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USING THE FIVE FACTOR MODEL TO STUDY PERSONALITY CONVERGENCE ON STUDENT ENGINEERING DESIGN TEAMS

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Abstract
The goal of this work is to identify changes in self and peer evaluations of personality among team members using the Five Factor Model. Multidisciplinary teams of five students in an undergraduate research design project-based course were used to evaluate their own and their peer's personalities over the course of one semester. Results show that team members' evaluations of their own personalities did not change significantly through four iterations. Team member's evaluations of their peers did change for Neuroticism, Agreeableness, and Extraversion.

Keywords: personality, collaborative design, design education, teamwork

1. Motivation to study student design teams
Engineering teams are used throughout industry and academia (Borrego et al., 2013). Industry teams may be formed to create new processes, products, and to make improvements to existing infrastructure, whereas academic teams range from undergraduate students to professors working on different projects (Borrego et al., 2013). These teams can be found in different settings such as class projects or multidisciplinary research teams. It is important in all instances that the team can cooperate to reach their common goal.
Currently, there does not appear to be a consistent method for forming student engineering teams, which can lead to underperforming or incompatible teams. Some teams are formed by random assignment, others based on self-selection, and others based on balancing individual characteristics (Ohland et al., 2012). Due to the many applications of teamwork beyond the classroom, it is important to give students opportunities to work in different types of teams, allowing them to develop valuable experience early on in their careers. Teams vary in size and structure, but can also vary depending on the learning objectives or goals of the team. Additionally, teamwork is dependent on the personality of the members of the team and how they interact with one another. In previous studies on teams, the focus has been performance or improvements to team performance, without focusing on the underlying attributes to these aspects of teams (Kichuk and Wiesner, 1997; Ogot and Okudan, 2007).
The goal of this study is to explore personality convergence of individual self-evaluations and team peer evaluations using the Five Factor Model (FFM) of personality. Using the FFM teammates can rate their own personalities (self-evaluations), as well as rate their peers' personalities (peer evaluations). The FFM gives each member a score from 0 to 50 on each of the five factors of personality, openness, conscientiousness, extraversion, agreeableness, and neuroticism. Using this model, it is possible to look at how student peer evaluations and self-evaluations change over time. For the purpose of this study, convergence is defined as there not being a statistically significant difference between the self and peer

evaluations when using t-test to compare them. This shows that the peer evaluations are in agreement with the corresponding self-evaluations.
This work is presented in the following format: a literature review including commonly used personality measures and the Five Factor Model is presented in Section 2. Section 3 focuses on the research questions, instrument used, and student population studied. Section 4 presents the current results and discussion which is followed by Section 5, which presents the conclusions of the present study.

2. Literature review

In order to look at the role personality plays on engineering design teams, we first must discuss the importance of teamwork in engineering as well as choose a method for assessing personality.

2.1. Engineering design teams

Cooperative learning, including the use of teamwork as part of the undergraduate curriculum, has been shown to have positive effects on students' learning outcomes (Smith, 1995). Furthermore, it has been shown that in engineering teams it is important to incorporate teamwork early on in higher education, allowing students to develop teaming skills before they are able to apply the breadth of their engineering knowledge in a team setting (Lewis et al., 1998). It has also been shown that senior level engineering student teams are similar to novice engineering teams, and thus they can be used as a model for industry teams (Teegavarapu et al., 2008; Borrego et al., 2013). Therefore, by using student teams to study the effects of personality, the findings can then be applied to industry teams.
According to a study on engineering and computer science teams, only 68.1% of teams reported that they achieved communicating clearly with their team members, 66.4% of teams reported they achieved helping one another on the team, and 63.9% of teams reported that they were able to ask for help from other members on their teams (Lingard and Barkataki, 2011). In previous work, it has been shown that team members who understand each other's personalities are better able to accentuate their teammates strengths and adapt to them, increasing communication between members (Ogot and Okudan, 2007). Thus, to be able to combine personality with communication in design teams, it should lead to better communication among members with an increase with teamwork skills from the design team experience.

