Interdisciplinary Design – Forming and Evaluating Teams

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Interdisciplinary Design – Forming and Evaluating Teams

Abstract

The College of Architecture and Environmental Design at California Polytechnic State University has offered an upper division, interdisciplinary experience for every student in the form of a project based, team oriented five unit studio laboratory. The course is now in its fifth year and requires small teams of architecture, engineering and construction students to complete the schematic level design of an actual building for a real client. The quality of the projects and student deliverables has been outstanding and students are clearly meeting the objective to prepare an integrated building design. The other course objective is to function as a member of an interdisciplinary team, which is more difficult to quantify. This paper focuses on the selection and assessment of teams in this course. Various personality and skills assessments are completed and used in the formations of teams. Assessment data on team performance are presented and future actions for this project are discussed.

Introduction

The College of Architecture and Environmental Design at California Polytechnic State University in San Luis Obispo is the only college in the nation that has departments of Architecture, Architectural Engineering and Construction Management in the same college. The institution has a 60 year tradition of collaboration between the engineering, architecture and construction disciplines, particularly at the lower division level. To enhance this collaboration, the college committed to providing an upper division, interdisciplinary experience for every student in the form of a project based, team oriented five unit studio laboratory that every student would take. The course is now in its fifth year and requires small teams of architecture, engineering and construction students to complete the schematic level design of an actual building for a real client.

The course has two learning objectives which create a dynamic tension and compete for emphasis on how the course is executed:

1. Create an integrated building design that includes a sound project approach (scope/budget/quality & constructability) including land-use, site development, architectural vision, space planning, and the integration/synthesis of building systems.
2. Function effectively on an interdisciplinary team.

The first objective has been relatively easy to assess as reported in previous papers [1,2,3,4]. The rubric for the intermediate and final design submissions allows the product to be subdivided into clear increments such as architectural plan, structural system, site plan, cost estimate, etc. Each is given a score providing a reliable direct measure of student performance. It is straight forward to pinpoint where a design submission is outstanding and where improvements are needed.

The second objective directly supports ABET program criterion 3d, the ability to function as a member of an interdisciplinary team.[5] This second objective is much tougher to assess. The quality of the design product assists in the assessment, but does not necessarily reflect the quality of the team. Team performance is as dependent on group dynamics, human behavior, leadership, cooperation, shared work effort and organization as it is on the knowledge and performance of individuals.

This paper focuses on the selection and assessment of teams in this course. Various personality and skills assessments were considered in the formations of teams and the Thinking Style Self Preference Test was ultimately chosen. Peer ratings and course end surveys provide assessment data. The quality of the product and the group presentation becomes a secondary measure of team performance. Suggestions for development are presented.

Course Description

The course (ARCE 415, ARCH 451, CM 415 or LA 405) Interdisciplinary Project Delivery is an upper-division, project-based, five unit interdisciplinary studio laboratory that meets for three days a week with core hours of 1:00 – 5:00 pm. The projects are different every quarter, typically have had little or no previous design work, are geographically close enough for student visits, have an identified client or clients who can participate in the course and have sufficient scope to challenge each of the four disciplines. The course has evolved into one with a target enrollment of 72 students from four disciplines, architectural engineering (ARCE), architecture (ARCH), construction management (CM) and landscape architecture (LA). It is team taught by four faculty members representing each of these same four disciplines with the class divided into small interdisciplinary student teams, typically twelve teams of approximately six students each. Ideally each team contains one or two architecture, one architectural engineering, two construction management and one or two landscape architecture students. The course has three major milestone submittals, each one with an oral presentation and a printed submittal.

