Developing Teamwork Competencies in a Design Course – Self-Perceptions of Students

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CONTEXT

In this paper we share the salient features and outcomes of a study aimed at examining the development of self-reported teamwork competencies in a senior design course that embodies an immersive design experience. Presented in the paper are a description of the subject course, an outline of the survey used and a summary of some of the survey findings: specifically those that deal with teamwork. Through better understanding and calibrating student perspectives, it follows that course design can be modified to better achieve course goals – which is a growth in relevant competencies.

PURPOSE

The hypothesis is that students self-realize improvement in their teamwork as they engage in an immersive design experience. To examine the hypothesis two questions are asked:

- How do students perceive attributes of teamwork while executing a design project?
- How do these perceptions change through the process?

APPROACH

A structured approach using surveys was implemented to track progressively the change in student self-perceptions of teamwork during a semester long immersive design activity. The subject course sits in the senior year of a mechanical engineering undergraduate degree and has its focus on learning the principles of design in the context of a "Warman like" project, which is a precursor to undertaking an industry sponsored capstone project.

OUTCOMES

The results presented represent the initial findings of a work in progress aimed at documenting student perceptions of their developing competencies. This activity ties to some parallel work examining student motivation and performance.

How do students perceive attributes of teamwork while executing a design project?
We believe that self-evaluation facilitates the development of competencies related to teamwork. Having students undertake a design, build and test a mechanism under competitive conditions provides a framework for students to experience, recalibrate and reapply teamwork competencies.

How do these perceptions change through the process?
The change in perception depends on the composition of the team and individual characteristics of students in the team. The drops and increases in student's perception are necessary elements of competency development.

SUMMARY

In this paper we focused on student perception of development of their own team-based competencies. We wanted to observe how the teaming competencies are developed in students when they work in courses with design problems. We used time-based tracking of student perceptions. The fact that some teams and individuals did not work well together or recognized they could have done some things better does not negate the development of competencies, rather it is natural and normal for learning to take place through failure and mistakes.

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Motivation

Corporations and employers have frequently pointed to a lack of professional awareness and low levels of communication and teamwork skills in engineering graduates (Bradford School of Technical Management 1984, Sparkes 1990, McLaughlin 1992, Evers, Rush et al. 2005). These issues have led the U.S. Accreditation Board for Engineering and Technology (Engineering Accreditation Commission 2007) to transform their accreditation criteria from a content-based approach to an outcomes-based approach. ABET now proposes to hold engineering schools accountable for the knowledge, skills, and professional values engineering students acquire (or fail to acquire) in the course of their education. Globalization and rapid change in technology has led to changes of expected competencies of engineers. One of these main changes is the need for competencies related to innovation and problem-solving, which are marks of domain expertise in applied fields (Feltovich, Prietula et al. 2006). One of the competencies for innovation and the engineering profession is the ability to effectively work in a team environment.

In order to improve engineering education the mode of instruction needs to be modified to play a significant role in empowering students to learn the complex engineering concepts in a useful format and work. Instruction modes need to allow students to grow as critical thinkers with proficiency in learning, and in problem solving for increasingly complex and uncertain engineering environments. Several learning approaches, such as project-, problem-, or case studies-based learning, have been developed and applied in engineering courses. These approaches allow students to learn through inquiry and scaffolded reflection, in many instances with peers. According to Bransford and co-authors, students learn best when presented with organized information that relates it in some way to their own experiences, and when they are given the opportunity to test themselves on their own understanding and when working on developing their understanding with other students, (Bransford, Brown et al. 1999). Thus, they emphasize the value of scaffolded authentic experiences in a group setting.

Subsequently, in the context of the subject course, two questions being addressed are:

- How do students perceive attributes of teamwork while executing a design project? and
- How do these perceptions change through the process?

Ill-structured problems significantly differ from well-defined text book problems, and require critical thinking and problem solving experience. In most instances, applying engineering principles to solve such ill-structured word problems is a very challenging task for students, moving them outside their comfort zone. Students struggle to frame the ill-structured word problem so that they are able to use what they have learnt previously through solving structured problems in engineering analysis courses. Yet this experience is authentic in its reflection of engineering practice. Students need to develop competence to use analytical skills in formulating, solving and interpreting results in a team-based environment. The importance of this in design courses is that in contrast much of engineering education continues in a “teacher-centred” mode that emphasizes content mastery and supports reliance on standard book problems solved in well-defined step-by-step processes. Common traditional teaching approaches fail to empower and nurture the development of skills, including team-work, needed by today’s engineers.

Frame of Reference

There are two levels of competencies in any professional field, field-specific task competencies, and generalized skill sets, or meta-competencies. The task-specific competencies are benchmarks for graduates in a given field, that define them as well-prepared to meet job demands and excel in the future (Earnest and Hills 2005, Allan and Chisholm 2008). The general (meta) competencies are skill sets that enable them to function globally, such as to work with others, function in systems and meet organizational demands, and transfer task-specific skills to novel problems or tasks they have not encountered before

(Wulf and Fisher 2002, Radcliffe 2005). Competencies are assumed to be identifiable, assessable, and relevant for practice (Caird 1992, Prahalad and Hamel 1997). The development of competencies to support engineering, in general, and innovation, in particular, is spiral in nature, with students building on some and adding new ones as they progress through a curriculum. Innovations in the future will increasingly come from teams of collaborators who can bring together multiple skills and perspectives. A systematic approach is required to ensure that the competencies are developed at a higher level of cognition.

Team based projects in design courses are extensively utilized to develop different aspects of team competencies. Development of these competencies, over time, as students go through different tasks of the design process is needed to better understand the effects of team based projects. In this paper we look at students' perception related to development of these competencies in a design course that presents an authentic, immersive learning experience.

A Study – Principles of Design (AME 4163)

Principles of Design (AME 4163), is a Senior Level Mechanical Engineering design course at the University of Oklahoma. In this course through appropriate scaffolding, students are provided with an opportunity to explore and experience issues and tools related to design in an authentic and immersive environment. Students are guided through authentic and immersive conceive-design-build-test-and-reflect experience, with an emphasis on the development of digital prototypes and using them for analysis. In AME 4163, a design process that combines steps from several general prescriptive models for designing is introduced to the students (as outlined in Figure 1).

