121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014

Paper ID #10128

# Improving learning productivity and teamwork skills in freshman engineering students through conative understanding

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## Improving learning productivity and teamwork skills in freshman engineering students through conative understanding

**Abstract**

The Accreditation Board for Engineering and Technology (ABET) requires that Universities teach engineering students to function productively as part of a multidisciplinary team. However, reliable strategies for *teaching* teamwork are notably absent from the engineering education literature. Existing approaches emphasize cognitive complementarity ensuring representation of appropriate knowledge experts and overcoming affective obstacles such as personality conflicts and problems in interpersonal communication. Comparatively less research has examined *conative* approaches, in which students explore the relation between knowledge of instinctive behavioral strengths and team productivity. This study reports the experiences of an instructional team at Arizona State University that introduced a new module on conation in a mandatory freshman engineering education course, FSE 100 Introduction to Engineering. All students completed an on-line assessment of their instinctive behavioral strengths called the Kolbe A™. During a three-hour lab period, the assessment results were interpreted with the class and teams were formed to test different combinations of instinctive strengths: 1) students with similar strengths (inertia), 2) students with different strengths (conflict) and 3) students with a complementary diversity of strengths (synergy). These teams were assigned an interim project requiring them to work together and observed peer behavior. Then, the instructor facilitated discussion of why teams with combinations of certain strengths succeed and others don't. Teams for a final project (design, construction, and race of solar powered cars) were formed based upon an understanding of conative strengths and team synergy gained from the interim project. Results from peer evaluations of teamwork and teammate satisfaction on the solar car project show that students were highly satisfied with the conative approach.

**Introduction**

ABET outcome Criterion 3 (d) requires that universities teach students to function productively as part of a multidisciplinary team. This study analyzes the effectiveness of teaching students to understand their instinctive behavioral strengths in regards to teamwork activities with the hope that this understanding leads to increased team productivity in addition to increasing retention and persistence in engineering.

The mind consists of three separate domains: cognitive, affective and conative [1, 2]. The cognitive domain houses learned information, a person's knowledge and skills. The affective domain houses emotional responses to this learned information, and determines such things as personality, values, and motivation. The conative domain houses instinctive behavior and describes how someone will most naturally approach a challenging situation. According to conative theory this is the only part of the mind that remains unchanging throughout a person's lifetime[1]. Existing approaches to teamwork instruction in engineering education emphasize cognitive complementarity (i.e., ensuring representation of appropriate knowledge experts) and overcoming affective obstacles (e.g., personality conflicts, problems in interpersonal communication) [3, 4]. However, conative attributes are largely ignored in STEM education.

This study introduces freshman engineering students to the concept of conation, provides them an opportunity to explore their own conative strengths and to learn how to use them to make the best use of their energy. It is hypothesized that knowledge of behavioral instincts will increase student effectiveness. This new understanding provides an opportunity to work in harmony with their natural talents rather than against them, especially when engaged in teamwork activities.

Utilizing conative theory in team formation is an area that is still relatively new to engineering education. However, recent studies show it to be an effective means of productive team development [5, 6]. A 2001 study found that teams of engineering students formed to maximize conative synergy as predicted by the Kolbe A™ index performed better than a group of teams formed randomly after controlling for previous academic achievement [7]. A two year study analyzing team projects in a computer science course showed a statistically significant correlation between conatively synergistic teams and team project grades [6]. The study acknowledged the Kolbe index as a positive technique for raising students' awareness of their potential as well as their need to understand how others may approach similar tasks differently, an important step in understanding the value of teamwork [6]. A qualitative analysis of conatively balanced and unbalanced teams in K-12 settings by Owings found an increase in positive communication and positive group interactions in conatively balanced teams compared to conatively unbalanced teams[8].

Studies relating conative factors to student satisfaction and retention in STEM fields are few; however, results are positive and encourage additional work in this area. A 2011 study examining cognitive, affective, and conative factors in persistence and found that learning intention (a conative measure) was crucially influential in students' levels of persistence in engineering, and affirmed the importance of identifying these intentions and fostering the link between intention and motivation for individual students [9]. Further, a 2005 study provides evidence that students with certain conative strengths either preferentially self-select for engineering programs, or are more likely to persist in those programs. This suggests that students with alternative strengths may be discouraged somewhere along the way from pursuing engineering degrees [10]. Incorporation of conation into the curriculum may improve retention in STEM and persistence of diversity in conative strengths. Conative diversity extends to diversity in other areas and addresses the need to improve success in educating underrepresented groups in science and engineering, including women and minorities [11].

