AC 2009-683: COGNITIVE DIVERSITY AND THE PERFORMANCE OF FRESHMAN ENGINEERING TEAMS

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Cognitive Diversity and the Performance of Freshman Engineering Teams

Abstract

Some researchers have indicated that teams with greater cognitive diversity produce superior results. Cognitive diversity can take a variety of forms, but in this work diversity of personality types is explored. The impact of cognitive styles on team performance was evaluated in a freshman environmental engineering (EVEN) course. The students worked on projects involving comparative analysis and some calculations, but no design or intrinsically "creative" requirements. Specifically, student teams in 2006, 2007, and 2008 evaluated solid waste landfills. In 2006 and 2007 the project encompassed three or four periods of in-class direction and work time. In 2008, the project was modified to compare the energy and environmental impacts of landfills to waste-to-energy incinerators and included only two class periods with instructor direction (lecture and question/answer). Three different methods were used to form the student teams. In 2006, student grades in the class to date were used to create groups with similar average scores. In 2007, each team included a non first-year student or a student in the honors program in an attempt to assign a potential "team leader" for each group. An evaluation tool to determine perception and judgment roles based on Jungian typology[38] was administered via a written questionnaire to the students on the first day that the semester-project was introduced. This enabled determination of the cognitive diversity on the pre-assigned teams. In 2008, the cognitive style inventory results were used to create teams with maximum diversity. Earlier in the semester, student groups assigned alphabetically compared drinking water alternatives.

The team performance on the landfill project across the three years of the project was compared. There was not a strong indication that consideration of cognitive diversity in team formation improved the quality of the project report as indicated by higher grades. The two different team experiences in 2008 were also compared. Again, consideration of cognitive diversity during team formation was not shown to improve the project scores. However, student satisfaction with their team was improved on the teams formed by cognitive diversity. In addition, the presence of a coordinator personality type on the complex project seemed to improve team performance. Note that the variable demographics across the three years of the course and differences in the assignment may confound interpretation of the results to determine cognitive diversity impacts. The class size varied from 29 to 59 students, with 34 to 54% females, 48 to 71% declared EVEN majors, and 55 to 76% first-year students. The strongest predictor of team performance was the average overall grades of the students on the team. More data is needed to determine if cognitive diversity or its lack has a real impact on the performance of engineering teams conducting comparative assessments. Cognitive diversity may be more important for teams working on full design projects. Further research is needed to explore these ideas.

Background

The ability to work effectively in teams is an important skill that students need to develop in order to succeed in engineering practice.[1,3,4] This has led to increased use of pedagogy that embraces cooperative learning and greater emphasis on group projects in various engineering courses. An important challenge of engineering professors is to group their students in a manner that will set the stage for effective learning. Many researchers have suggested criteria that should be used when instructors form the teams.[18,22,27,28] Common strategies are to form teams of three to five students with a heterogeneity of grades and/or abilities, and avoid isolating minorities. Best practices appear to vary with the course level (first year, senior year, etc.) and possibly activity types.

Researchers have found that the personality types and the so-called cognitive diversity of team members will impact the performance, creativity, and overall experiences of the teams. This has been extensively researched in business and more recently in engineering education settings. The five factor model (FFM) or "Big Five" personality traits of openness to experience, conscientiousness, extraversion, agreeableness, and stability/neuroticism have been shown to correlate with various metrics of team performance in business settings.[8,9] In both business[21,36] and academic settings, the Meyers-Briggs Type Indicator (MBTI) personality inventory has been used.[13,14,15,16,17,22,24,25,26,29,32,34] The MTBI is based on Jung's theory and 16 personality/ psychological types can be determined based on an individual's stated preferences for perception and judgment and attitudes toward the external world. Wilde[38,39] has developed team role maps for the perception and judgment domains based on Jungian typology and an associated brief, written instrument to assess where a person falls on these dimensions. This is similar the MTBI but specifically applied to the purpose of determining team roles in an engineering setting. Wilde's model is also similar to the nine team roles proposed by Belbin[10] that were shown to correlate to different personality types.[7] Although there are some questions about the reliability and validity of the MTBI,[11] it still is the most popular instrument used to evaluate personality style and associated cognitive preferences.