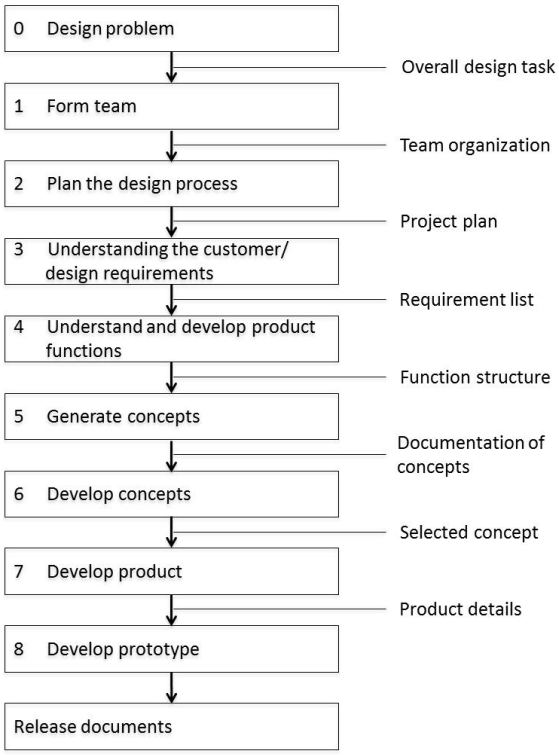


Figure 1: AME 4163 Design Process

One student learning objective is to gain a better understanding of and confidence in the execution of the design process itself. Another addresses learning, by encouraging students to observe and reflect upon their own journey thereby taking charge of their own

development by embracing life-long learning. It follows that of specific interest to the academics involved are the following:

- facilitating the development of competencies and meta competencies in the course through course design,
- understanding how students achieve the course learning objectives, and
- measuring how successful students were in achieving the course learning objectives while immersed in an authentic learning experience.

Lectures and assignments in the course are related to empowering students to learn through their experience. The students self-form groups, typically of 4 students, and work on a two-third semester-long design and build task. The task is the same for all groups in a given semester and is assigned at the beginning of the semester through a published scenario and set of rules. It is expected that at the end of the semester the students will have developed a range of competencies and will:

1. Understand the design process.
2. Be able to plan and execute a successful design process.
3. Be able to formulate and apply a systematic approach to solve design problems.
4. Be able to generate, evaluate and develop design concepts by applying knowledge of facts, science, engineering science, and manufacturing principles.
5. Be able to generate solid models and engineering drawings using 3D modeling software.
6. Be able to use analysis and simulation tools to understand design performance and then improve the design.
7. Be able to manufacture a design prototype.
8. Be able to make an oral presentation and demonstrate their design project.
9. Be able to work effectively on a team to complete a design project.

An overview of topics covered and when the surveys were administered in the course is provided in Table 1.

Table 1 - AME 4163 Syllabus and Survey Schedule

Week	Major Lecture Topics	Assessment Items Due / Surveys Conducted
1	Introduction and forming teams Basic team organization Steps in the design processes Meta design, Designing and scheduling	
2	Building and testing bridges Machine shop tour Safety instructions	SA: Team form SA: Setting goals and evaluating your competencies SA: Understanding the design process –bridge
3	Understanding customer needs, House of Quality (HoQ), List of requirements	Assignment 1A: Problem Definition and Planning **Survey 1A**
3	Function structure Generation of concepts	
4	Concept evaluation	Assignment 1B: Customer Needs **Survey 1B**
5-6	CAD modeling and simulation Basic animation with SolidWorks Motion FEA –introduction and brief overview (structural and heat transfer)	Assignment 2A: Function Structure and Concepts **Survey 2A** Assignment 2B: Concept Evaluation **Survey 2B**
7-8	CFD – introduction and brief overview	Assignment 3A: CAD Modeling and Analysis Assignment 3B: Simulation Based Design – FEA and CFD Analysis of Concepts
9	Build prototype Design for assembly and life-cycle	
10-11	Ethics Build prototype	Assignment 4: Detail Design **Survey 3&4**
11	Project demonstration	
12	Project presentations	
13-15	Capstone project - introduction	Final report and Learning essay SA: Professional and ethical responsibilities

SA: Short Assignments

Method and Instrument

To assess student perceptions, ethics approval from the institutional review board (IRB) was obtained to conduct student surveys in AME 4163. The data was collected using an online "quiz" mechanism within the "Desire2Learn" environment; the University's learning management system.

A total of 46 different questions were asked across 5 surveys (coded as 1A, 1B, 2A, 2B and 3&4 in line with the assignment schedule). The questions were focused on competency development which includes teamwork. From survey to survey, students were not provided feedback on how they had previously responded to the questions asked and it was hoped that they would answer in accordance with their current perceptions independently of prior assessments. The administration sequence of the surveys is shown in Table 1. Each survey response window closed following the submission of a significant piece of assessment as students progressed through the design process. The questions asked were tailored to address the experiences to that point in the course and some questions were asked in multiple surveys.

Of the 46 questions asked, 12 on teamwork are the prime focus in this paper, namely, questions numbered 25-36. Questions 25-30 were asked in Survey 1A and all 12 were asked in the subsequent four surveys. The students were asked "at this stage of the project and from your perspective, how well did the team work together on …:

25. understanding the requirements,
26. meeting together,
27. listening to everyone's ideas,
28. decision making,
29. written communication,
30. design documentation,
31. how to work in a group,
32. how to carry out a project,
33. importance of organization,
34. skills in organization,
35. skills in problem solving, and
36. estimating time to complete a project."

These questions were structured to explore different aspects of competencies related to team work in design projects. A seven point scale was used:

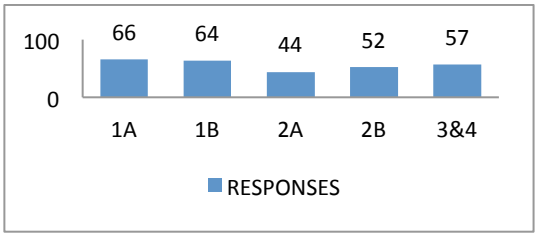
1. Very Poor.
2. Moderately Poor.
3. Mildly Poor.
4. Neither Poor nor Well.
5. Somewhat Well.
6. Mostly Well.
7. Very Well.

The class of 2013 comprised 76 students. As shown in Figure 2(a), of the 76 the most number of students, 66, responded to Survey 1A, while the least number of respondents was 44 for Survey 2A. A tally of the number of responses made by an individual student is presented in Figure 2(b). Across the five surveys, 24 of 76 responded to all five surveys and only two students failed to respond to at least one survey.

