Design Teams in a Civil Engineering Capstone Course: Formation, Preparation, and Performance

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The following paper describes our experience working with student design teams in a two-quarter capstone course in civil engineering. Each student completes a survey that defines his or her academic coursework, industrial experience, status with respect to Engineer-In-Training (EIT) certification, current grade point average, and experience with computer-aided design software. The course instructors use this information to subdivide the class into six-person teams, ensuring that each team has a comparable degree of background and experience. The teams are multi-disciplinary in that each member is assigned a specific role that relates to his or her elective coursework and industrial experience. After forming teams, the students complete a three-part, month-long lesson on communication. The lesson includes presentations and activities that focus on team building, active listening, communication styles, and assertiveness. These lessons are described in the paper. The intent of the lessons is to prepare the students to successfully interact and work together over the six-month course sequence. The approach to forming and preparing student teams has proven successful, as evidenced by peer evaluations and by project assessments completed by faculty and local engineering professionals.

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Introduction

Several years ago we revamped our civil engineering capstone design sequence by changing it from an individual study course into a directed study offering.[1,2] In the new course, students work in six-person multi-disciplinary teams to complete an integrated design for a private sector development or public works project. During the first term of the course, the student teams research the design and prepare a written Statement of Qualifications in response to a specific Request for Qualifications. During the second term, the student teams prepare a written Design Report with a full set of calculations and design drawings. Considerable time is spent outside of class preparing the design submittals. At the end of each term, the students present their submittals to a panel of faculty and practitioners.

In addition to the design element, the new capstone sequence includes seminar-style presentations on such professional issues as leadership, professional licensure, consensus building, and project management. Faculty members and senior-level practitioners conduct these seminars. All students attend these seminars together in a lecture environment, and concepts are reinforced through in-class reflection exercises.

In redesigning the capstone course to be more team focused, we recognized the need to provide the students with additional training and practice in teamwork and communication. Therefore, we included a three-part, month-long communication lesson in the new course curriculum. The lesson includes presentations and activities that focus on team building, active listening, communication styles, and assertiveness. The students work through these lessons in their design teams. The intent of the lessons is to prepare the students to successfully interact and work together over the six-month long course sequence.

In this paper, we discuss the procedure followed to form the multi-disciplinary student design teams. In addition, we describe the three-part communication lesson that is provided to each student team. Assessment results are briefly summarized.

Team Formation

In the new course, essentially all student work (except for exams) is completed as a member of a multi-disciplinary team. Therefore, considerable thought is given to selecting team rosters. The students complete a survey at the first class meeting that defines (1) their academic coursework, (2) their industrial experience, (3) their status with respect to Engineer-In-Training (EIT) certification, (4) their current grade point average (GPA), and (5) their experience with computer-aided design software. The course instructors use this information to subdivide the class into six-person teams, ensuring that each team has a comparable degree of technical breadth and depth, practical experience, professional preparation, and academic preparation. With regard to academic preparation, the instructors attempt to ensure that each team has a comparable average GPA and a comparable level of CAD experience. Table 1 summarizes student participation in the capstone course during the past four years.

Table 1: Student and Team Participation in the Capstone Design Course

Variable	Course Offering			
	2006	2007	2008	2009
Number of Students	138	146	173	160
Number of Teams	23	25	29	27

Each member of a given team is assigned a specific role that relates to his or her elective coursework and industrial experience. On the survey, the students report the top two civil engineering emphasis areas that they are interested in pursuing. Emphasis area choices include geotechnics, structures, transportation, water resources, or general (which indicates interest and experience in several different areas of civil engineering design). Since the design project is multi-disciplinary and includes elements of geotechnics, structures, transportation, and water resources, we ensure that at least one team member assumes a role in each of these emphasis areas. The final two team slots are filled with generalists who are able to assist in all different elements of the project. Every effort is made to assign a role corresponding to the student's first choice. Indeed, during the past four years, approximately 80 to 85 percent of our students were assigned first choice roles.

About 20-25 percent of our civil engineering seniors are female. Once the course instructors have assigned the teams based on the criteria described above, a final check is made to ensure gender balance. The instructors modify the teams so that no female is grouped alone with five other males.

Team Preparation

Once the teams are formed, the students participate in a month-long series of lessons designed to prepare them for working with one another. The lessons focus on three topics, as described in the following sections. Each topic is delivered in a lecture-type setting with the entire class present and working together in teams. The lessons serve to complement teamwork discussions that are covered in previous lab courses.

