambiguity aversion scores have a statistically significant effect on  
 605  $P_N$  scores ( $B = -0.12$ ,  $p < 0.05$ ). This result indicates that teams with a higher tolerance for ambiguity (lower scores  
 606 on ambiguity aversion) tended to select more novel concepts, see Figure 5.

607 **Table 2:** Summary of multivariate linear regression analyses between team  $P_N$  and  $P_Q$  scores and risk measures.  
 608

Independent Variables	Behavioral Economics Measures		Psychometric Domain-Specific Measures		
	Risk Aversion	Ambiguity Aversion	Financial Risk Behavior	Ethical Risk Behavior	Social Risk Behavior
$P_N$ and $P_Q$ combined	Wilk's $\lambda = 0.98$ $F = 0.08$ , $p > 0.93$	Wilk's $\lambda = 0.49$ $F = 3.71$ , $p > 0.08$	Wilk's $\lambda = 0.91$ $F = 0.29$ , $p > 0.76$	Wilk's $\lambda = 0.52$ $F = 2.77$ , $p > 0.14$	Wilk's $\lambda = 0.79$ $F = 0.82$ , $p > 0.49$
$P_N$	$B = -0.01$ , $p > 0.85$	$B = -0.12$ , $p < 0.05$	$B = -0.01$ , $p > 0.77$	$B = -0.05$ , $p > 0.08$	$B = 0.03$ , $p > 0.31$
$P_Q$	$B = -0.15$ , $p > 0.72$	$B = 0.57$ , $p > 0.15$	$B = -0.08$ , $p > 0.51$	$B = 0.30$ , $p > 0.11$	$B = 0.11$ , $p > 0.57$



**Fig. 5** Significant negative relationship between team propensity for novel concept selection,  $P_N$ , and average team ambiguity aversion scores.

A second multivariate linear regression was conducted with the independent variables being team financial, social, and ethical risk behavior scores, and the dependent variables being team propensity for novel concept selection,  $P_N$  and team propensity for quality concept selection  $P_Q$  scores. This analysis revealed that financial risk behavior (Wilk's  $\lambda = 0.91$ ,  $F = 0.29$ ,  $p > 0.76$ ), ethical risk behavior (Wilk's  $\lambda = 0.52$ ,  $F = 2.77$ ,  $p > 0.14$ ), and social risk behavior (Wilk's  $\lambda = 0.79$ ,  $F = 0.82$ ,  $p > 0.49$ ) could not predict team  $P_N$  and  $P_Q$  scores, see Table 2 for summary.

These results highlight the important role that risk attitudes can play in a design team setting, and show that teams with an overall higher level of tolerance for ambiguity (lower ambiguity aversion scores) are more likely to select novel concepts. This result is supported by prior research on team creativity that showed that new and original ideas tend to be viewed with skepticism in team settings, likely discouraging the selection of these ideas (Baer et al. 2007). However, teams that are more comfortable with making decisions under uncertainty and who are more willing to select ideas with unknown parameters are more likely to engage in the creative process, negating the general bias against creativity in team settings (Bradshaw, Stasson, and Alexander 1999; Camacho, and Paulus 1995). The fact that no significant relationships were found between risk aversion, financial risk behavior, ethical risk behavior, social risk behavior, and team propensity for novel and quality concept selection in this study suggests that perceptions and attitudes toward ambiguity in design dominate in team concept selection tasks, outweighing team attitudes toward other domains of risk. In addition, the results of our study show that tolerance for ambiguity only plays a role on propensity for selecting creative ideas in the novelty dimension, and not in the quality dimension, suggesting that participants' perception and preference for novelty may be more affected by team risk attitude factors compared to quality. Nevertheless, since novelty is often considered an essential criteria for innovation and invention (Slaughter 1998), and is one of the components of creativity (Shah, Vargas-Hernandez, and Smith 2003), it is important to study the factors that may affect design teams' preferences for novel ideas during concept selection.