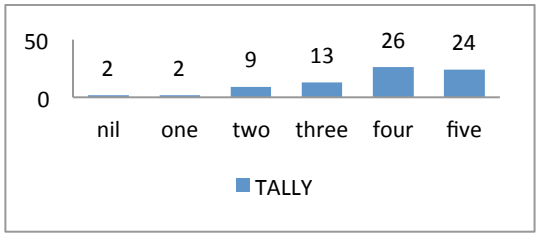
In Survey 1A (global Question 41), students were asked about how they formed their project teams. Possible responses and the number off and the percentage of the class responding in this way were:

1. I teamed with strangers (responses 11/66, 16.7%),
2. I teamed with people who lived near me (responses 0/66, 0%),
3. I teamed with my friends/study partners (responses 43/66, 65.2%),
4. I teamed with people who had similar time availability (responses 2/66, 3.0 %),
5. I teamed with people who had similar aspiration for class (responses 8/66, 12.1%), and
6. Other (responses 2/64, 3.0%).

It is interesting to note, but it is not surprising, that two-thirds of the class when given the chance to work with friends/study partners did so. On the other side of this circumstance, one-sixth of the class explicitly indicated they worked with "strangers".

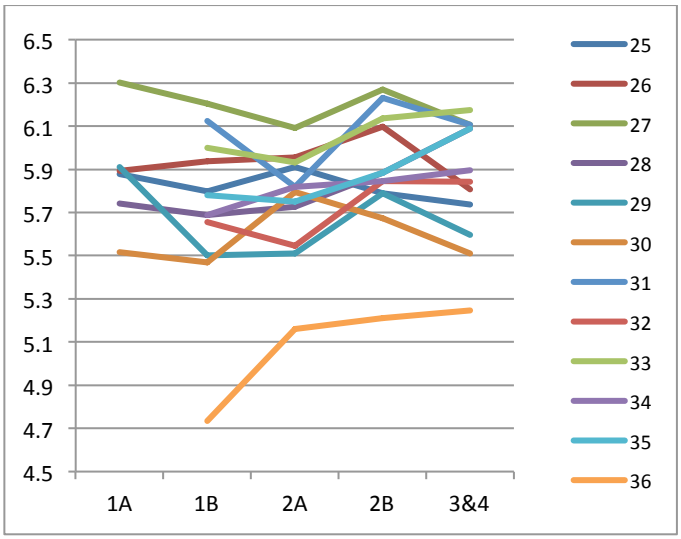


(a) Responses to each survey



(b) Tally of surveys completed by individuals

Figure 2 – Survey Statistics



KEY: at this stage of the project and from your perspective, how well did the team work together on:

25. understanding the requirements
26. meeting together
27. listening to everyone's ideas
28. decision making
29. written communication
30. design documentation
31. how to work in a group
32. how to carry out a project
33. importance of organization
34. skills in organization
35. skills in problem solving
36. estimating time to complete a project

Figure 3 – Mean Responses to Questions from survey to survey

Discussion of Results – Whole Class

For the 12 questions (number 25-36) asked, the mean responses for each question in each survey are shown in Figure 3. Some fluctuations are evident in the mean values recorded across the five surveys. We believe, these changes are due to students readjusting and calibrating their self-perceptions as new challenges, related to working in teams arise and are addressed. These changes are crucial for development of competencies through authentic experiences.

Considering only the first and last time a question was asked, these mean response values are presented in Figure 4. A companion table to Figure 4 is Table 2. In Table 2, the questions have been ordered based on the differences in mean response from the first time the question was asked to the last time it was asked. Written communication shows the greatest negative difference while estimating time to complete a project is the greatest positive. Overall, four of the questions (written communication, listening to everyone's ideas, understanding the requirements and meeting together) show a decrease in mean value, two are very flat (slightly negative – how to work in a group and design documentation) while the remaining six exhibit an increase.

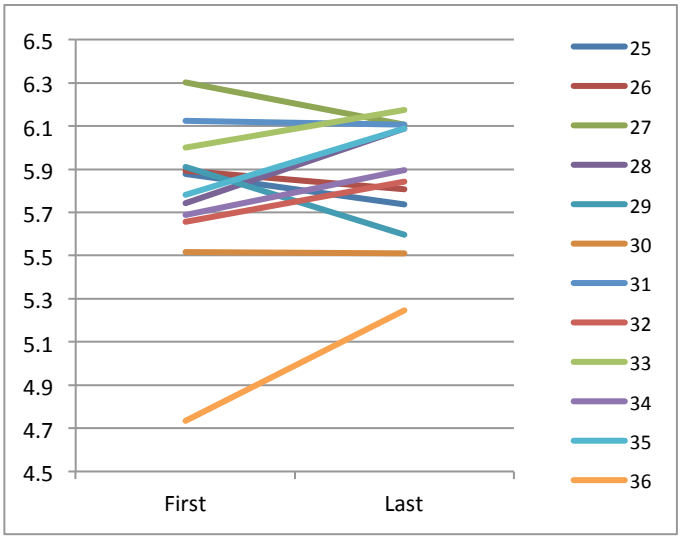


Figure 4 – Mean Responses to Questions from first to last time asked

Table 2 – Questions ordered based on differences in mean responses from to last time asked

Q#	1st	Last	Diff	Issue
29	5.9	5.6	-0.313	Written communication
27	6.3	6.1	-0.198	Listening to everyone's ideas
25	5.9	5.7	-0.142	Understanding the requirements
26	5.9	5.8	-0.087	Meeting together
31	6.1	6.1	-0.020	How to work in a group
30	5.5	5.5	-0.006	Design documentation
33	6.0	6.2	0.175	Importance of organization
32	5.7	5.8	0.186	How to carry out a project
34	5.7	5.9	0.207	Skills in organization
35	5.8	6.1	0.306	Skills in problem solving
28	5.7	6.1	0.345	Decision making
36	4.7	5.2	0.511	Estimating time to complete a project

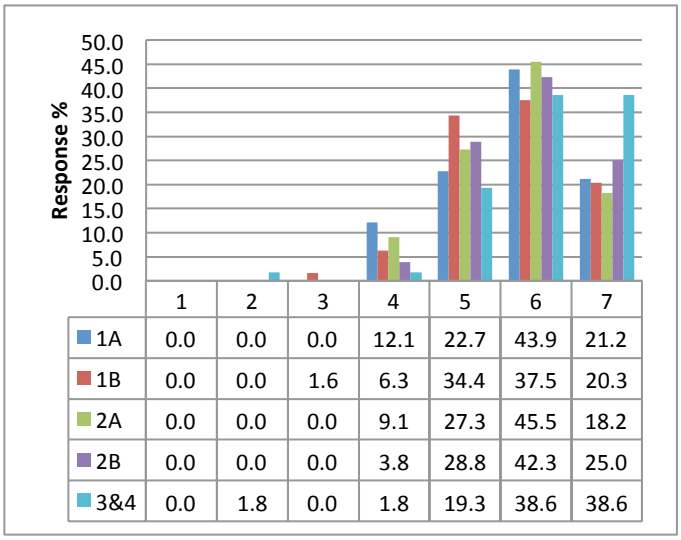
The distribution of responses to Questions 28 and 36 are shown respectively in Figures 5 and 6. Noting that answers to these questions exhibit the greatest increase in mean value, by examination it can be seen that the mean of each survey distribution is shifting to the right by visualizing and comparing the curve associated with each survey. In these cases the shift in mean indicates that students in the class have perceived they are improving these aspects of team competencies as they progress through the semester and engage with the authentic experiential activities. But are these perception differences statistically significant? Statistical significance is the probability that a difference in data samples is not due to random variation.