2.2. Myers Briggs Personality Type Indicator

One of the most prominent personality instruments used in team formation in industry is the Myers Briggs Type Indicator (MBTI). This metric classifies people into one of sixteen different personality profiles, identifying individuals as extraverted or introverted, sensing or intuitive, thinking or feeling, and judging or perceiving (Boyle, 1995). One of the most prominent uses of MBTI in engineering team formation is in the application of teamology (Wilde, 2008). Using the data from the MBTI, different cognitive modes are determined for each person which are then used to form teams of the greatest diversity of cognitive modes (Wilde, 2008). Other studies using the MBTI with engineers try and improve team performance, identify personality incompatibilities, and form engineering design teams (Shen et al., 2007; Duhne, 2009; Licorish et al., 2009).
Although this test has been widely used, it is not a reliable or valid measure for personality (Bjork and Druckman, 1991; Boyle, 1995; Pittenger, 2005). There are many psychometric limitations to consider when using the MBTI to measure personality, including the test-retest reliability. Several studies have found that the reliability between tests is not adequate, with one or more of the attributes changing when administered with 4-5 weeks in between tests (McCarley and Carskadon, 1983; Myers et al., 1998). The MBTI measures people on a binary scale. However, because humans are not binary but reflect a range of personality traits, this is not a valid measurement for personality (Pittenger, 2005).

2.3. Five Factor Model

The Five Factor Model (FFM) of personality has become the prominent measure when looking at personality metrics (Furnham, 1996). Furnham and McCrae have both tried to relate the MBTI to the Five Factor Model, however in both cases the MBTI has not been able to recognize all five of the factors in the FFM (McCrae and Costa, 1989; Furnham, 1996). Neuroticism has been shown to effect many of the characteristics identified in the MBTI, and as such it prohibits the MBTI from being translated directly to the FFM.

The Five Factor Model measures personality using five traits, Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (referred to as OCEAN). Extraversion is typically characterized as being someone who is talkative, assertive, and energetic while agreeableness is characterised as being good-natured, cooperative, and trustful. Being conscientiousness reflects orderly, responsible and dependable people, and high levels of neuroticism show anxiety, being unhappy, and having negative emotions. Finally, openness relates to intellect, imagination, and independent-minded thinking (John and Srivastava, 1999). The meanings of a high and low score for each factor can also be seen in Figure 1.

The Five Factor Model has been validated for various populations, and for both self-reports and peer evaluations (McCrae and Costa, 1987; Goldberg, 1992). The specific tool being used in this study is the International Personality Item Pool (IPIP) 50 Item Version of the Big Five Markers, which is based on Goldberg's markers for the Five Factor structure (Goldberg, 1992). The IPIP is an open source repository of questions and surveys based on personality traits (Goldberg et al., 2006). This specific survey has been used for multiple studies on personality in engineering and beyond, due to its availability and short time for completion by participants (Feldt et al., 2008; Burton and Dowling, 2010; Vreede et al., 2012; Kanij et al., 2015).