The course faced immediate challenges in three major areas: institutional, logistical and pedagogical. Previous papers[1,2,3] have chronicled these challenges in detail. The projects for the last seven quarters are summarized below:

- Creation of a 30,000 sf iconic Botanical Gardens that houses meeting rooms, theaters, banquet areas, classrooms and support areas.
- Renovation of a 1937 vintage, 8000 sf unreinforced masonry building and the construction of a 10,000 sf building for an Historical Archive Complex
- Green Building Competition - 1,000 sf residences in New Orleans, $100,000 budget, sustainable and accessible with the main floors elevated above the maximum predicted flood levels
- Sedgewick Nature Reserves
- Crandall Gymnasium & Natatorium - Redevelopment of a 1927 gymnasium and adjacent 1937 natatorium into a state of the art digital fabrication center.

- UCSB College of Creative Studies – 60,000 sf building(s), parking, site work
- Athletic Department Complex – 100,000 sf building(s), 1,000 car parking structure, 15,000 seat stadium, building renovations, sitework

Although challenging to the students, the projects are exciting and are comparable in complexity to those the students will undertake in practice. For many students, these projects present an appropriately complex culminating experience. Another important aspect is the presence of an actual client for each project. The class has been fortunate to engage clients that provide programs, overall goals and visions and attend the three project presentations by each team. The clients have made useful and sometimes blunt comments that supplement those of the instructors. Students have observed that individual client representatives sometimes have contradictory views and sometimes change the scope of the project.

Functioning on a team

The second learning objective, function effectively on an interdisciplinary team, is equally as important as the first objective, but has been addressed and assessed to a lesser extent. A lecture on personality types and the consideration of personality types in the formation of student teams provided some basis for discussions on teamwork. Some quarters have included lectures on teamwork and project management.

The expanded version of the second course learning objective is:

2. **Function effectively on an interdisciplinary team:**
    a. Communicate effectively utilizing verbal, written and graphical methods
    b. Integrate standards of professional and ethical responsibility into the working classroom relationships and the development of the integrated design.
    c. Apply the basic project management skills of team dynamics and decision-making strategies.
    d. Demonstrate the behavior of a functioning team in terms of respecting teammates, meeting internal deadlines, reacting well to change, following a coordinated plan, and contributing outside one's own discipline.

The assessment of this course objective is more difficult. Efforts to date have included peer ratings, surveys, essay questions, faculty observation, elements of the final presentations, and the overall quality of the design. These assessments are more subjective and less reliable. For example, peer ratings are skewed by different student attitudes toward grading their friends. The quality of the design can be determined by one good student who insists on doing all of the work. The issues of how to compose teams, what constitutes a good team, and how does one effectively assess the quality of a team effort are long term questions that this course intends to study.

Creating teams

The literature is filled with articles on how to best divide students into teams. Common options are self-selection, random selection, or instructor selection based on some criteria such as grade point averages, expressed skills, common course schedules, personality types, or demographic diversity. There is no consensus in the literature, except that self-selection for teams while easiest on the instructor is the least effective[6]. Because the course described in this paper is an interdisciplinary design course where the various team members each bring an area of expertise that the other students do not possess, the first criterion for team composition is to ensure that each team has an architect, an architectural engineer, a construction manager and a landscape architect.

Further break out of students required some experimentation.

- In the spring of 2010, the teams were formed in two stages. In the first stage the instructors formed eight teams composed of ARCH and LA students and eight teams composed of ARCE and CM students. They conducted breakout sessions where ARCH/LA and ARCE/CM teams were given different assignments to complete. Deliverables included a report out to the entire class. The ARCH/LA teams were encouraged to "shop" for an ARCE/CM partner while watching the ARCE/CM report. Likewise the ARCE/CM teams were encouraged to "shop" for an ARCH/LA partner. At the end, teams were asked to list up to three preferred partners, in the order of their preference. In the second stage the instructors matched ARCH/LA and ARCE/CM teams together to form final partnerships, accommodating their preferences wherever possible.

- In the fall of 2010, ten teams with six members were formed in one stage with an instructor making all of the selections outside of class. All teams were heterogeneous by discipline. According to Porter[7], teams become higher functioning when they are heterogeneous by discipline but homogenous by interest. After surveying student interests, it became impossible to create teams that were heterogeneous / homogeneous based on the results. It turned out that heterogeneous / heterogeneous teams were the best that could be assembled given the data for that group.