While the 7 point scale has been used some of the data sets are naturally skewed (having asymmetry in the distribution of responses). However, all data sets associated with Questions 32, 34, 35 and 36 satisfy the normally distributed criterion based on a skew test.

Assuming for a given question the samples for the “first” and “last” are normally distributed, the confidence interval for claiming that the course experience had a “significant” influence in “treating” the students can be tested using a t-test. It follows that the results of

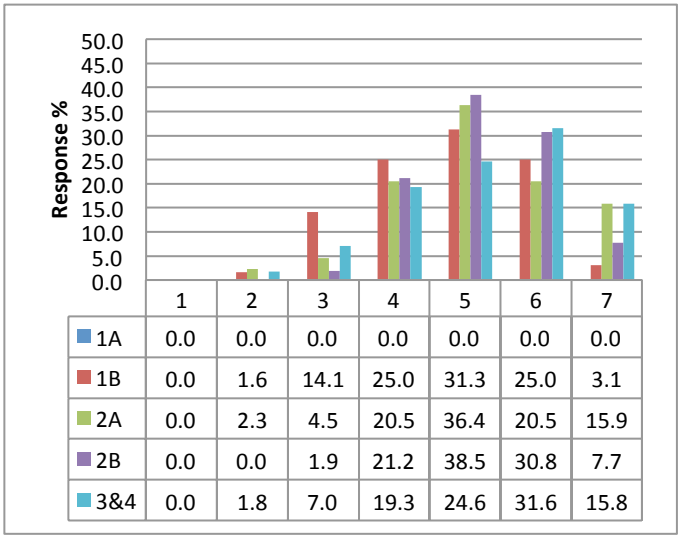
questions 35 and 36 are significant (<0.05) with one-tailed t-test values of 0.039 and 0.015 respectively. A much weaker case can be made for questions 32 and 34 with one-tailed t-test values of 0.132 and 0.153.

In the context of the preceding, in the next section, the response of individual teams is analysed.



	1	2	3	4	5	6	7
1A	0.0	0.0	0.0	12.1	22.7	43.9	21.2
1B	0.0	0.0	1.6	6.3	34.4	37.5	20.3
2A	0.0	0.0	0.0	9.1	27.3	45.5	18.2
2B	0.0	0.0	0.0	3.8	28.8	42.3	25.0
3&4	0.0	1.8	0.0	1.8	19.3	38.6	38.6

Figure 5 – Distribution of responses to Question 28
How well did the team work together on decision making?



	1	2	3	4	5	6	7
1A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1B	0.0	1.6	14.1	25.0	31.3	25.0	3.1
2A	0.0	2.3	4.5	20.5	36.4	20.5	15.9
2B	0.0	0.0	1.9	21.2	38.5	30.8	7.7
3&4	0.0	1.8	7.0	19.3	24.6	31.6	15.8

Figure 6 – Distribution of responses to Question 36
How well did the team work together on estimating time to complete a project?

Discussion of Team Results

Leading on from the discussion of the composite results for the class, four teams have been examined in more detail. As discussed in relation to Figure 2, 24 students completed all five surveys and a significant number of these students were members of four teams, coded for this research as Group 7, 15, 17 and 18. These students covered the spectrum of academic performance in the subject class and some characteristics of the teams are

presented in Table 3. Collectively, Group 7 and Group 15 each completed 19 of 20 possible surveys. Groups 17 and 18 each completed collectively 18 surveys. Group 18 contained three “A” students and one “B” student. The overall course grades for the members in the groups are shown in the Table header.

The data shown in Table 3 represents the differences in mean responses from the first time a question was asked to the last by group members. Cells where the differences are greater than 0.25 are shown in green and those less than -0.25 are shown in red. While there are exceptions, observations include a general positive trend in the differences but differing trends in the experiences of individual teams in relation to teamwork issues. For questions 25, 30, 32, 35 and 36, there are no red flags. While seven questions have attracted red flags, only two questions have more, two for listening and two for written communication.

The greatest positive average difference of 0.56 for these four teams is connected with Question 25, “understanding the requirements” and the results are plotted in Figure 7. Similarly, the differences in relation to question 29, a strong negative case, are shown in Figure 8. Interestingly Groups 15 and 17 show no degradation in perception level for Question 29, “written communication” while the other two teams are strongly negative. Plots for Questions 31 and 36 are also depicted in Figures 9 and 10. In comparing these they represent the highest and lowest average response, 6.47 for question 31 “how to work in a group” and 5.04 for question 36, “estimating time to complete a project”. The high response value indicates the teams are more confident in this aspect and the lower value that more work could be done in assisting students improve, in this case their ability to estimate the time taken to complete a project.

Similar to Figure 4, provided in Figures 11 to 14 are plots of the mean responses for each of the groups. Shown as a representative case in Figure 11 are plots of both the survey to survey and first to last views. Given the sample size is a maximum of four, the randomness in mean value is not unexpected. Each group’s plots are quite different and there would naturally be an interesting story attached to each as the individual and the collective group experienced their learning journeys. To promote student reflection and learning, one useful extension of the research would be to provide the data back to the students and ask them to provide a qualitative explanatory interpretation. Such an extension would require IRB approval.