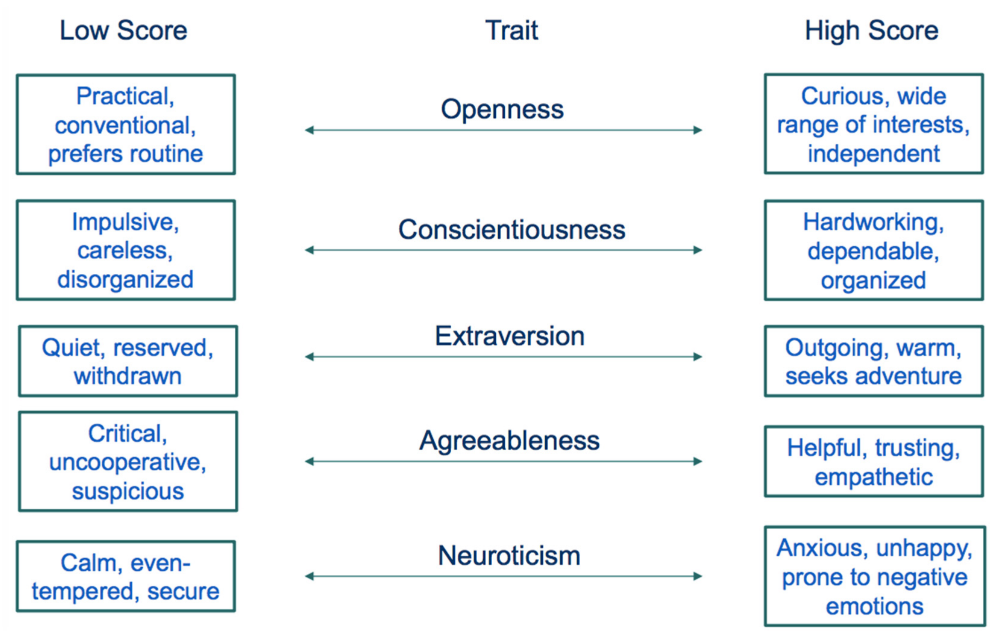

Figure 1. Personality traits for high and low scores of the factors in the FFM

2.4. Five Factor Model and engineering design teams

Although the FFM has not been widely adopted for use in industry, it has been used in different educational settings investigate different aspects of engineering design teams. In one study of 419 subjects, the Five Factor Model was used to look at the success of design teams, and it was found that successful teams as a whole showed higher levels of extraversion and agreeableness while also having a lower level of neuroticism (Kichuk and Wiesner, 1997). Similarly, others showed that when using the FFM to study new product development teams, the higher levels of team agreeableness and conscientiousness were associated with more effective team performance (Reilly et al., 2002). The FFM has also been used to study creative outcomes from a class assignment, where significant effects of certain personality dimensions on creative outcomes were found on studies of 33 and 37 students (Okudan et al., 2012; Toh and Miller, 2016). Recently, the FFM has been used to relate personality to student team performance, and how the levels of each factor for a team as a whole effect their performance (Lugo et al., 2017). In this study, the FFM will be used as a method to look at personality convergence on a team.

3. Research study method

3.1. Research questions

For improvements to be made to aspects of teams such as selection and performance, it is first necessary to understand the teams most basic characteristics, and this can be done using the Five Factor Model. In order to use the FFM, the following research questions were developed to look at student engineering design teams:

1. Using the Five Factor Model, will student peer evaluations match self-evaluations?
2. Over time, will student peer evaluations change?
    a. Will the group evaluations converge to the individual evaluations?
3. Over time, will student self-evaluations change?
    a. Will the individual converge to the peer evaluations?

The relationships between the self-evaluations, peer evaluations, and iterations of the FFM can be seen in Figure 2.

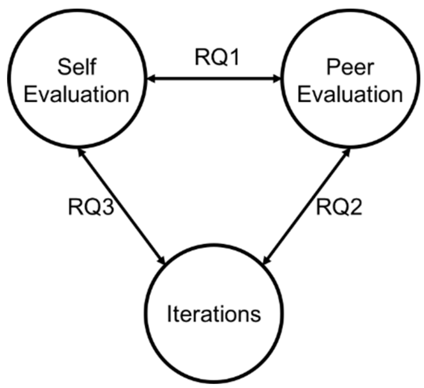

Figure 2. Relationships between research questions and student evaluations

By understanding how peers view each other, steps can be taken to identify which combinations of personality work well together and which to avoid. This method goes beyond identifying which personalities work well together on self-evaluation standpoint and allows the researchers to take into account the views teammates have of one another. This is important from a teaming aspect because if two people with different personalities can identify each other's personality but can't get along, the team may not perform to their greatest abilities.

3.2. Pilot study

A pilot study was conducted during Summer of 2017 for feasibility of collecting the self and peer evaluations of the FFM using online forms. This study was done on a total of 23 participants that were enrolled in the second half of the Capstone course at Clemson University. The study took place over five and a half weeks, with the FFM survey being administered a total of three times, during the first class, during week 3 and at the end of week 6. The participants were split up into four teams with two teams on a project.

Results from the pilot study indicated that a new method was needed for collection of the peer evaluations. The method that was tested asked the students to fill out one self-survey and a separate peer survey for each of their teammates. The students would complete the self-survey, but often would not complete a peer evaluation for each of their teammates or forget which teammates they had already evaluated. Thus, a peer survey was created for each team in the Fall 2017 study, that allowed the students to rate their peers all at the same time using one online form.

3.3. 50 Item version of the IPIP version of the Five Factor Markers

The 50 Item International Personality Item Pool (IPIP) version of the Five Factor Model was chosen to assess students' personalities on a self and peer basis. This metric was chosen because of its use in previous studies, and its open source nature. It was also chosen because it can be administered using an online form. Each of the fifty questions correlates to one of the five factors: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. The questions are either plus keyed or minus keyed, depending on the wording of the question and the answers are provided using a 5-point Likert scale. The number of each type of question and the associated factor can be seen below, in Table 1. Using the plus or minus key on each question, the score for each factor can be calculated with a 1 being assigned to the "Very Inaccurate" response for plus keyed items and a 1 being assigned to the "Very Accurate" response on minus keyed items. Each factor is calculated by summing up the numerical value of the answer to the factors associated questions. For example, if every plus keyed item for agreeableness received a score of 2 and every minus keyed item received a score of 5, the total for the agreeableness factor would be 16 (2x6+4x(6-5)=16).