- By the spring of 2011, the instructors attempted to introduce individual traits into the team selection process rather than the expression of student interest. Two potential choices would be to use the Myer-Briggs personality indicator[8] or the Felder Learning Styles index[9]. Instead, the instructors turned to the Allen Harrison and Robert Bramson Preference Self Test (PST)[10] instrument that was not a personality type profile, but a thinking styles profile. The PST classifies individuals as synthesists, idealists, analysts, realists, and pragmatists. The instructors used PSTs to identify extreme opposites and avoid placing them on the same team. Team performance did not seem to be affected by avoiding extreme opposites. Ironically, the biggest problems surfaced within the teams that had similar thinking styles.

- In the fall quarter of 2011, the PSTs were engaged to select teams that were heterogeneous not just by discipline but also by thinking styles. This seems to provide the best overall results and has been continued in the course through the latest iteration in fall quarter 2012.

Thinking Style Self Preference Test

In its most succinct form, the five thinking styles in the PST are: *synthesists* who can look at the integrated whole and put the pieces of a puzzle together, *idealists* who use a value system to formulate a problem and welcome a broad range of views, *analysts* who interpret the facts through a mental model and value logic and deduction, *realists* who want concrete results and rely on facts and personal experiences, and *pragmatists* who are adaptive and will accept the most direct means of solving a problem. The general population is comprised of 10% synthesists, 30% idealists, 35% analysts, 10% realists, and 15% pragmatists. In addition, 50% of the population has one thinking style, 35% has two thinking styles (usually Realist-Analyst or Synthesist-Idealist), and 3% has three thinking styles.[10,11,12]

The PST instrument is a series of questions where the respondents rank order five possible responses from highest to lowest based on their personal preferences. An example question is:

When there is a conflict between people over ideas, I tend to favor the side that:

a. Identifies and tries to bring out the conflict.
b. Best expresses the values and ideals involved.
c. Best reflects my personal opinions and experience
d. Approaches the situation with the most logic and consistency.
e. Expresses the argument most forcefully and concisely.

The highest ranked option receives a score of 5 and the least preferred option receives a score of 1. Each answer to the question corresponds to one of the five thinking styles. There are a total of 18 questions. For each question, there are a total of 5+4+3+2+1 = 9 points to be distributed for a total of 270 points for the entire survey. The degree of preference for any of the five thinking styles is determined by the scores listed in Table 1.

Score	Degree of Preference
72	Commitment
66	Strong Preference
60	Moderate Preference
48	Moderate Disregard
42	Strong Disregard
36	Neglect

Table 1 Score required for different degrees of preference on the PST instrument

Since it is possible to have preferences in multiple categories and no preference at all, there are lots of possible combinations of classification. For the 66 students in the Fall 2012 iteration of this course, the thinking style distribution of the class is shown in Table 2.

7	Realist (R)
18	Analyst (A)
12	Analyst-Realist (AR)
1	No Preference (D)
3	Single Disregard (DS)
0	Dual Disregard (DD)
7	Idealist (I)
4	Idealist-Analyst (IA)
0	Idealist-Analyst-Realist (IAR)
1	Idealist-Pragmatist (IP)
0	Idealist-Realist (IR)
0	Other (O)
1	Pragmatist (P)
3	Pragmatist-Analyst (PA)
0	Pragmatist-Analyst-Realist (PAR)
6	Pragmatist-Realist (PR)
2	Synthesist (S)
1	Synthesist-Analyst (SA)
0	Synthesist-Idealist (SI)
0	Synthesist-Pragmatist (SP)
0	Synthesist-Realist (SR)
66	Total

Table 2 Student classification on the PST for the Fall 2012 quarter

Given the large number of classifications and the distribution of student preferences, it made sense to create a smaller number of categories for composing teams. The five chosen categories were Realist (R), Analyst (A), Analyst-Realist (AR), Integrator (I), and Nascent Collaborator (NC). The Integrators combined all of those preferences shown in light blue on Table 2 and combines all of the students with an idealist or synthesis preference. The Nascent Collaborators[13] are those who can work with anybody. This category combines the pragmatists with those who display no preference.