Table 3 – Group Based differences in mean responses from first time question asked to last time question asked

	Group member’s course grades	BBBC	ABBB	AABD	AAAB	
	Surveys completed by group members	19 (44344)	19 (44344)	18 (44433)	18 (44244)	
Q #	**Issue**	**Group 7**	**Group 15**	**Group 17**	**Group 18**	**Average**
25	Understanding the requirements	1.00	0.75	0.50	0.00	0.56
26	Meeting together	0.25	-0.75	1.00	0.25	0.19
27	Listening to everyone's ideas	0.50	-0.50	-1.50	0.25	-0.31
28	Decision making	1.50	0.00	-0.50	0.00	0.25
29	Written communication	-0.50	0.00	0.00	-0.75	-0.31
30	Design documentation	-0.25	-0.25	0.25	0.50	0.06
31	How to work in a group	0.00	-0.25	-0.75	0.25	-0.19
32	How to carry out a project	0.50	0.75	0.00	0.00	0.31
33	Importance of organization	-0.50	0.00	-0.08	0.25	-0.08
34	Skills in organization	0.75	0.25	0.17	-0.75	0.10
35	Skills in problem solving	0.50	0.50	0.00	0.25	0.31
36	Estimating time to complete a project	1.25	-0.25	0.58	0.25	0.46

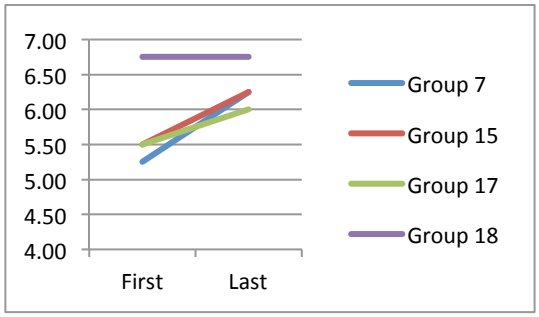


Figure 7 – Mean Responses to Question 25 for Groups
How well did the team work together on understanding the requirements?

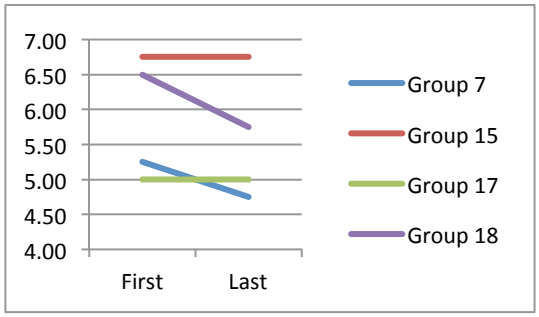


Figure 8 – Mean Responses to Question 29 for Groups
How well did the team work together on written communication?

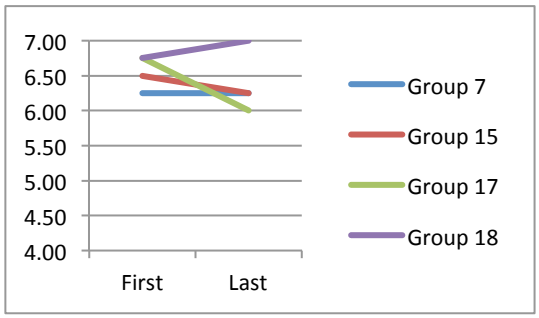


Figure 9 – Mean Responses to Question 31 for Groups
How well did the team work together on how to work in a group?

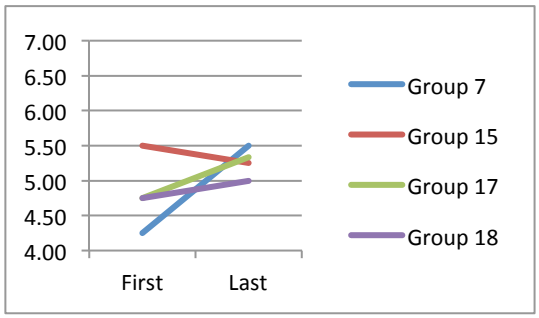


Figure 10 – Mean Responses to Question 36 for Groups
How well did the team work together on estimating time to complete a project?

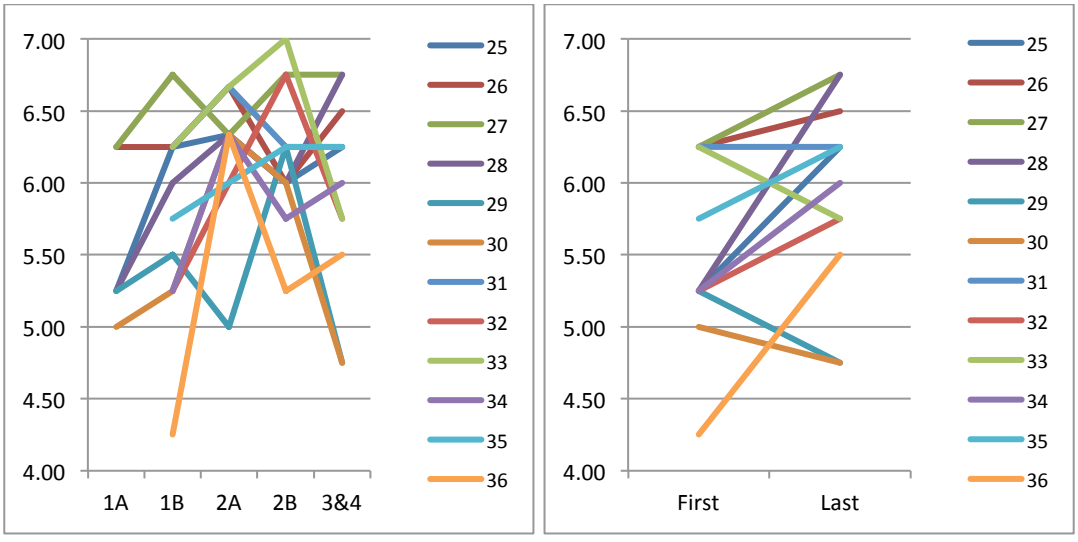


Figure 11 – Mean Responses for Group 7
(two views shown, "Survey to Survey" and "First and Last")