#### 4.4 Hypothesis 4: Student personality traits will predict the teams' propensity for creative concept selection.

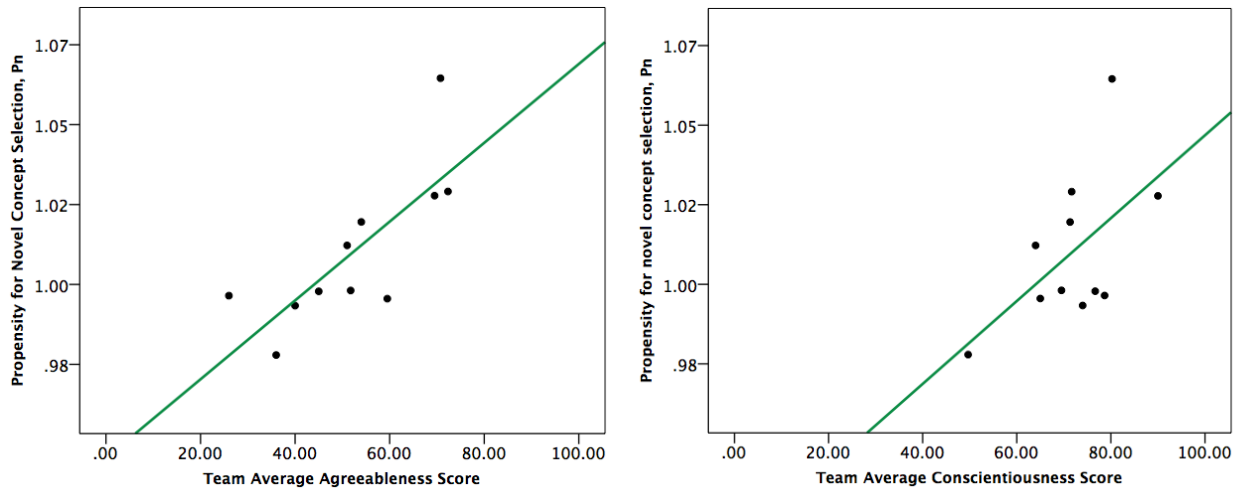
Our fourth and final research hypothesis sought to investigate the impact of team personality traits on the teams' propensity for selecting novel concepts,  $P_N$ , and propensity for selecting quality concepts,  $P_Q$ . In order to understand this relationship, a multiple linear regression analysis was conducted with the dependent variables being team  $P_N$  and  $P_Q$  scores, and the independent variables being team personality trait scores on all 5 traits. The multiple linear regression analysis results revealed that team personality traits do not significantly predict the combination of both  $P_N$  and  $P_Q$  scores, see Table 3 for summary. However,  $P_N$  scores alone could be significantly predicted by team personality traits ( $R^2 = 0.88$ ,  $R^2_{\text{adjusted}} = 0.77$ ,  $p < 0.02$ ). Specifically, higher levels of team agreeableness ( $B = 0.001$ ,

648  $p < 0.03$ ) and conscientiousness ( $B = 0.002$ ,  $p < 0.04$ ) were found to relate to a higher propensity for novel concept  
 649 selection in teams, see Figure 6.  
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**Table 3:** Summary of multivariate linear regression analyses between team  $P_N$  and  $P_Q$  scores and personality traits.

	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
$P_N$ and $P_Q$ combined	Wilk's $\lambda = 0.85$ $F = 0.35$ , $p > 0.73$	Wilk's $\lambda = 0.30$ $F = 4.74$ , $p > 0.08$	Wilk's $\lambda = 0.30$ $F = 3.34$ , $p > 0.12$	Wilk's $\lambda = 0.61$ $F = 1.29$ , $p > 0.37$	Wilk's $\lambda = 0.77$ $F = 0.60$ , $p > 0.59$
$P_N$	$B = 0.000$ , $p > 0.42$	$B = 0.001$ , $p < 0.03$	$B = 0.002$ , $p < 0.04$	$B = 0.001$ , $p > 0.13$	$B = 0.000$ , $p > 0.29$
$P_Q$	$B = 0.00$ , $p > 0.26$	$B = -0.003$ , $p > 0.54$	$B = -0.003$ , $p > 0.74$	$B = 0.004$ , $p > 0.53$	$B = 0.000$ , $p > 0.95$

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**Fig. 6** The relationship between team propensity for novel concept selection and team agreeableness levels (left) and team conscientiousness levels (right).