Team Building

The first lesson includes a three-hour team building exercise. During the first half of this exercise, the students participate in an icebreaker activity. In recent years, we used the "Coat of Arms" exercise, where students express important aspects of themselves with drawings or short phrases[3]. During the activity, the students prepare a personal coat of arms, or emblem, and explain it to their teammates. The emblem is divided into quadrants, as shown on Figure 1. Each student prepares their emblem using drawings or short phrases to represent answers to the four prompts on Figure 1. The students then share their emblems with their teammates. The activity takes about 25 to 30 minutes. Before the activity begins, one of the course instructors shares his or her coat of arms with the class.

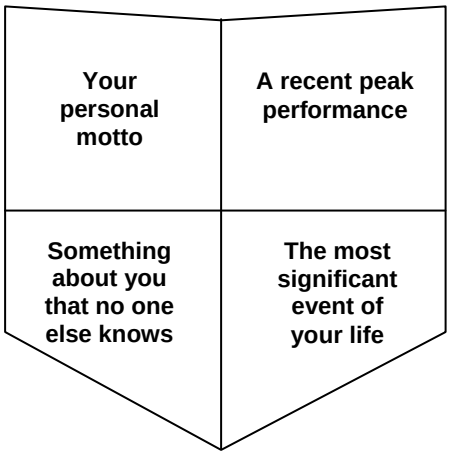

Figure 1: The "Coat of Arms" and Prompts used during the Team Icebreaker Activity

During the second half of the team building exercise, the students develop team identities. The teams are tasked with selecting a team name, preparing a team logo, and choosing a team motto. The course instructors provide the teams with pencils, colored marking pens, and poster board so that they can prepare their logos. The teams take approximately 90 minutes to complete this task.

For the final 30 minutes of this lesson, the students present their team names, logos, and mottos to the class during short one- to two-minute presentations. The team captain, who is selected by the team during this exercise, leads each presentation. Each team is photographed with their logo after their presentation is complete. At the very end of the lesson, the course instructors present two or three prizes to those teams judged to display the most spirit during the activity. The prizes are gift certificates to local coffee houses or restaurants (where the teams are encouraged to schedule their first meeting).

Each year, we create a PowerPoint presentation showing the group photographs, mottos, and logos for all of the design teams. We show this presentation during at the beginning of the next lesson to recognize student efforts. The presentation is always well received and serves as an icebreaker for the second lesson on communication.

Interpersonal Communication

The second lesson includes a two-hour interactive presentation that covers topics related to interpersonal

communication. The course instructors lead this presentation, covering the following topics in detail:

- Modes of interpersonal communication
- Active listening
- Non-verbal communication
- Effective meetings

The instructors rely on their past experience in developing the content for this presentation. They also incorporate important communication tips and advice emphasized in the text by Culp and Smith [4].

During this lesson, the instructors incorporate reflection exercises for the students to work on with their teammates. A typical exercise will introduce the students to an active listening case history where they analyze a conversation and comment on the listening techniques being used by the different participants. Students are strongly encouraged to utilize the tools described during the lesson throughout the two-quarter capstone design sequence, and problems are included on the course final examinations to assess student abilities.

Communication Styles and Assertiveness

The third lesson focuses on communication styles and assertiveness and is taught by an organizational coach with expertise in this area. One way to become a better communicator and team member is to understand that people have distinct, preferred, and predictable ways of communicating. Other instructors have incorporated personality assessment exercises into their capstone design courses to help improve team communication and performance[5]. We decided to use a similar method whereby the students assess their own "communication styles," which are based primarily on the degree to which the individual is assertive and outgoing.

Farley and Donaldson[6] identify four predominant communication styles with the following names: "medic" (amiable, harmony seeker), "cheerleader" (expressive, excitement seeker), "computer" (analytical, detail seeker), and "steamroller" (driver, results seeker). Each style has different strengths and blind spots, but no style is considered “better” than another. A person’s predominant style is determined by completing a short self-assessment survey. The chart in Table 2 lists the characteristics of the four possible communication styles. Table 3 summarizes the distribution of student communication styles observed during each offering of the capstone course. The results show that most of our students demonstrate a preferred communication style corresponding to that of a "computer." Overall, the results are remarkably similar for the four years we implemented this exercise in the course.