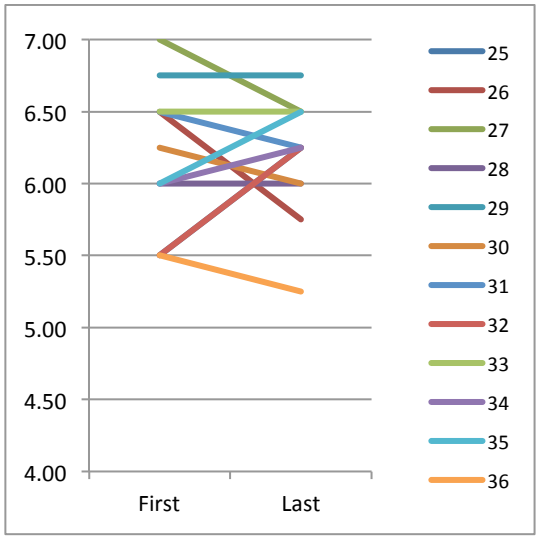


Figure 12 – Mean Responses for Group 15

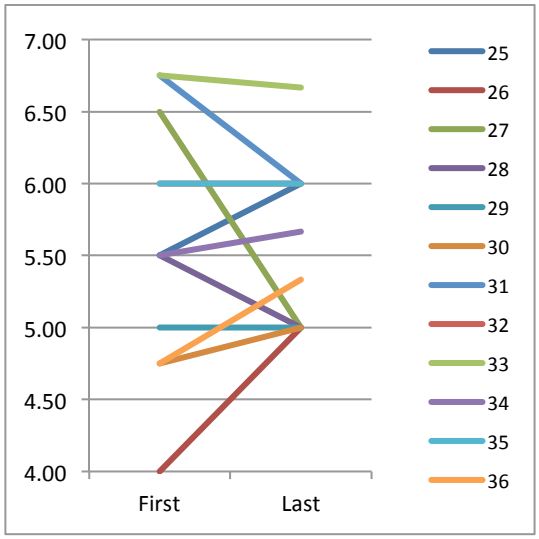


Figure 13 – Mean Responses for Group 17

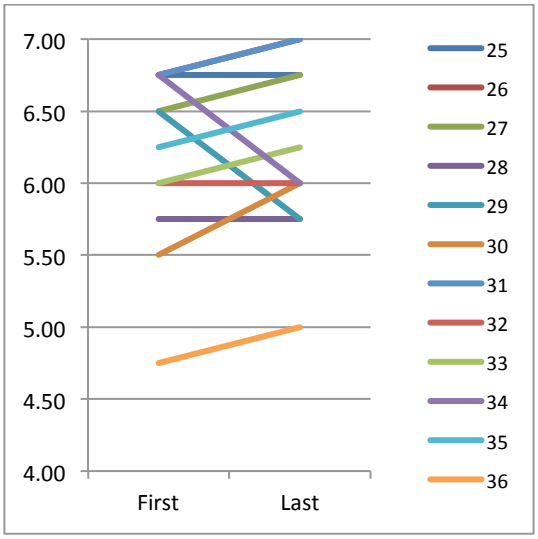


Figure 14 – Mean Responses for Group 18

The most diverse team based on achieved grade, with two "A" students, a "B" and a "D", student was Group 17. As an example group, how have the individuals in Group 17 viewed their teamwork? Their responses to their first and last surveys are shown in histogram form in Figures 15-18.

Student "A1" was reasonably consistent in response as shown in Figure 15. The modal response is 6 and the range is 5 to 7. However, note that the "last" survey completed by this student was 2B and much of the teamwork in designing, building and testing the prototype was yet to be done.

In contrast, Student "A2", as shown in Figure 16, had a greater initial range of responses (2-7) but a much tighter and higher concluding set (1x5, 7x6 and 4x7).

By the end of the semester, Student "B" identified that the team was performing very well in all areas responding with straight 7's in the last survey (see Figure 17). Perhaps this is a view through rose colored glasses in comparison to teammates.

Interestingly, Student "D" in the team had a very different view as shown in Figure 18. While student "D" had an initial perception not too dissimilar from teammates, by the end of

the semester Student “D” identified that in four areas the team worked moderately poorly (26, 27, 28 and 30). For no question did Student “D” identify that an aspect of teamwork had improved over the semester. Was this view a function of personal performance?

A comparative view of the team members’ first responses is provided in Figure 19 and of their last responses in Figure 20.What the students in this team think is quite different.

Was there more apparent concensus within the other teams that were from a grade perspective, more homogenous? Group 18 had three “A” students and one “B”, Group 15 had one “A” and three “B” and Group 7 had three “B” and one “C”. The last responses for each of these three groups are shown in Figures 21 to 13.

Group 7 has two questions with a range variation of 3, 2 with a range of 2 and 8 with a range of 1. Group 15 has a maximum range per question of 2 with six questions only having a range of 1. Group 18 shows greater variation with three questions having a zero range in response (absolute agreement), three with a range of 1, 3 with a range of 2, 2 with a range of 3 and one a range of 4.

In the next section we present without comment exerpts related to teaming by students in the highlighted groups. These comments qualitatively align with the quantitative results presented in this section.