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These results show that personality traits are linked to team novelty during concept selection, supporting prior research that has shown that personality is related to creative idea generation potential (Stafford et al. 2010). However, the results of our study show personality traits only relate to a teams propensity for selecting novel ideas, not their propensity for selecting high-quality ideas. This result suggests that personality traits may play a larger role in affecting participants' perception of novelty compared to quality. Specifically, our study found that agreeableness and conscientiousness personality traits are positively related to novel concept selection supporting by prior research that shows that teams with high conscientiousness and agreeableness levels are more motivated to achieve goals (Bell 2007) and thus, tend to be more creative (Woodman, Sawyer, and Griffin 1993). Interestingly, results from other studies that explore these personality traits at the individual level show that agreeableness personality trait is negatively related to creativity (Feist 1998), indicating that team-level personality traits may differ from individual-level personality traits at a fundamental level. In fact, researchers have acknowledged that individual attributes interact in complex and dynamic ways in teams, resulting in team outcomes that are simply more than an aggregation of team-member attributes (McGrath 1998).

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Our result suggests that team-based perceptions and preferences for novel ideas is ultimately a function of the composition and heterogeneity of the design team; teams who are composed of many individuals with high creative potential may not necessarily select the most creative ideas and vice versa. In addition, the results of this study show that the composition of individual attributes in small design teams can affect the selection of novel ideas in a relatively simple design task, in an engineering education context. Thus, educational strategies that leverage the diverse distribution of individual attributes such as risk attitudes and personality traits should be implemented in order to encourage novel concept selection. In addition, more research efforts are needed to help identify design team configurations that encourage the most creativity throughout the design process.



## 5 Implications for Engineering Design Research and Education

The results of this study bear significant implications for research in engineering design and the instruction of design methods in engineering education. First, this study provides a better understanding of how concepts are initially screened during the design process, showing that highly creative teams do not necessarily select creative concepts. Our study also identifies that teaching or encouraging creative concept generation is not sufficient for ensuring the selection of these creative concepts during the later stages of the design process. Therefore, traditional methods of concept selection, such as those they rely on the expected utility framework for selecting concepts do not take creativity into account and are insufficient for encouraging creativity during the concept selection stage of the design process. This is due to the fact that most concept selection methods do not include creativity as an important aspect of the design while assessing ideas during concept selection. Thus, research is needed to develop and study methods and techniques for encouraging creativity that go beyond the mere expected utility of an idea during concept selection in order to increase overall creativity in the design process.

Another important finding of this study is that personality traits and risk attitudes are linked to novel concept selection in design. The results of this study provide empirical evidence that team-level personality attributes such as agreeableness and conscientiousness affect a design team's perceptions and preference for the novelty dimension of creativity. While there exists a wealth of prior research that has shown that these personality traits can greatly affect *individual* creativity (Batey, and Furnham 2006; Furnham, and Yazdanpanahi 1995), the effects of these personality traits on *team* creativity is much less studied (Mumford 2012). Some studies have shown that team-level personality traits can influence creative idea generation in teams (Baer et al. 2007; Bell 2007; Woodman, Sawyer, and Griffin 1993), but few studies have explored team-level personality traits in the context of creative concept selection.

The results of this study also found contradictory results on the role of team personality and creativity; Baer et al. (2007) found that high levels of extraversion and openness and low levels of conscientiousness in teams resulted in the *generation* of highly creative ideas while our study found that high levels of agreeableness and conscientiousness resulted in the *selection* of more novel ideas. This is supported by prior research that states that the types of cognitive and social factors that influence these two stages of design are fundamentally different and involve different sets of mental processes (Reiter-Palmon 2009). Thus, the formation of teams that have diverse personality traits can help ensure that creativity is encouraged throughout the design process. This notion of beneficial diversity is not novel, as it has been argued by researchers to be crucial in building teams that have high creative performance (Klein, DeRouin, and Salas 2006). However, this study highlights the need of this diversity during the concept selection process. Therefore, efforts to build the 'perfect' team composed of individuals with personality traits highly associated with creativity can be seen as a practice in futility since different types of personality traits may be linked with creativity at different stages of the design process.