Alternative methods to evaluate cognitive style are also available. One popular method is the Kirton Adaptation-Innovation Inventory (KAI).[7,12,20,23] Strong correlations between the KAI and MBTI have been found, particularly in the sensing-intuition and judging-perceiving scales.[23] Other options are the Cognitive Style Index (CSI)[2,6] and the Cognitive Style Inventory (CoSI) [37], although these assessments do not appear to have been applied in engineering educational settings. Due to its widespread use in engineering settings, an MBTI-based inventory was selected for this research.

For individuals, the MTBI has been used to identify preferred learning styles. For example, introverts may prefer a lecture format, extraverts may prefer active learning and talking. It has been historically stated that engineering attracts NT types.[14] N represents intuition, which has been linked to abstract conceptual learning and preferring self-directed learning. T represents thinking, which has been indicated to correlated with abstract conceptual and sequential learning and be comfortable analyzing a problem or situation. Rosati[34] found that students with ITJ personality types had a greater probability of graduating in engineering from a Canadian university. Felder[19] and Ramsay[32] found that cooperative learning environments were preferred and particularly beneficial for extraverts, sensors, and feelers. The implication is that the traditional teaching style at engineering universities may favor ITJ types, and weed out or discourage other personality types.

Some researchers recommend that teams for group projects should be formed by grouping students with opposite or different personality types.[7,14,22,30] However, they do not report on the success or failure of this approach. The theory is that different steps in the process of problem solving are best linked to different personality types. Daigle[17] summarizes the process in this manner: "facts gathered by Sensing are then analyzed by iNtuition for possibilities. During decision, facts organized by Thinking are then evaluated by Feeling in accordance with the problem requirements." Thus a project team that lacks a person with strength in each area may be disadvantaged in the overall process due to a weakness in a key step in the problem solving process. Wilde[38] compared three different methods of student teaming in Stanford's Mechanical Engineering Design course over 22 years. Across 251 teams there was a correlation in the cognitive diversity of the teams with the percentage of Lincoln Arc Welding Foundation prizes that the teams won in the nationwide competition. When students self formed teams they won 9% of the silver, gold, and best awards, compared to 23% winning when the teams contained a diversity of perception domain roles and 35% winning when the teams contained a diversity of both judgment and perception domain roles. This correlates success to the cognitive diversity of the teams, although a critical aspect on these projects was creativity. Other researchers have also linked personality types to individual and team creativity.[9,24,31,33,34]

Karn[25] studied five student teams of five to six students each who working on software projects together over an entire academic year. Using a self-developed written workgroup cohesion questionnaire, they found that a mixture of personality types resulted in very cohesive teams, but also noted the teams with homogeneous personality types worked consistently well over the duration of the project with minimal conflict. They found that teams with a high level of cohesion tended to perform better than teams with less cohesion, but social and technical cohesion is distinct and can produce different results on the quality of the team output. The Team Climate Inventory[5] may be a useful tool to measure teamwork attributes.[31] Team leadership qualities[21] have also been linked to personality types, and leadership in turn to team performance. However, different leadership styles are better suited to different types of team activities, specific to the type of work needed or problem being solved.

Most of the work reported on the impacts of personality types and cognitive styles on engineering team projects has been conducted with senior design teams and in disciplines outside of environmental engineering. Different types of projects may lend themselves more readily to different mixtures of personality types. For example, creativity plays a more important role in projects with a research and development focus.[31] Therefore, it was of interest to see how personality types would impact team performance on short term non-design projects in a freshman environmental engineering course.

Team Projects

All first year students in engineering at the University of Colorado at Boulder are required to take a 1-credit course to introduce them to their major of interest. Students transferring into the program and students in the College of Arts and Sciences may also enroll in the course if they are interested in learning about the major. The primary goal of the Environmental Engineering course is to inform students about what environmental engineering is and what environmental engineers do on the job. Since 2006, rather than solely bringing in a variety of guest speakers to the class, students also work on projects to illustrate types of work done by environmental engineers. By nature, the projects cannot be too technical or involved since the background of the students is minimal. The fifteen 50-minute class periods is the course also limits the scope of what can be done and expected from the students.