Team science, on the other hand, is a field rife with evidence; however specific training in interdisciplinary team science, while widely acknowledged as very important, has very few methodologies that are practiced [12-14]. For example, the Comprehensive Assessment of Team-Member Effectiveness (CATME) is an NSF funded, online team-building tool that is used in many engineering programs. CATME lets the instructor select teams based on factors of convenience and traditional cognitive abilities (e.g. GPA) as well as some affective aspects (e.g. how students feel about their team or class). CATME allows instructors to choose criteria and weighting that they think are most relevant to successful classroom teamwork; however most instructors aren't experts in teamwork and therefore may struggle with the criteria selection process [3]. CATME does not explicitly address teambuilding based on conative assessment. In this study, the CATME tool built very different teams than the Kolbe conative assessments, and students reported more satisfaction with their conatively synergistic teams than with their CATME built teams.

Continued advancement in teaching teamwork and communication skills in engineering education is necessary to address industry needs and prepare a more diverse set of students to be successful engineers [15, 16]. Effective and productive teamwork is an essential asset in industry, and one that companies are willing to pay for. For example, Motorola reported spending $30 million per year on training, mostly on teams [17]. The Kolbe approach to teamwork has been applied successfully in hundreds of industry settings over the past 30 years, within Universities, Fortune 500 companies, and government agencies [18].

This paper presents the results of a semester-long study in using the Kolbe approach to conation and teambuilding in a freshman Introduction to Engineering course. The results are positive and encourage further research in this area. Results show that teams achieved high productivity and satisfaction among team members.

**The Kolbe Conative Index®**

There is a commercially available test for assessing an individual's conative profile, the Kolbe A™. Kolbe A™ results are reported along four Action Modes® as described here and illustrated in Figure 1.

- Fact Finder – collection and dissemination of information
- Follow Thru – inclination to seek patterns and organize
- Quick Start – treatment of risk and uncertainty
- Implementer – management of space and tangibles

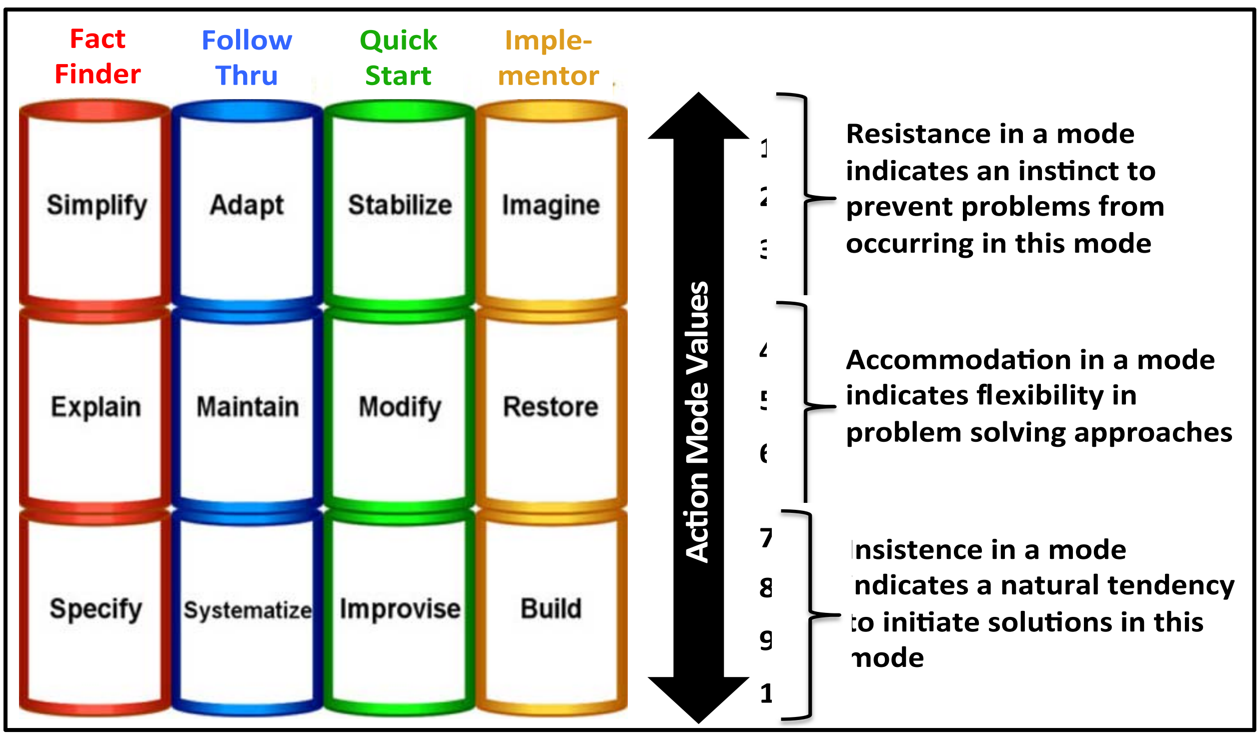


**Figure 1. Kolbe action mode continuum and Kolbe Strengths™. Kolbe A™ Index results characterize a person's behavioral instincts as resistant (1-3), accommodative (4-6) or insistent (7-10) within each action mode.** ***Adapted from Kolbe 2004 with permission*** **[19].**