This survey was administered to 434 students in the College of Architecture and Environmental Design[14]. Using the categorizations listed above, Figure 1 shows the distribution of results.

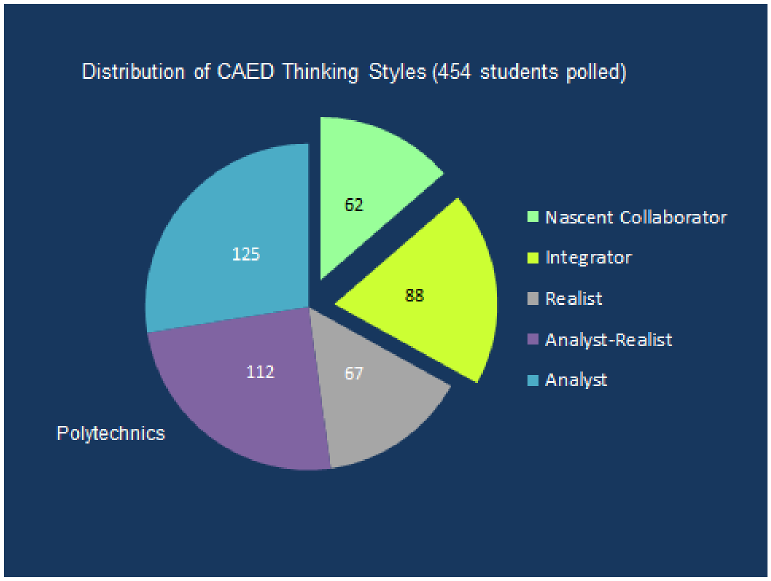


Figure 1 Distribution of Thinking Styles in the College of Architecture and Environmental Design

The Polytechnics are those thinking styles that include the realists, analysts, and analyst-realists. It is not surprising that 67% of the students in a polytechnic university fall into this category as opposed to 45% in the general population. The survey results are broken down by discipline as shown in Figure 2. It makes sense that the Architectural Engineering students have the largest proportion of polytechnics (R, A, and A-R) and the Landscape Architects have the least and most closely mirror the general population.