The first year 1-credit Introduction to Environmental Engineering course with 59 students included two team projects in fall 2008. The first project was a team based comparison to determine the best drinking water. The students had previously conducted individual evaluations of five different water types: local tap water; local tap water with point-of-use treatment by a Brita pitcher filter; and three different bottled waters. The team project grouped together four to five students who had evaluated different water types and required the group to share information and select the best water overall. The group defined the decision criteria, which typically included the safety of the water for human health, cost, pollution, and energy consumption. Almost a life-cycle assessment of each water type was conducted to look at overall environmental impacts balanced against consumer safety and cost. The group also determined the relative importance of the decision criteria. They then rated each water type against the decision criteria and determined which water was best. The assignment could be largely completed individually with only minimal requirements for teamwork. As such, a single in-class period the 4th week of the semester was provided for the students to work together and the assignment was due two weeks later. The expectations for the project were fairly straight-forward and required the students to create a weighted decision matrix, then individually score each water type for each criterion, and then simply average the individual scores. Some supporting text discussion was needed and a single document was submitted by each group. The students also submitted a confidential rating of how much each team member contributed to the group report; this information was used to derive individual grades from the team project scores.

The second team-based project in 2008 required the students to compare the environmental impacts and energy yield from landfilling versus waste-to-energy incineration of non-recycled municipal solid waste (MSW). Each team was assigned a different future scenario related to MSW production rates and MSW diversion to recycling. Each team was provided an Excel spreadsheet to assist in the waste quantity and energy content calculations. The project also required the teams to use the US EPA LandGEM model (http://www.epa.gov/ttn/catc/products.html). The project in 2008 was modified from previous years in order to emphasize energy issues, due to the stated interest of the students in energy. The project spanned three weeks of lecture starting in the 10th week of the semester: week one introduced the problem and project; week two allowed for in-class team work; week three the course instructor answered student questions in an open format. The project was due the following week.

A similar landfill evaluation project was completed in 2006 and 2007. In 2007 there was a first lecture in the second week of class to introduce the problem and project, followed by three more class periods that combined lectures and in-class team work time. The 5th week the project was due and the class discussed the outcomes from the student projects. In 2006, there was an initial lecture on the project in the 9th week of the semester, followed by two class periods of lecture plus in-class team work time. The 4th week the groups presented their results in class. The class sizes were smaller which facilitated student presentations and group discussion; 29 students in 2006 and 45 students in 2007. The variation in the timing and specifics of the assignment complicates interpretation of the results and the attribution of differences to the personality composition of the teams rather than other factors.

Methods

In 2006 teams of four to five students each were assigned by the instructor. These six teams were created using the following guidelines: (1) no team contained a single female student; (2) no team contained a single minority student; (3) each team had similar overall average grades on the preceding homework assignments in the course; (4) each team included at least two students majoring in EVEN; (5) each team had at least one non-freshman student; (6) each team included students interested in at least three sub-discipline areas indicated on the first homework assignment. The goal was to somewhat evenly distribute academic potential among the teams and create an environment that would not feel isolating. In addition, the various aspects of the project involved both air and water contamination issues, and at least one student on each team was particularly interested in each of these areas. Cognitive diversity among the students was not discussed and is unknown. This case serves as a blind comparator against the cognitive diversity team model.

The Wilde[39] cognitive style inventory was administered to the EVEN freshman classes in 2007 and 2008. The advantage of this instrument is that it is short. There are only 20 questions. Five questions each are used to distinguish preference for Extrovert vs. Introvert, Judgment vs. Perception, Sensing vs. iNtuition, and Thinking vs. Feeling. These scores are combined to compute scores in the Information Collection/Perception and Decision Making/ Judgment domains. The maximum possible sub-scores are 20 points each. In the Information Collection domain the 4 sub-scores are experiment (ES), ideation (EN), knowledge (IS), and imagination (IN). These scores are then used to classify the student into nine different roles. Similarly, in the decision making domain the four sub-scores are organization (ET), community (EF), analysis (IT), and evaluation (IF), which are used to classify the student into nine different roles. Only positive sub-scores are recorded.

In 2007, the cognitive survey was given out on the first day of the team landfill project, and the differences in personality type discussed to a small degree. The teams had already been formed. The algorithm used to form the teams was similar to that used in 2006. The project began the second week of class and some students dropped after the point that the teams were formed. Therefore, 2 of the 10 teams did end up with a single female, and one team contained only two interest areas. There was also only a single assignment on which to base the average academic performance of the students.