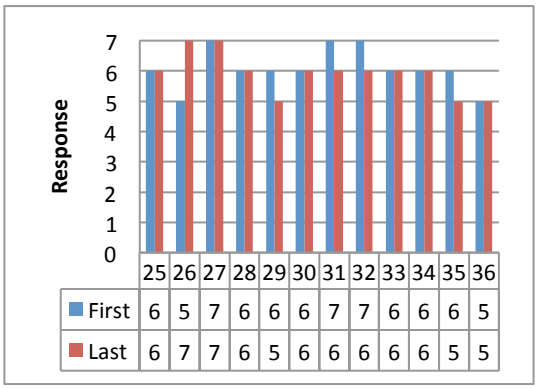


Figure 15 –Responses for student “A1” in Group 17

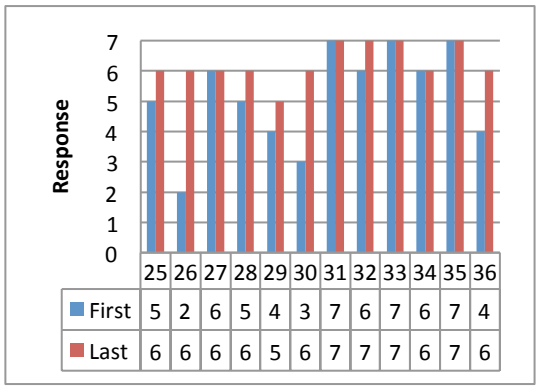


Figure 16 –Responses for student “A2” in Group 17

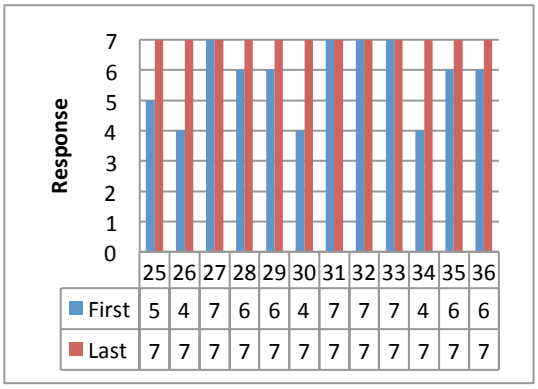


Figure 17 –Responses for student “B” in Group 17

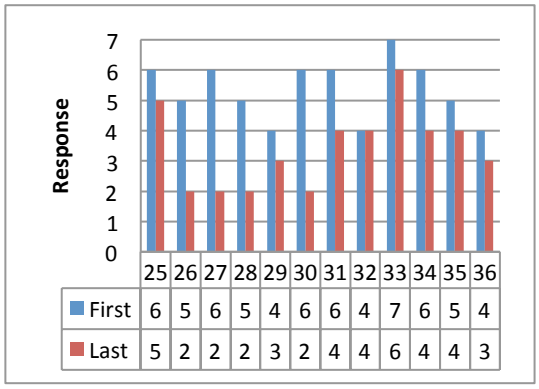


Figure 18 –Responses for student “D” in Group 17

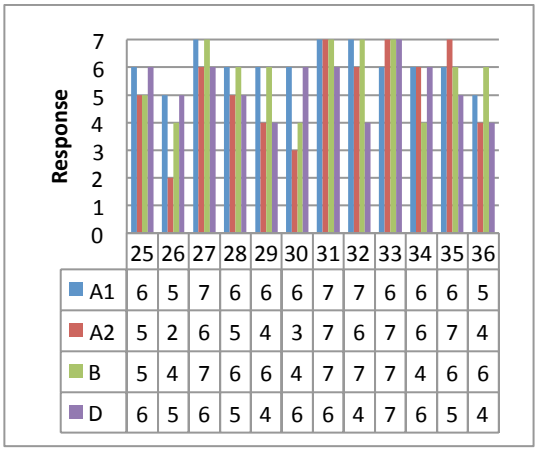


Figure 19 –First responses for students in Group 17

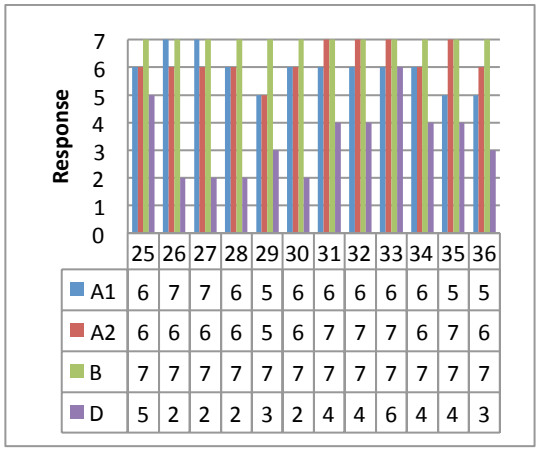


Figure 20 – Last responses for students in Group 17

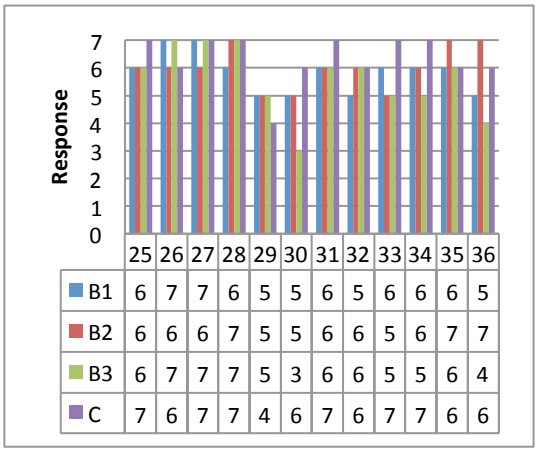


Figure 21 – Last responses for students in Group 7

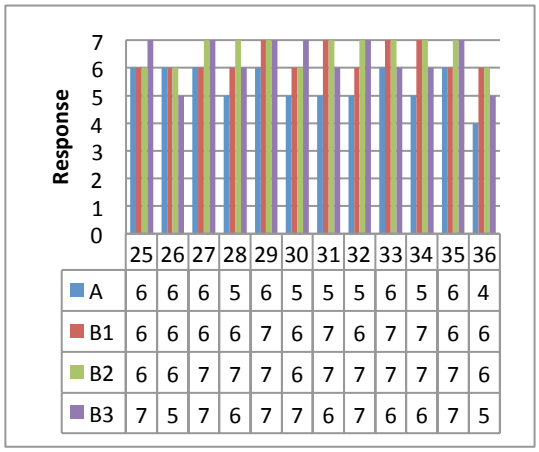


Figure 22 – Last responses for students in Group 15

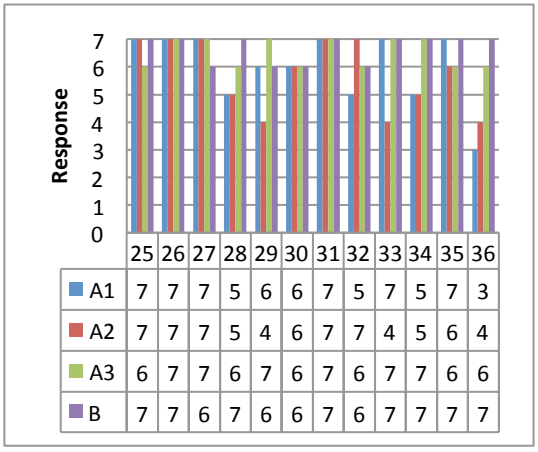


Figure 23 – Last responses for students in Group 18

Comments from Semester Learning Essays

Selected Comments from Group 7

Student "C" commented, *"Due to the team nature of this course, I learned how to work better within a team. … Through working in a team to build (the prototype), we learned how to respect each other."*

Student "B1" stated from experience, *"Team projects have always been hard to coordinate. But through the team contracts and (sharing) resumes and listing all the tasks that need to be done throughout the project, it was easy to cooperate with the other teammates. I learned that when everyone has a responsibility that they are held to, a sufficient amount of work can be accomplished and team projects can run smoothly."* This recognition of the importance of planning, coordination and commitment was powerful for many students. He went on to say *"Throughout this class I learned that my ideas may not always be the best so it is important to listen to all the ideas and thoughts of the other team members because some of their ideas may work out better than your own."*

Student "B2" wrote *"I became conscious of the usefulness of assigning responsibilities when my team started duplicating work efforts."* For this student this was a valuable lesson in communication and understanding context and taking personal responsibility. Another of his observations was *"I learned that having a team that works hard and well together, but understands each other's need for down-time, as well, makes a substantial amount of difference to team moral."*

Student "B3" articulated that *"everyone (in my team) thinks in different ways and that is a good thing. If you didn't think of something it was likely that someone else in the group thought of it."* While not explicitly stated this implies developing good communication skills is important.