Finally, one of the main goals of this research was to draw a link between team-level risk attitudes and propensities for teams to select creative ideas. The results of this study show that social risk attitudes play an important role in the selection of novel ideas in teams, agreeing with prior research that has shown that creativity is heavily influenced by social factors in a team setting (Woodman, Sawyer, and Griffin 1993). In this study, new and original ideas were likely viewed with skepticism in the team, likely discouraging the selection of these ideas. However, teams that are more comfortable with making decisions in ambiguous situations and who are more willing to select ideas have unknown parameters are more likely to engage in the creative process, negating the general bias against creativity in team settings (Bradshaw, Stasson, and Alexander 1999; Camacho, and Paulus 1995). Thus, perceptions and attitudes toward ambiguity appear to dominate in team concept selection tasks, outweighing team attitudes toward other types of risk. The development and adoption of environments and practices that encourage student designers to embrace ambiguity and take risks can allow students to openly and feely discuss ideas can help increase team creativity (Edmonson, and Roloff 2009).

While the results from the current study identifies important links between propensity for creative concepts, risk taking and personality traits in teams, future work is need to understand the underlying factors of creative concept selection by investigating the role of individual attributes in the perception and preference for creative ideas in team settings. In addition, engineering design educators should focus on forming functionally diverse teams in order to encourage a well-rounded focus on creativity throughout the design process. Lastly, student designers should be exposed to environments and practices that encourage social risk-taking and open idea sharing in an effort to educate the next generation of design engineers that are creative and effective in teams.

## 741 **6 Future Work and Limitations**

742  
743 While this study establishes a link between personality traits, social risk attitudes, and novel concept selection,  
744 several important limitations should be noted. Most important is that this study was developed primarily to explore  
745 engineering student's concept selection process in teams *in situ*, through the lens of creativity. Future work should  
746 focus on studying design teams in industry to compare the results found in this study with design practice. Similarly,  
747 larger sample sizes may reveal a link between creative concept selection and risk attitudes, such as interaction  
748 effects between factors, where one was not found in this study. Future work that explores the impact of personality  
749 and risk attitude compositions in teams (overall level and spread of traits) using controlled laboratory studies where  
750 teams with specific compositions of factors are assigned can also help add to our understanding of how these factors  
751 impact creative concept selection. More research is also needed to develop and study risk measures that are  
752 appropriate for use in creative contexts, since existing measures of risk may not fully capture the risk-taking  
753 behaviors of designers during creative concept selection (low reliability scores for scales). In addition, while this  
754 study provides knowledge of how student designers select concepts for a design project where students were  
755 specifically asked to be 'innovative', future studies should explore how the concept selection process is impacted in  
756 tasks that require varying degrees of innovation (e.g. tasks that require working rather than truly novel solutions).  
757 Similarly, more studies are needed to examine the impact of explicit instructions to select ideas that are both novel  
758 and useful on designer behavior during concept selection, and to understand if designers are selecting ideas that are  
759 more feasible in favor of ideas with higher novelty. Other areas of further investigation include examining the use of  
760 voting methods or prototyping activities during concept selection that may lead to a narrower scope of selected ideas  
761 and may impact creative concept selection in a different manner. Finally, the framing of the concept selection task  
762 could also lead to different results. For example, the impact of risk attitudes on creative concept selection may vary  
763 if designers are asked to choose their best concept, instead of a collection of their preferred ideas. Therefore, future  
764 work is needed to explore these interesting and challenging problems.

## 765 766 767 **6 Conclusions**

768  
769 The current study was developed to understand the relationship between creative idea generation ability, personality  
770 traits, risk attitudes, and creative concept selection in student design teams. Our results highlight the fact that teams  
771 that generate highly creative ideas do not necessarily select creative concepts. It was also found that team  
772 personality traits and social risk attitudes relate closely to novel concept selection. However, financial risk and  
773 ambiguity aversion were not linked to creative concept selection indicating that social risk perceptions dominate  
774 team-based concept selection activities. Our results serve as an empirical basis for further research on creative  
775 concept selection and are used to provide recommendations for design instruction in engineering education.

## 776 777 778 **7 Acknowledgements**

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## 781 782 **8 References**

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