In 2008, a hard copy of the Wilde survey was given out on the first day of the team water project early in the semester and the students informed that the results would be used to form teams for the landfill project later in the semester. It was discussed in class that different cognitive styles were likely on their team, could lead to differences in preferred work and communication styles, and that a diversity of these styles had been shown to optimize team performance. However, in both 2007 and 2008 a full discussion of preferences for specific work tasks versus personality style was not held. (This is a planned addition in the 2009 class). Many of the students in the 2008 class indicated that they had completed a similar personality inventory in their first year projects course. The projects course is a 3-credit class where students work on a single team throughout the entire semester. The projects course spends a significant amount of time discussing effective teaming, personality types, etc.

The teams for the first 2008 team project to compare different drinking waters were formed alphabetically. Because some students added/dropped the course during the first two weeks of class, there were some exceptions to the strictly alphabetical groupings. The result was that 2 of 12 teams contained a single female, two teams contained a single minority student, six teams contained all first year students, and three teams included only two different EVEN sub-topic interest areas. The project began the second week of class so there wasn't a strong history available to determine the academic potential of the teams in advance.

The teams for the second project in 2008 were formed using two criteria. First, the predominant type in the perception / information collection area (ES, EN, IS, IN) were determined for each student; then they were placed on teams to avoid multiple students with the same predominant type on the same team while also maximizing the number of different types on a team. Note that each style did not have an equal number of students; most students were in the EN and IS categories and very few were in the IN and ES categories. A better approach would probably be to base the teams on final domain roles, but due to the large number of roles (18 total when perception and judgment are combined) and the relatively small teams (4-5 students each) and total class size (46 who completed the inventory), it was decided that this would be too difficult. Some students did not complete the cognitive style inventory, so those students were placed on teams using the second criterion. The second teaming criterion was to achieve maximum diversity in the students' predominant interest area which they had identified on the first homework. For example, given that the landfill assignment included aspects pertaining to energy, air pollution, and water pollution at least one person with of each of these interest areas was placed on each team. Other declared interest areas of the students on the first homework assignment included ecology, remediation, engineering for developing communities (EDC), sustainability, etc. The stated primary interest areas of the students did change over the course of the semester. For example, at the beginning of the semester the percentage of the students in the class with a stated primary interest in energy, water, air, and remediation were 35, 30, 8, and 7, respectively. At the end of the semester, the distribution was 19, 37, 10, and 14% in energy, water, air, and remediation, respectively. So frequently the sub-interest areas were not highly certain nor exclusive. Many students were at least somewhat interested in multiple areas of the EVEN discipline.

Results and Discussion

Student Cognitive Preferences

The demographics of the survey respondents are summarized in Table 1. In 2007, 89% of the students in the class reported their cognitive survey scores, compared to only 80% in 2008. Only about half of the students who completed the survey were declared EVEN majors at the beginning of the semester, with most of the rest undeclared engineering majors or various Arts & Sciences majors. Most of these students were considering EVEN as a major and wanted to find out more. Some of these majors had changed by the end of the semester, and some students also stated in their final essays that they planned to change their major. Only ~74% of the survey respondents were first year students; the rest were generally sophomores still exploring their major and/or transfer students being required to take the course. Therefore, characterizing the students as “first year environmental engineers” is a generalization.

Table 1. Students in the course and those who completed the cognitive evaluation survey

Year	# students in course	# students completing survey	% female	% Declared EVEN majors at start of semester	% 1st year
2006	29	0	52[†]	48[†]	55[†]
2007	45	41[*]	32	54	73
2008	58	46	54	59	74

[†] demographics for the students enrolled in the course rather than only the survey respondents
[*] 41 supplied their full scores; three other students just emailed their domain roles (2F, 1M)

First, the results of the average cognitive style scores from the students are summarized in Table 2. Using the individual types, students have the highest ES = Experimentation and ET = Organization tendencies and the lowest IN = imagination and IF = evaluation preferences. For example, given the fact that in 2008 there were 12 student teams, at least six teams would be lacking someone strong in IN regardless of what team formation algorithm is used. Looking at the data another way, the final row of the table shows the number of students with a strong preference for different roles, defined as scoring 11 or above. Students exhibited much stronger preferences for the information collection / perception roles, with 16% of the students strongly favoring IS = knowledge. Such predominance of some personality styles among engineers has been previously reported. Using the Myers-Briggs Type Inventory, Chang[14] found that 55%, 19%, and 19% of the electrical engineers in their study were SJ, SP, and NT, respectively.