Each action mode spans a continuum of attributes ranging from resistance in a mode, through accommodation, to insistence. Resistance in a given mode indicates that the tendency for the individual is to *prevent* problems in this mode, whereas insistence in a mode is the tendency to *solve* problems in this way. Accommodation in a mode, as it sounds, indicates that a person is naturally inclined to accommodate either style of problem solving [19]. The continuum for each mode spans from a value of 1 to 10, where 1-3 marks resistance, 4-6 accommodation, and 7-10 insistence. Each of these zones identifies a specific conative strength. The Kolbe A™ results are reported along the four Action Modes® providing a single value within each, identifying the four unique strengths of that particular profile.

For example, a Kolbe A™ of 6 8 2 4 indicates (a) an insistence in Follow Thru with a value of 8 suggesting that this individual will approach a problem by sorting it out and organizing it first, (b) a resistance in Quick Start with a value of 2, indicating this person is resistant to risk and will naturally work to prevent risk associated problems, and (c) accommodation in both Fact Finder and Implementer with values of 6 and 4 respectively, indicating an ability to work with basic information or to dig into details, and an ability to work with abstract concepts or with tangibles.

When working with others, a potential for conflict arises when there is a difference of 4 or greater within any action mode. One person seeks a solution using a method that the other is naturally inclined to avoid or prevent, and the result is a stressful situation with decreased productivity. Similarly when there is very little difference in conative profiles progress can stop altogether, Kolbe refers to this as a problem of inertia [19]. These issues can be overcome in a variety of ways, first off simply being aware of the difference in natural tendencies makes people more accepting of each other, but ideally, working relationships and teams can be formed understanding the importance of conative synergy – complementary conative profiles.

## Methods

Conation concepts were integrated into team exercises in two freshman Introduction to Engineering courses at Arizona State University taught by the same instructor. The course is a required 2-credit course with a maximum enrollment of 40 students, with a male to female ratio of 5 to 1. Learning objectives include establishing familiarity with tools and software used in engineering and learning how to work effectively in teams and recognize the value of teamwork.

### Concept Introduction

A week-long conation module was used to introduce and illustrate the concept. Teams for the final semester project were formed using the newfound understanding. The semester project spanned five weeks requiring the student teams to design, build and race solar powered cars as well as develop a report and group presentation on their results. The success of using conation to facilitate teamwork was measured using student completed team and peer evaluations.
The concept of conation was presented in a short module where students completed on-line Kolbe A™ assessments before class and watched a short online presentation interpretation of their results. During the following three-hour lab everyone's results were shared and discussed with the class by the course instructor, who is Kolbe Certified™.

To illustrate conative strengths in action a variety of teams of three to four students were formed to test strength combinations: (1) students with similar conative strengths were put together to form an "inertia" team, (2) students with conflicting problem solving approaches were put together to form a "conflict" team, and (3) students with a complementary mix of talents were put together to form a "synergy" team.

Students then performed team activities requiring them to work together, during which they are able to observe each other to see whether they really exhibit these strengths. For example, in one of the games each team was given a hula hoop and told that they had to, as a team, stand around the hula hoop holding it above their heads with the hula hoop resting on each team member's index fingers. When the instructor signaled START, the teams raced to lower the hula hoop to the ground without losing contact until it was completely on the ground, and all of the team members had to get inside of the hula hoop. The first team all inside the hula hoop was the winner. Students who were not on one of the participating teams, observed the activity and acted as the jury in deciding the winners.

The Synergy team completed the task in a matter of seconds, seeming to quickly realize the overall simplicity of it. However, the Conflict team struggled to get started and appeared to disagree about what it was they were doing, but they managed to get it together and finish second. And the Inertia team, heavy with insistent Fact Finders, had a difficult time completing the task because they could not make sense of the rules, and finished last.

Another activity that was used to illustrate instinctive problem solving behavior was the Glop Shop [19]. Three students were selected by the instructor based on their Kolbe A™ indexes, the combination of strengths selected by the instructor created a team that would display a range of conative strengths, with some conflict. The students selected were asked to leave the room while the rest of the class determined the exercise they would perform when they returned. The activity consists of (1) providing the team with a sack full of miscellaneous items such as cat toys, office supplies, ribbons, and even some broken items, (2) instructing them on the "rules", which are they must (a) construct an item from the materials in the sack in 2 minutes, and then (b) sell the item to the class in a 60 second infomercial. While the volunteer students were out of the room, the class discussed the Kolbe profiles of those students and predicted how they thought the students would behave in the glop shop. The students were brought back into the room, given the task, and the rest of the class observed. After the completion of the activity the instructor and observing students commented and discussed what conative traits were seen. The glop shop activity was repeated with another group of three students with a range of conative strengths, but the second time the strengths were more complementary and synergistic.