Selected Comments from Group 15

Student "A" stated he *"realized the importance of constant communication and in-person meetings between team members in order to complete an assignment. (This included) that the team must set its own deadlines."* It was also important to him to have a diverse team. *"Different people understand problems differently and will come up with their own approach. Hearing others' ideas can help you better understand the problem yourself and create better solutions."* A lesson well learnt the hard way was in planning and management as *"when we encountered problems building the device, I realized that our team had not fully understood the customer requirements."*

Comments from student "B1" related strongly on commitment to and expectations of the team: *"I learned that if I don't get a grip on my personal problems they will directly affect my portion of a group assignment and indirectly affect the work of my team mates. From struggling with my portion of a group assignment I realized that I shouldn't be afraid to get help from other members of the group. I (also) learned not to assume others are willing to work on weekends just because I want to."* He also identified that he *"found (he) sometimes had to be assertive for ideas to be heard."*

The third member, "B2" wrote: *"While working with a group the entire semester, I realized how critical it is to stay in communication with each other to make sure everybody knows their assignments and stays updated with the progress of assignments and the project. I became conscious of the fact that group/team discussions can be very effective when creating ideas or advancing pre-existing ideas. I learned that even though it can be an awkward situation, it may be necessary at times to tell a group member that they are not contributing enough to the group or that they are doing too much of the work and need to relinquish some of their workload to the other members."*

A comment from student "B3" on working in a group was, *"I learned that getting to know your team members and understanding how they learn and work makes it much easier to work with one another."*

Selected Comments from Group 17

A comment from a student "A1" related to team dynamics and responsiveness, or lack of it: "*While working on our (project), I became conscious that it is vital to the team to answer phone calls and text messages. There were times where team members wouldn't respond to messages immediately, and it ended up making things for other team members much harder."* The synergy a group affords was also recognized during the design phase where *"I realized that everyone in the group has different ideas on what would be the best way to approach the problem, and listening to all ideas really helped open my eyes to ideas that in most cases were better than my own."*

A comment from "A2" relating to team morale was *"Through analyzing the relative productivity of our team meetings, I realized that team meetings were actually significantly more productive as a whole if break times for food and socialization were strategically woven into the agenda … (finding ways to) make the project fun and add valuable pride of ownership actually helped keep us motivated (as a team)."* Another thought expressed was *"the varied perspectives proved invaluable in helping us to more comprehensively consider different factors and angles of the challenge. Through my team experience I also learned the value of being decisive and making a tough decision."*

Student "B" was perhaps the most forthright, stating *"working with my team, I learned that I actually didn't have an open mind to different design ideas and I had to work on that skill."* The student also identified that they worked positively on building tolerance: *"not all team members worked on the project at the same time, (and this) led to minor team disorder. From being angry at one person for criticizing the rest of us when he didn't even show up (and contribute), I learned that I should just ignore people when they complain or say things that don't matter."*

Reflections from student "D" were that he *"further developed an ability to handle the stress of a team and (its) schedule."* He also spoke of the need to manage team morale and of developing a greater understanding of team dynamics. *"It was important that everyone have a job to do so that nobody felt useless in (the workshop) environment. People can feel marginalized by a situation like that, and it is again important for morale to keep the team cohesive."*

Selected Comments from Group 18

Student "A1" *"discovered the importance of a thorough team contract."* He further stated *"it is important to get along. Do what is expected of you and avoid irritating group members – (if you can) find people to work with that have the same values and work ethic."*

Student "A2" observed during the bridge building assignment *"that time constraints greatly change the way people should work - because our group planned for too long resulting in too short a time for construction and a rushed product."* This student also commented that they *"learned the importance of communicating often with all group members. When properly communicating within a group the work will be completed more quickly and with better quality."*

Student "A3", while repeating some of the other themes such as the importance of communication, claimed they had *"learned the importance of having an effective team organization and collectively prioritizing the steps needed to successfully complete a task."*

Student "B" reflected that *"From working with my team in the design phase I learned that being open minded is a huge benefit because it engages insightfulness and creativity."* They also commented on handling a chaotic situation such as a failure in testing. *"When*

something goes wrong in a project it is very important not to deal with the situation alone, but to rely on your team to get the problem solved."

Concluding Remarks

In this paper we focused on student perception of development of their own team-based competencies. We wanted to observe how the team-based competencies are developed in students when they work in courses with design problems. The fact that some teams and individuals did not work well together or recognized they could have done some things better does not negate the development of competencies, rather it is natural and normal for learning to take place through failure and mistakes.

The results presented represent the initial findings of a work in progress aimed at documenting student perceptions of their developing competencies, and in this case, teamwork. This activity ties to some parallel work examining student motivation and performance (Smith, Siddique et al. 2014). The answers to two questions were sought, namely:

- How do students perceive attributes of teamwork while executing a design project?
- How do these perceptions change through the process?

How do students perceive attributes of teamwork while executing a design project?

We believe that self-evaluation facilitates the development process of competencies related to team-work. Using design projects in courses, with specific steps provides a framework to experience, recalibrate and reapply team-work competencies.

How do these perceptions change through the process?

The change in perception depends on the composition of the team and individual characteristics of students in the team. The drops and increases in student's perception are necessary elements of competency development.

Opportunities for further work include mining the data already collected for further insights, particularly through correlation with assessment and demonstration of true competence. A lot more can be gleaned from all the questions asked but that goes beyond the scope of this conference paper. Repeating the study with the following cohort of students to further validate and confirm would also be a natural extension to the work.

To conclude, the lessons learned by the authors in conducting the subject class can be generalized with a view to improving aspects of the engineering education we deliver. With appropriate scaffolding, ill structured (design, build and test) problems are highly recommended to provide an opportunity for students to internalize design principles. They provide valuable authentic, immersive experiences and our students are regularly reminded of this. Such activities can be utilized by students to explore and learn the principles of design and teamwork generally, going beyond the specific task at hand. They are useful to teach lessons about such things as design solution fixation and the need to think broadly and holistically. Teams do latch onto specific solutions and through the process, perhaps learn the hard way, that they should have discarded it and started again. Others lose sight of key issues or criteria when building a prototype. Classic examples include failing to consider the effects of friction or the influence of the centre of gravity on stability. Overall, our learning and teaching philosophy is that engineering design involves complex technical and problem solving skills that are best acquired through activities that involve students in authentic, immersive and team based engineering tasks and environments, such as the one described in this paper.

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