Table 2. Average cognitive mode scores and types for Freshman EVEN students

	Information Collection/Perception				Decision Making/Judgment			
	ES	EN	IS	IN	ET	EF	IT	IF
2007 average	5.5	2.7	3.4	0.5	3.8	1.9	2.2	1.3
2008 average	4.0	3.8	4.3	1.1	4.2	2.5	2.8	2.2
Total % student scores ≥3	57	39	40	10	52	26	29	22
Total % student scores ≥11	11	11	16	1	8	5	8	2

Using the scores on the categories listed in Table 2, the domain roles of each of the students were determined. In many cases the student falls into multiple categories, which is why the % students exceeds 100% when all nine roles per domain are added. Results are summarized in Table 3. In the perception domain most students were optimally suited to the roles of prototyper / mock-up maker and test pilot. Very few students were well suited to the strategist and visionary roles.

In the judgment domain, most students were best suited to the schedule and coordinator roles, with few students in the diplomat and critic roles. In general, students were more evenly distributed among the judgment roles than the perception roles.

Table 3. Domain Roles of the Students

	# of students in 2007	# of students in 2008	% of students
Perception or Information Collection Role			
Entrepreneur	13	17	34
Innovator	10	18	32
Inspector	12	18	34
Investigator	15	20	40
Prototyper	**23**	**22**	**52**
Observer	9	6	17
Strategist	*3*	*5*	*9*
Test Pilot	**21**	**20**	**47**
Visionary	*3*	*6*	*10*
Judgment or Decision Making Role			
Conciliator	7	12	22
Coordinator	**17**	**22**	**45**
Critic	*6*	9	17
Diplomat	8	10	21
Mediator	9	*5*	16
Needfinder	7	9	18
Reviewer	8	11	22
Scheduler	**17**	**22**	**45**
Simulator	9	14	26

Cognitive and Interest Diversity of the Teams

The cognitive diversity of the various teams in the first-year Environmental Engineering course are summarized in Table 4. Teams for the landfill project in 2007 and the 2008 water project were formed without prior knowledge of the cognitive preferences of the students. The first two sets of columns represent the number of the nine potential perception and judgment roles that were missing from various teams. Some students did not complete the cognitive evaluation survey, and therefore the values in Table 4 may underestimate the actual cognitive diversity of some teams. The amount of unknown student information contributing to the data in Table 4 is summarized in Table 5. For the 2007 teams, the diversity on only one team is not fully known. In 2008, a smaller percentage of students completed the cognitive style inventory and thus there is a higher potential for significant under-reporting of the cognitive diversity. The landfill project has the largest number of teams (9 of 11) for which the cognitive diversity is not fully known. In 2009 the survey non-responders will be grouped together so that more complete information is available; this approach is recommended to other researchers interested in exploring this topic. Based on what is known, there was not a significant difference in the cognitive diversity of the teams across the three projects based on the number of different perception or judgment roles on each team.

Table 4. Various Diversity Measures of the Teams Assigned for the Three Different Projects

# teams lacking	2007 LF	2008 water	2008 LF	2007 LF	2008 water	2008 LF	2007 LF	2008 water	2008 LF	2007 LF	2008 water	2008 LF
	Perception Roles			Judgment Roles			Cognitive Mode Scores			EVEN Sub-Area in EVEN		
none		2	2	1	2	1	1	2	3	0	0	2
1	3	1	3	2	2	3	2	5	3	7	5	5
2	3	2	4	2	3	3	3	2	6	3	4	5
3	1	5	2	1	1	0	3	2			3	
4	1	1	1	3	2	5		1				
5	1			*1**	2†							
6		1†										
7	*1**											