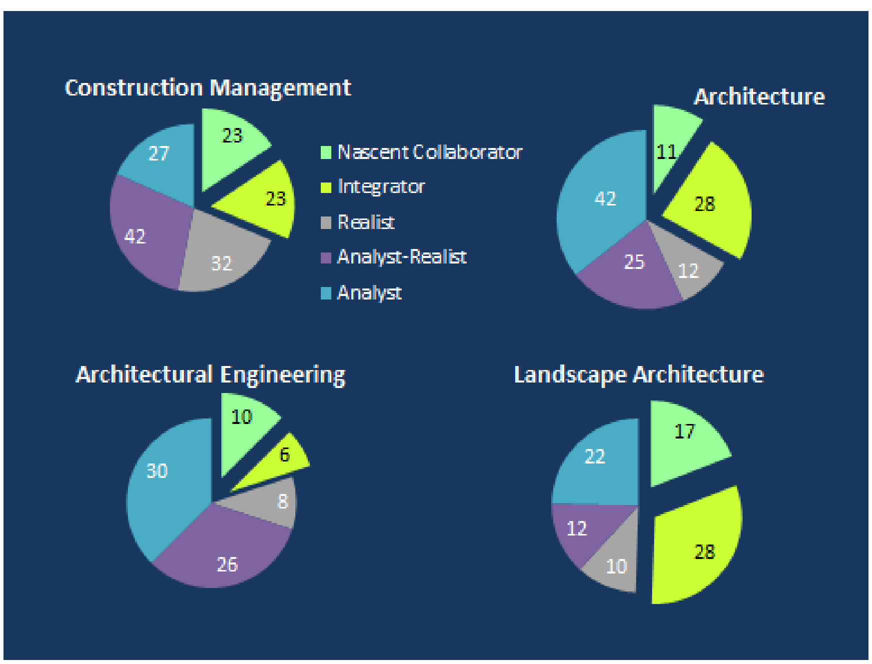


Figure 2 Distribution of thinking styles by discipline

Table 3 shows the distribution of teams for the Fall 2012 quarter based on discipline and thinking style preference. The team composition was heterogeneous with respect to both.

		L.A	ARCH	CM	ARCE	I	P	AR	A	R
Team 1	6	2	1	2	1	1	1	1	1	1
Team 2	5	1	2	2	0	1	1	1	1	1
Team 3	5	2	1	2	0	0	1	2	2	0
Team 4	6	1	2	2	1	2	1	1	1	1
Team 5	6	2	1	2	1	1	1	1	2	1
Team 6	6	2	1	2	1	2	1	0	2	1
Team 7	5	2	1	2	0	1	1	1	2	0
Team 8	5	1	1	2	1	1	1	1	0	0
Team 9	6	1	2	2	1	1	1	1	2	0
Team 10	5	1	1	2	1	2	1	1	1	0
Team 11	6	2	1	2	1	1	1	1	2	1
Team 12	5	2	1	2	0	1	0	1	2	1

Table 3 Composition of interdisciplinary design teams based on discipline and thinking style preference

Peer Ratings

Part of the process for assessing the quality of team performance is peer ratings at both mid-course and end-of-course. Each student was asked to rate each of their team members with respect to the following questions:

Did this teammate...

- ...complete the work that was expected to be completed?
- ...behave in a way that did not lead to arguments?
- ...show respect for your opinion?
- ...admit when s/he was wrong?
- ...behave in a friendly manner?
- ...listen to what you had to say?
- ...try to understand your feelings and thoughts?

Students gave each teammate a score that ranged from 6 (highest – Strongly agree) to 1 (lowest – Strongly disagree) for each of those questions. The students received a total score that was the sum of the ratings for all seven questions. The maximum possible score was 42. At the mid-course review the mean student score was 40.24 with a standard deviation of 1.97. The lowest student score was 34.5 and the highest was 42 which was also the most common score. The end-of-course survey results were strikingly similar with a mean of 40.20 and a standard deviation of 2.2. The lowest student score was 32.4. The student peer ratings are extremely high. The average student rating over all questions was 5.75 at the both the mid-course and end-of course ratings.

Team	Mid course peer rating	End-of-course peer rating
1	5.39	5.85
2	5.61	5.61
3	5.77	5.67
4	5.83	5.81
5	5.59	5.89
6	5.59	5.98
7	5.83	5.73
8	5.74	5.54
9	5.76	5.71
10	5.66	5.43
11	5.97	5.82
12	5.89	5.79

Table 4: Average peer-rating results by team for the Fall 2012 quarter

The composite average score for each team at the mid-course and end-of-course ratings are listed in Table 4. While the average score stayed constant between the rating periods, eight teams scores got worse by the end of the course, two got better, and one team stayed the same. The difference in scores just happened to be much bigger for the two teams whose scores improved. The ratings are all so high that few valid conclusions can be gleaned from the data. It is unreliable to even analyze where improvements could be made by investigating which questions brought the lower ratings.

The surveys provided the opportunity to make open-ended comments which were more insightful than the numerical scores. Several sample comments were:

- "Got along well within the group but, when it came to working out the details, did not accomplish tasks by the desired time."
- "xx is an effective speaker. Although CM portion of work always completed on time; he did not make much of an effort to see if aid in other ways could be provided for the team."
- "Was not present for our first presentation and was not involved at the other 2 (did not speak up ever to discuss his design). xx was not a great communicator or listener throughout the entire quarter and I was hard to work with him."
- "Difficult to work with...non responsive and very hard to communicate with. Often did not speak, even when asked a direct question."