Table 1. Plus and minus keyed items for the FFM

	+ keyed	- keyed
Openness	7	3
Conscientiousness	6	4
Extraversion	5	5
Agreeableness	6	4
Neuroticism	2	8

3.4. Student study

The population used for this study was taken from an undergraduate Mechanical Engineering Creative Inquiry course focused on the NASA Micro-g NExT Project at Clemson University. This undergraduate course is open to students of different levels and disciplines. The purpose of the course is to allow undergraduate students to focus on a year-long, team based and interdisciplinary research project. This type of course is not part of the graduation requirements for undergraduates at Clemson University. The population included four teams of five students each. The teams were randomly assigned to have equal numbers of students from each academic level. The different majors of the students include Mechanical Engineering, Materials Science, Computer Engineering, Chemical Engineering, and Bio-Engineering. More information on the student demographics can be seen in Table 2.

Table 2. Population demographics

	Male	Female
Sophomores	6	5
Juniors	4	1
Seniors	3	1
Total	13	7

Each team chose one design project from four challenges outlined by NASA for their Micro-g NExT Challenge for undergraduate students. Teams chose their project based on interest, scope (# requirements), and feasibility (# concepts). Over the course of the semester the students designed a device based on those requirements and wrote a formal proposal that was submitted to NASA on their device. Two teams have been selected to compete in Spring 2018 in the Neutral Buoyancy Laboratory at Johnson Space Center.

Using an online form specific to each team of students, the 50 Item IPIP version of the Big Five was administered approximately every three weeks, for a total of four iterations during one Fall 2017. The students completed one form to evaluate their teammates, and a separate form to evaluate their own personalities. Completing the form was part of the students' participation grade for the class. Other assignments included reflections on the design process and individual contributions to the team, as well as assignments focused on project planning and design requirements.

4. Results

Through all four iterations of administering the FFM, there was a 98.75% response rate for both the self and peer surveys. Any missing or incomplete surveys were omitted from the data set.

4.1. Change in self evaluations

Due to the nature of the Five Factor Model and its test, re-test reliability, no significant differences were expected between iterations of the self-evaluations. Responses from iterations 1 and 4 were compared based on the average score and standard deviation for all students, as seen in Figure 3.

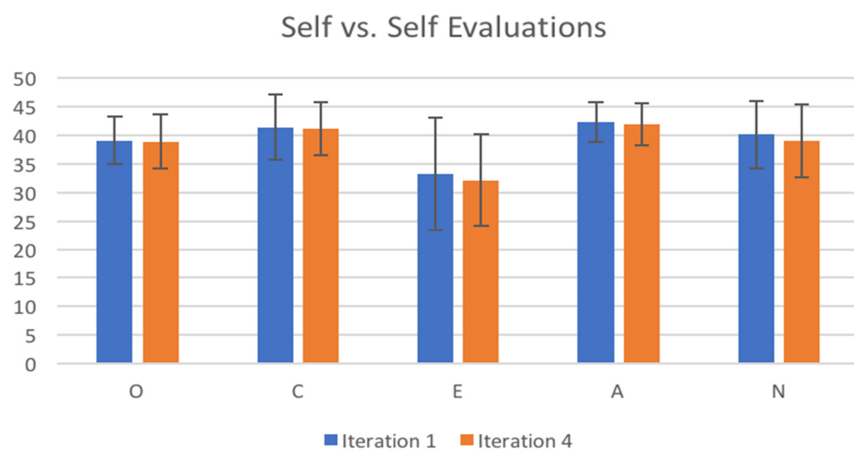

Figure 3. Self vs. self-evaluations for iterations 1 and 4

Comparison of mean scores for each of the factors suggests that self-evaluation from iteration 1 and iteration 4 are not significantly different. In order to ensure statistical significance, a two-tailed t-test with a 95% confidence interval for two-sample unequal variance was performed. A comparison of the first and last iterations, as well as the consecutive iterations (1 and 2, 2 and 3, and 3 and 4) can be seen in Table 3.