Blank indicates that none of the teams had these characteristics
** indicates that 3 of 5 students on this team self-reported their roles, but did not give their scores and may have computed them incorrectly*
† One team with only 2 of 5 students who completed the cognitive mode survey
# interest topics: 4.5 or more = lack none; 3.5-4 = lack 1; 2.5-3 = lack 2 ; 2-1.5=lack 3

For the 2007 data, the team which had incomplete data was removed from further analysis. Of the nine teams with complete information, one team was significantly lacking in cognitive diversity, missing five information collection roles and three decision making roles. Four more teams were moderately lacking in cognitive diversity with five to six total perception plus judgment roles missing. For the 2008 water project groups, one of the teams only had information for two of five individuals and therefore this data was removed from further analysis. Two of the teams had 7 to 8 of the cognitive roles lacking, and an additional four teams lacked 5 to 6 cognitive modes. The manual method of trying to create teams with a combination of cognitive diversity and interest diversity for the 2008 landfill project was time consuming and not entirely effective. On one team only 3 of 5 students completed the cognitive evaluation survey and as such lack as high as eight cognitive modes. This group was removed from further data analysis. Of the remaining 11 teams, four teams lacked 5 to 6 cognitive modes.

Another way to consider the cognitive diversity of the teams is to look directly at the eight calculated cognitive mode scores that represent experiment, ideation, etc. A cut-off score of four has been used. In this case there does appear to be the most cognitive diversity among the 2008 landfill groups when cognitive style was considered when forming the teams.

Finally, due to the different aspects of the landfill project which encompass air, water, and energy issues it seemed that students would enjoy the project more if each team included students with interests in a broad range of topics. This diversity of sub-interest areas was generally well achieved.

Table 5. Missing Cognitive Style Information on Various Teams

	Total # on team	2007 LF	2008 water	2008 LF
# teams with all students known	4 or 5	9	3	2
# teams with 1 student unknown	4 5	0 0	0 7	1 7
# teams with 2 students unknown	4 5	0 1	1 0	0 1
# teams with 3 students unknown	5	0	1	0

Team Performance

The number of different team roles encompassed by the individuals in a group was not a strong predictor of the group performance as indicated by the quality of the product indicated by the grade awarded. Figure 1 shows the general lack of correlation between the number of different perception plus judgment roles encompassed within each team compared to the score received by the team. All of the regression lines have positive slopes but the correlation coefficients were all less than 0.33. The best correlation occurred for the Water project which was the most simple.

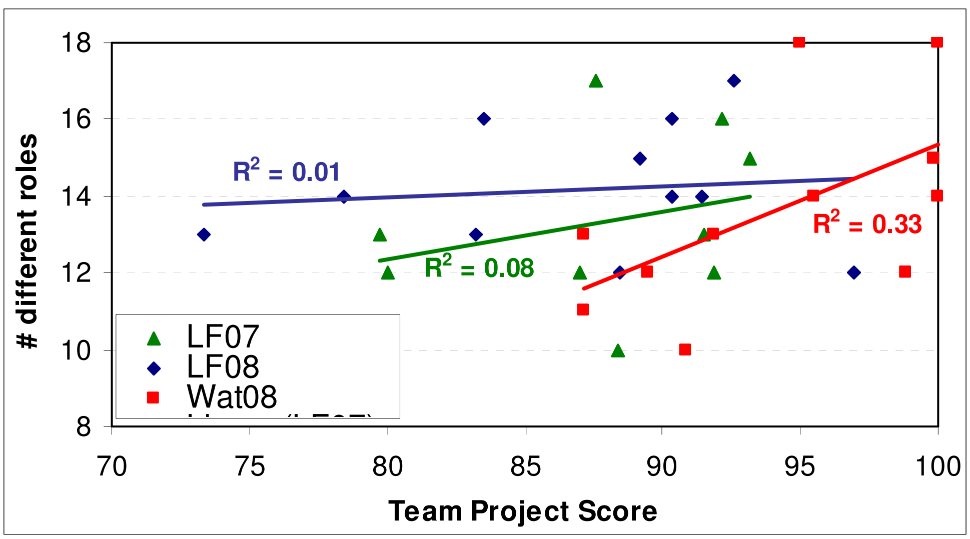

Figure 1. Comparison between the score earned by team versus the number of different team roles encompassed by the individuals on the team