A larger collection of student comments would be helpful in developing a rubric that quantifies what makes a good and bad member of a team. There is a lot to be gained if the students could be convinced to think critically about this issue and provide a rating in a candid manner.

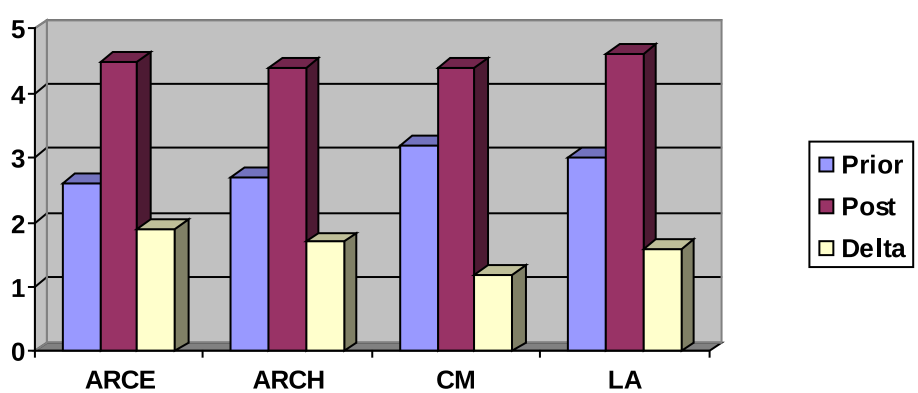
Defining the characteristics of a good team is a challenge. Some would contend they recognize it when they see it but have a hard time defining it because a good team relies heavily on some combination of collaboration, cooperation, leadership, personality differences, work ethics, and individual abilities. When Joseph Lowman was faced with the similar challenge of defining what constitutes good teaching[15], he accumulated over 500 teaching awards and used the narrative comments to devise a two-dimensional model that quantifies good teaching. If enough student narrative comments could be gathered, a similar approach could be used to develop a rubric for defining what makes a good team.

Student Course Evaluations.

Student course evaluations have now been collected for seven quarters. Each student assesses his/her abilities relative to the two course Learning Objectives. The students are surveyed prior to entering the course and upon completion of the course on a scale of 1 to 5, with a score of 1 being little or no understanding and a score of 5 being a thorough understanding.

The assessment for Learning Objective 2**,** Function Effectively on an Interdisciplinary Team, for the Fall 2011 quarter shows a consistent increase in student self-assessments for all disciplines with an average improvement for all disciplines of 1.7/5.0 as shown in Figure 3. Prior to the course CM students appeared generally more confident in their abilities to function on an interdisciplinary team than other students. Just as with Learning Objective 1 assessment results, students from all disciplines achieved a similar high level of confidence by the end of the course.

These results are similar to data from previous quarters[2,3] where student self-assessments also improved for all disciplines with an average for all disciplines of 1.2/5.0. This appears to represent a significant increase in improvement in a year and was consistent across all disciplines. Data from the earlier quarters showed that CM students reported a higher confidence prior to the course and all disciplines reported a high level of confidence by the end of the course.



ARCE	ARCH	CM	LA	
3.0	2.1	3.4	2.9	Prior

4.5	**4.4**	**4.5**	**4.8**	**Post**
1.5	**2.3**	**1.1**	**1.9**	**Delta**

Figure 3 Assessment of Learning Objective 2

In Fall 2012, the students in all disciplines reported on their ability to achieve the sub-portions of Learning Objective 2 which are:

2. **Function effectively on an interdisciplinary team:**
    a. Communicate effectively utilizing verbal, written and graphical methods
    b. Integrate standards of professional and ethical responsibility into the working classroom relationships and the development of the integrated design.
    c. Apply the basic project management skills of team dynamics and decision-making strategies.

The results of the assessment are shown in Figure 4. The results are similar to those reported in previous years.