Table 3. P-values for self-evaluation comparisons between iterations

	Iteration 1 to 4	Iteration 1 to 2	Iteration 2 to 3	Iteration 3 to 4
O	0.9143	0.9151	0.6615	0.6724
C	0.8849	0.7180	0.7336	0.5555
E	0.7051	0.8599	0.7318	0.8001
A	0.7260	0.5078	0.7370	0.4614
N	0.5952	0.6138	0.4907	0.5397

Since all p-values are much greater than 0.05, there are no significant differences between any of the self-evaluation iterations. Thus, over time the student self-evaluations did not change in this instance (RQ3). This also shows that the individuals will not converge to the peer evaluations, since the self-evaluations did not change significantly over time (RQ3a).

4.2. Change in peer evaluations

In contrast to RQ3, the expectation for RQ2 was that the peer evaluations would change over the course of the semester. Similar to the self-evaluations, a two-tailed t-test with a 95% confidence interval for two-sampled unequal variance was performed for the average peer evaluations between Iterations 1 and 4. The results of the t-test showed that there was not a significant difference between peer to peer evaluations between Iteration 1 and Iteration 4, as seen in Table 4. A comparison of peer evaluations between consecutive iterations was also performed and can be found in Table 4.

Table 4. P-values for peer evaluation comparisons between iterations

	Iterations 1 and 4	Iterations 1 and 2	Iterations 2 and 3	Iterations 3 and 4
O	0.6724	0.2711	0.1572	0.7512
C	0.7203	0.2323	0.2824	0.8082
E	0.4528	0.0787	0.2607	0.9081
A	0.5027	0.0508	0.1258	0.7251
N	0.0036	0.0467	0.9311	0.3234

Between Iterations 2 and 3 and 3 and 4 all p-values are greater than 0.05, and thus no significant differences were found in the peer evaluations between these iterations. However, it is also shown that there is a significant difference for the Neuroticism factor between Iterations 1 and 2 and 1 and 4 since the p-values for these comparisons are less than 0.05. Between Iterations 1 and 2, the students are getting to know each other and how to work together. The consecutive iterations of 2 and 3 and 3 and 4 show a gradual change in the ratings, and between Iteration 1 and 4 there is a statistically significant change between evaluations. Thus, there are some changes between peer evaluations through four iterations of the FFM administration (RQ2).

4.3. Change in self vs. peer evaluations

In order to determine if the peer evaluations were converging to the self-evaluations, the evaluations were compared using a 5-axis plot. An example of a plot for self vs. peer evaluations can be seen in Figure 4.

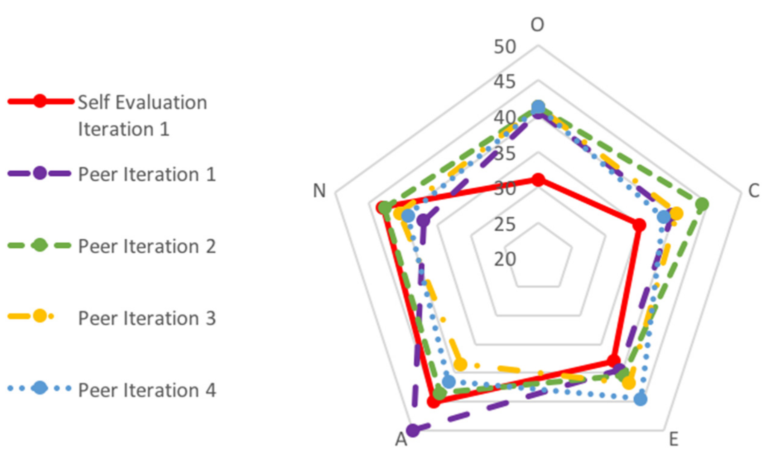

Figure 4. Example self vs. peer evaluations using a 5-axis plot

This plot represents the initial self-evaluation for one student, and the average evaluation for each factor by that students' peers in each iteration. Since there were no significant differences between self-evaluations found, the first iteration was chosen for use in the plot. Using these plots, it can be determined if the peer evaluations are converging to the self-evaluations, and if the peer evaluations are changing over time. This type of plot also shows the entire picture of how similar the ratings are, since it is easy to identify how similar the ratings are on each axis. Figure 4 also shows an example of the variance in the different factors over four iterations. An example of this can be seen in the Agreeableness factor, which has a wide range in scores over the four iterations. This is in contrast to the Openness factor, where the peer evaluations were in agreement over four iterations, but still did not agree with individual's self-evaluation.