Looking more closely at the data from the 2008 landfill project, the highest performing team with 97% had only 12 known team roles covered; however, one individual's characteristics were not known and he/she may have complemented the known roles of the other team members. Another distinctive aspect of this team was that one student was a transfer student with sufficient credits to be considered a senior and another was a sophomore. This team may have therefore had a strong leader in one of the more senior students which resulted in superior performance. Another team with better performance than the general trend earned 88% and had only 12 known team roles covered; again one individual's characteristics were not known and he/she may have complemented the known roles of the other team members. This team had one junior student; again, potentially serving a role as a team leader due to more maturity.

Clearly, factors beyond cognitive diversity alone impacted the performance of the student teams. The strongest predictor of team performance on the 2008 projects was the average overall grade of the individuals on the team. This relationship is illustrated in Figure 2, where the percentage score on the team project is plotted against the average final grade of the students in the team (4.0 = A; 3.7 = A-; etc). Given the general trend, it may be informative to look specifically at the outliers.

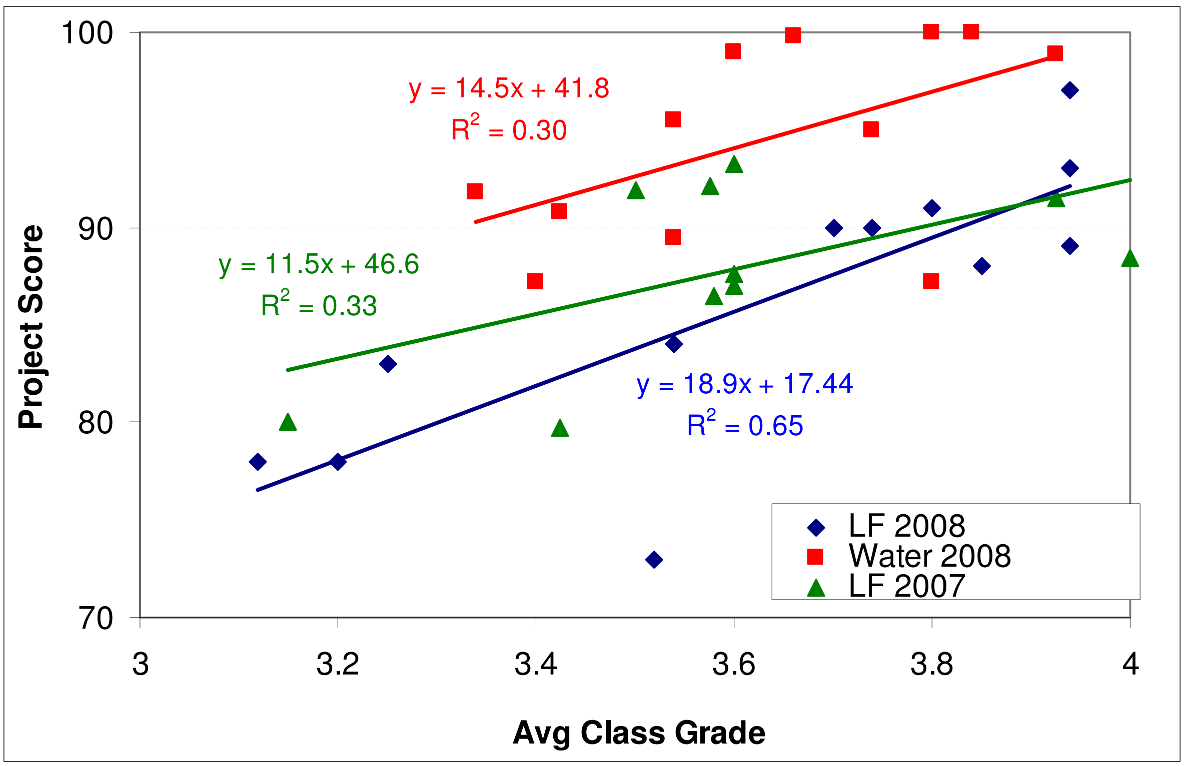

Figure 2. Comparison of team project scores versus the average overall course grade of the students on the team