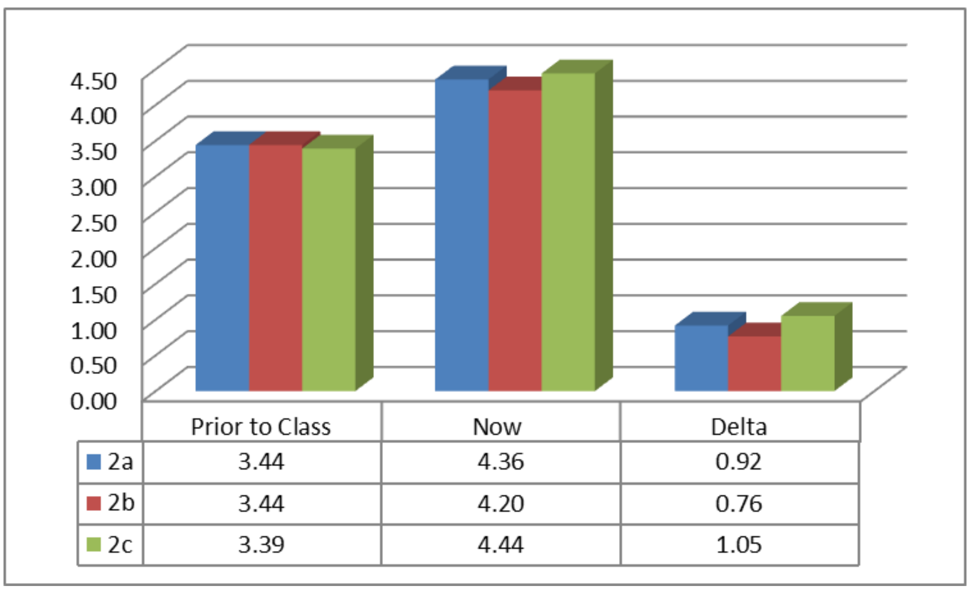


Figure 4 Student ratings of performance in the sub-element of learning objective 2 (functioning on an interdisciplinary team) for Fall 2012

Other Assessment

Student assessment of team functioning has occurred in two other ways. A survey was distributed to students during one quarter and students were asked to respond to questions on a scale of 1 to 5. The results are plotted in Figure 5. Team functioning has also been assessed by end-of-class qualitative student peer assessments. A future improvement would be to implement these types of student assessments on a more comprehensive basis.