Table 2: Characteristics of Farley and Donaldson’s Four Communication Styles

High Responsiveness / Very Outgoing

Low Assertiveness / Less Forceful

MEDIC (AMIABLE)	CHEERLEADER (EXPRESSIVE)
Slow at taking action and making decisions	Spontaneous actions + decisions
Likes close, personal relationships	Likes involvement
Dislikes interpersonal conflict	Dislikes being alone
Supports and "actively" listens to others	Exaggerates and generalizes
Works to develop self-direction	Jumps from one activity to another
Works slowly and cohesively with others	Works quickly and excitingly with others
Seeks security and belongingness	Seeks esteem and belongingness
Easily gains support from others	Tends to dream and inspire others
Good counseling skills	Good persuasive skills
COMPUTER (ANALYTICAL)	**STEAMROLLER (DRIVER)**
Thorough actions + decisions	Firm actions + decisions
Likes organization + structure	Likes control
Dislikes over-involvement with others	Dislikes inaction
Asks many questions and wants specific details	Low tolerance for feelings, attitudes, or advice
Prefers objective, task-oriented activities	Prefers maximum freedom
Likes an intellectual work environment	Strong manager of self and others
Wants to be right	Cool and independent
Relies on data collection	Competitive with others
Works slowly, precisely alone	Works quickly and impressively alone
Seeks security and self-actualization	Seeks esteem and self-actualization
Good problem-solving skills	Good administrative skills

High Assertiveness / Very Forceful

Low Responsiveness / Not Very Outgoing

Table 3: Distribution of Communication Style

Year	Percentage of Enrolled Students			
	Cheer.	Medic	Comp.	Steam.
2006	11%	20%	58%	11%
2007	12%	17%	54%	17%
2008	10%	17%	56%	17%
2009	13%	22%	56%	9%
All	12%	19%	56%	13%

Prior to the third lesson, students complete the communication style survey. During the lesson, the organizational coach discusses assertiveness and the characteristics of the four different communication styles. The students then examine and discuss case histories. In-class activities allow the students to work together to better understand that people have predictable and preferred patterns of behaving and

communicating. The students are given tips and practice exercises on how to communicate with persons having communication styles that are different from their own.

Team Performance

Direct and indirect measures of student learning are taken on a regular basis as part of our program's continuous improvement efforts. The capstone course incorporates many opportunities for assessing student learning at a critical point (just prior to graduation) using a consistent methodology. Indeed, the data collected in the new course during the past four years have contributed significantly to the program's self-evaluation process. In the course, analysis and design assignments, reflection exercises, written project reports, oral project presentations, exam problems, and student/evaluator surveys are used to assess student learning relative to more than forty program-specific outcomes and performance metrics. Scoring rubrics and multiple reviewers are used to assess student work whenever possible.

For example, a twelve-person interview panel consisting of eight practitioners and four faculty members is responsible for assessing student projects and presentations at the end of each term. Using well-defined scoring rubrics, the panel members grade team performance for categories related to design approach, design calculations, design drawings, presentation effectiveness, and response to panel questions, among others. These panel members also complete a survey at the end of the second term of the course where they rate overall student performance for twenty-five different program outcomes, including those related to team performance. Their assessments are based directly upon their observations in working with the students and scoring their reports and presentations. Summarized in Table 4 are results for the survey question most closely linked to team performance. We consider these scores high, in comparison to other categories, indicating excellent team performance by our students. All scores exceed the established metric goal of 70 percent.

Table 4: Assessment of Team Performance by Practitioner/Faculty Interview Panel Members

Year	Percentage Acceptable Performance: "Rate the ability of the students to work as a team to complete the design project."
2007	86%
2008	73%
2009	100%

At the end of each term, the students prepare peer evaluations for their teammates following the approach proposed by Martinazzi[7]. The evaluation survey includes questions related to respect shown for teammates, attendance at meetings, preparation for meetings, communication effectiveness, and acceptance of assigned tasks. A student's peer evaluation score can fall between 0 and 100 percent. The score, as a decimal, is used as a direct multiplier on the term project score when assessing a student's grade for the term. Collective scores for the past four years are summarized in Table 5. These scores are overwhelming positive. It is noted that we review peer scores and short reflection essays on team performance prepared by the students after the first term of the capstone course. For teams struggling with communication and teamwork, we provide extra counseling to get them back on track prior to the second term of the course.

Table 5: Distribution of Peer Evaluation Scores for 2006-2009

Peer Evaluation Scores				
(90-100%)	(80-90%)	(70-80%)	(60-70%)	(< 60%)
86%	10%	2%	1%	1%

We also evaluate team performance and the achievement of communication-related outcomes using exam questions, reflection exercises, and student self-assessment surveys. Length restrictions for this paper prohibit us from discussing these additional assessment results in detail. However, results indicate that we are meeting (and exceeding) our performance goals for all team-related outcomes and metrics.

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