The 2008 landfill project scores appear to be the most influenced by the overall academic performance of the team members, given the best R^2 of the regression line among the three different projects. The low outlier that was the worst overall project score was a team of five first-year students (one of whom ended up on academic probation at the end of the semester due to a low semester GPA across all courses). This team lacked an IN person, which wasn't unusual as six other teams also lacked this personality style. The team members did not report a highly uneven distribution of work, although one student stated: "... we had to divide up the work between two smaller sub-groups. We were pretty much in the dark to what our subgroups were doing." This lack of coordination may have resulted in the poor quality of the final product. Another person stated: "We noticed some possible error in Q 1-5 but not for sure." So the teammates didn't do a good job of reviewing each other's parts and/or didn't necessarily assign questions in the strength area of each individual.

Another set of teams to compare are the three teams all with an average GPA of 3.94 with varying project scores ranging from 89 to 97 (the top score in the class). The group that underperformed was known to be missing only three team roles and an IN but no other elements. Only one person on the underperforming team indicated an uneven distribution of effort. Two students stated that everyone put in equal effort, and two students did not give feedback (it was stated to the class that no feedback would be interpreted as equal effort for all). The student who provided detailed feedback stated: "Our group did not work as well together as it could have since we were not very organized and didn't divide up the work in the way that we should have. The other members ... tried to contribute somewhat; however, they waited until the last few days to start on their part. We just needed to learn how to work better as a team and each member needed to take more responsibility." This indicates that one student was aware of a problem with the project. The statement of the student indicates that perhaps the group needed a strong coordinator to organize them. Indeed, no student on the underperforming team was strongly identified in the domain role as a coordinator, compared to one or more coordinators in the average and over-performing teams. The over performing team was missing six team roles, an IN, and a strong IF person. So cognitive diversity or the lack of an IN personality does not appear to cause the performance variations. More important than these differences among the teams may have been the maturity level of the students on the teams. The under performing team was all first year students, compared to the other teams that included two students at the sophomore or higher level (due to transferring into the EVEN program or arriving with sufficient AP credit to be classified as a sophomore).

Students on the teams indicated a more even distribution of work on the teams assigned by cognitive diversity. These results are summarized in Table 6. However, the quality of the outcomes of the student work was not noticeably improved. It is true that the project requirements were changed significantly in 2008 which could account for some of the lower scores. The new project expectations on waste-to-energy incineration may not have been described well or supported well with documentation for the students. Alternatively, the fact that the project expectations were similar but covered in only two lectures in 2008 rather than three to four lectures in 2006 and 2007 may have led to the poorer performance in 2008.

Table 6. Summary of Student Ratings and Performance on Team Projects

		Percentage of students rating >10% difference in contribution of team members		Mean Grade as % on Team Projects	
Year	Total # students	Assigned teams without cognitive diversity	Teams assigned based on cognitive diversity	Teams assigned without cognitive diversity info	Teams assigned considering cognitive diversity
2006	29	41		90	
2007	45	31		88	
2008	58	36	14	95	86

Jensen[24] reported the team grades received in a course where two different teaming models were used. The highest team grade was earned by team that met both MBTI and 6-Hats criteria, followed by the team that met 6-Hats criteria, and then MBTI criteria. The three lowest scores were earned by teams that did not meet the formation criteria. Thus, there are some indications that preferences for group interactions impacts team performance defined by the grade received, but the link appears less strong with personality types.

Summary

A short cognitive evaluation survey was given to the students in a first-year introduction to environmental engineering course. In 2007 the survey was used as a tool to open a discussion about teamwork and differences in cognitive styles and optimal work tasks. In 2008 the results of the survey were partially used to form teams with diverse cognitive styles. However, in the small study completed to date it was not found that the level of cognitive diversity on the teams correlated to improved performance on the project. In final reflective essays in 2008, 88% of the students discussed teamwork in some context; for example, they enjoy it, don't like it, believe it is one of their strengths, etc. Recognizing differences in work styles may facilitate better team experiences, as the students may be willing to try to accommodate these differences. Project complexity, student maturity, and other factors also appear to be important determinants of team success on these analysis-based environmental engineering projects. Continued research on cognitive modes is planned. In the future, a grouping algorithm more similar to that used by Jensen[24] based on the MBTI types will be used.

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