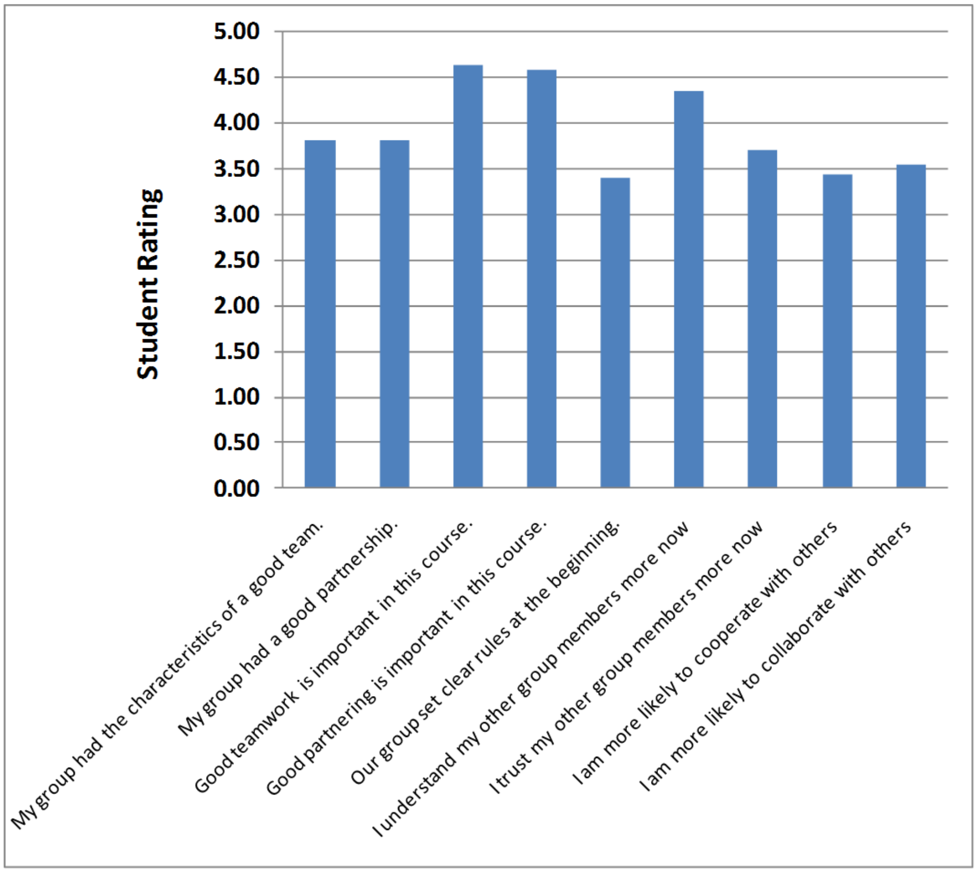


Figure 5 Student teamwork survey results

Faculty also provide assessments of the teams based on observation of team dynamics over the course of a quarter. Similarly, the quality of a team is also apparent in group presentations as observed through transitions between speakers, similar formats in slides, not presenting contradictory information or repeating what another speaker has already stated, organization and structure of overall presentation, evidence of rehearsal, and even coordination of clothing worn.

To a certain degree, the quality of the final product is a measure of the performance of an interdisciplinary team. If a building project really does require levels of expertise that only certain members of the team possess, then one can rightly conclude that an excellent final project design can only occur if all members of the team are contributing. The architectural layout, the structural system, and project estimate are clearly separate skill sets taught in the architecture, architectural engineering and construction management programs, respectively. Because the quality of the submitted design is graded with such precision, a high grade on the integrated design is an indirect indicator of successful teamwork.

Conclusion

Measuring the performance of an interdisciplinary team remains a highly subjective task. In the execution of the integrated project delivery course in the College of Architecture and Environmental Design, progress has been made in forming high quality teams and using instruments such as peer reviews and course surveys to assess their performance. The surface has barely been scratched however and this course presents the ideal laboratory for further developments in team performance assessments.

Some suggested expansion of these assessment efforts of team performance includes:

- Increased faculty emphasis on teamwork and project management in both class content and grading. Greater focus should improve student teamwork, enhancing those skills and improving the student's experience.
- Create more assessment tools focused on teamwork and project management. The assessment of team performance needs to be explicitly built into the grading rubric for the integrated design where a numerical score is assigned.
- There can to be some class exercises that deliberately require team work and provide some direct measurement indicators of performance. The exercise does not even need to be based on course content, but the instructor observations how the team completes the assignment would provide a direct assessment measure. A second iteration of the exercise later in the course would allow an assessment of improvement. An after action review assignment and survey of the exercise would cause all students to reflect, think critically, and provide some useful assessment data.
- Develop a rubric of what constitutes a good team and a bad team. This paper suggests how an assimilation of student narrative comments is a possible approach to the problem
- Formalize the grading rubric of the group presentations to include a team assessment portion that includes many of the factors listed in this paper.
- Further quantify the benefits of selecting teams that are heterogeneous in both discipline and thinking styles.
- Find ways to reward students for more critical thinking and candor in their peer reviews of team. If the peer reviews could be structured in a non-threating manner and students gave reliable feedback, the assessment data would be more useful. It would be possible to better compare team performance, isolate those elements where improvement could be gained, and even determine if the peer evaluations are asking the correct questions.

These measures should make for an improved experience for the students, improve the quality of the student projects and better prepare them for an industry that increasingly values collaboration.

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