In addition to looking at the individual scores for each iteration, the difference between the average peer evaluation and self-evaluation for Iteration 1 was calculated. As seen in Figure 5, the average difference between the self and average peer scores did not vary much between iterations.

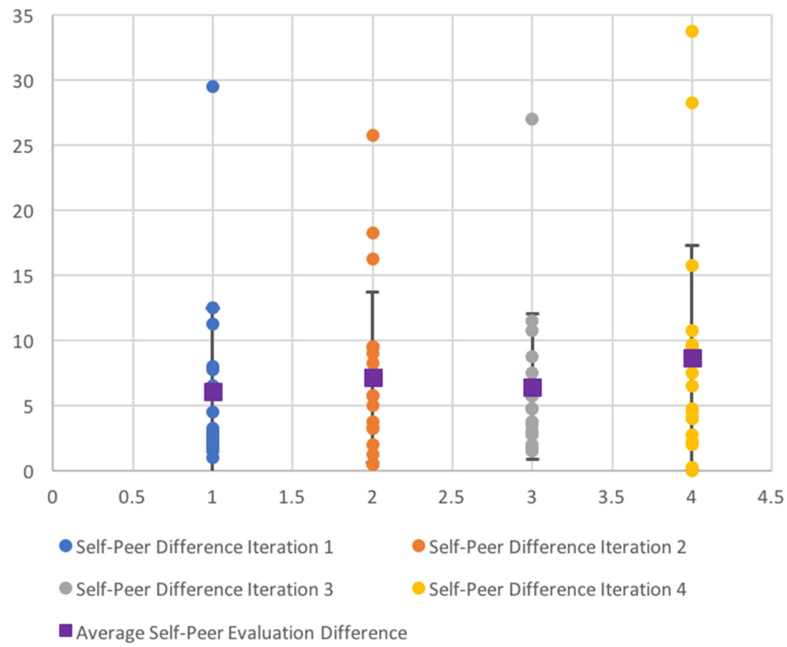

Figure 5. Difference between self evaluation iteration 1 and peer evaluation iterations 1-4 for extraversion

To determine if the peer iterations were significantly different from the self-evaluations between iterations, a two-tailed t-test with a 95% confidence interval for two samples of unequal variance was performed. It was anticipated that the peer evaluations would not match the self-evaluations until iteration 4, at the end of student's project together (RQ1). For RQ2a, it was anticipated that the peer evaluations would converge to the self-evaluations over time. Using the p-values for the self vs. peer evaluations, found in Table 5, it was shown that there was only one factor that was significantly different between the self and peer evaluations for iterations 1, 3, and 4.

Table 5. P-values for self vs. peer evaluations, all iterations

	Iteration 1	Iteration 2	Iteration 3	Iteration 4
O	0.6949	0.2238	0.6738	0.8270
C	0.3790	0.7158	0.8402	0.4063
E	0.3296	0.0561	0.0797	0.0458
A	0.0065	0.4297	0.0666	0.0979
N	0.2794	0.5868	0.0486	0.1947

5. Conclusions

By using the self and peer versions of the Five Factor Model for each student, it is seen that there are some changes in the evaluations of student's personality over four iterations for students on an engineering design team. During Iteration 1, the students accurately evaluated their peers' personalities on each of the five factors except Agreeableness (RQ1). This was similar to Iteration 3, where they did not accurately evaluate Neuroticism and Iteration 4 where they were only unable to accurately evaluate

Extraversion (RQ1). This data also confirmed the stability of the FFM to evaluate one's own personality, with no statistically significant differences found in the self-evaluations through all four iterations (RQ3). Finally, the peer evaluations showed agreement between the first and last iterations on every factor except for Neuroticism (RQ2).

Some specific limitations to this work include:

- Engineering population at Clemson University
- Personalities found in population as measured by the Five Factor Model
- Random team selection process and variety of personalities found on teams as a result

Future work for this study includes incorporating if students have worked together before, major, year of study, and previous experiences such as co-op or internship experience. Relation of convergence to team performance will also be analysed, with performance being determined as acceptance into NASA's Micro-g NExT Program.

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