The conation module concluded with an instructor facilitated class discussion about why teams with combinations of certain strengths succeeded and others didn't. The experience was eye-opening and validating for most students.

One elated student told the instructor after class, "This is great, I want you to know that I really believe this, I was the only one on my team who was resistant in Fact Finder and I was the only one able to see how simple the solution was! Everyone else just stood there wondering what additional rules they needed to know about."

The conation module's introductory activities (hula hoop and glop shop) are not graded assignments; they are used to highlight the importance of considering natural talents when working with other people and forming teams.

Students had been working in teams formed using online tools from CATME.org [3], and were instructed that after the conation lab there would be an opportunity to change teams if they wished to do so. Every team chose to disband and reform with new members.

Immediately following the conation lab another student eagerly approached the instructor saying, "We talked and we want to switch teams, we are all the same (i.e. all have similar conative insistence and resistance), we want to form a new team," then added, "I want to be on a synergy team."

This team exemplified the problem associated with using only cognitive and affective measures to form teams and ignoring the conative attributes of the team members. This was a group of students who, on paper, should make a good team. They were an intelligent group that all got along, and worked hard. But, they were an inertia team. After seeing how this played out in the introductory activities and begin given the vocabulary to discuss why their team efforts had been difficult they immediately recognized the benefit of having a complementary mix of conative abilities on a team.

Even at the freshman level a lack of conative diversity is present in engineering. This phenomenon was also shown by Lingard et al. [10]. Typically successful engineering students will be insistent Fact Finder and/or insistent Follow Thru. The insistent Quick Start is rare, and even less seen is the insistent Implementer – the conation module is especially beneficial to those students who study, learn, and *do* things differently. Conative awareness on the part of the student and the instructor allows for a better understanding of potential difficulties and road blocks and can therefore be proactively addressed.

Team Formation

Final project teams were constructed in the following class meeting by student selection and instructor approval using this new knowledge of conative inertia, conflict, and synergy. All students wrote their Kolbe A™ index numbers on the white board in the front of the classroom, the students then formed new teams of four. They proposed the new team and conative mix to the instructor for approval. There was not enough conative diversity in the class to create all new teams with perfect conative blends. So, as new teams were approved the instructor provided insight into where problems could arise due to cloning of strengths as well as strengths that were missing on the different teams.

The final project required teams to design, construct, and race a solar powered car. It was hypothesized that incorporation of conative awareness (of themselves and their peers) would result in improved team performance and satisfaction with team experiences. Student satisfaction was measured with a self-report satisfaction assessment during the solar car project activities to gauge the success of the team activities and conative-based team structures. The results are presented here.

Assessment
To assess student satisfaction with the teamwork experience and with their teammates, students completed confidential peer evaluations. Students were provided letters informing them of the study and their option to participate or not. No student declined to participate.

The evaluations were done in two parts. The first part asked the students: ***How satisfied are you that your team is working at its best? What can you do to ensure that it does?***

The second part required students to rate their teammates and themselves and to justify their ratings with commentary. They were instructed to provide ratings using the following scale [20]:

- **Excellent:** Consistently carried more than his/her fair share of the workload.
- **Very good:** Consistently did what he/she was supposed to do, very well prepared and cooperative.
- **Satisfactory:** Usually did what he/she was supposed to do, acceptably prepared and cooperative.
- **Ordinary:** Often did what he/she was supposed to do, minimally prepared and cooperative.
- **Marginal:** Sometimes failed to show up or complete assignments, rarely prepared.
- **Deficient:** Often failed to show up or complete assignments, rarely prepared.
- **Unsatisfactory:** Consistently failed to show up or complete assignments, unprepared.
- **Superficial:** Practically no participation.
- **No show:** No participation at all.

Submitted evaluations account for over 70% of students who participated in the course and teamwork activities.

**Results**

Study results show a high satisfaction rate among students for the effectiveness of their teams and for the contributions of their teammates during the Solar Car Project.

Figure 2 is a summary of Part 1 of the student peer evaluation. Student responses were coded using a standard Likert scale [21] distribution. More than half of the students responded Very Satisfied, and 95% of the respondents were either Satisfied or Very Satisfied. This is a very encouraging result especially since students frequently report a strong dislike of teamwork experiences in academics [4].

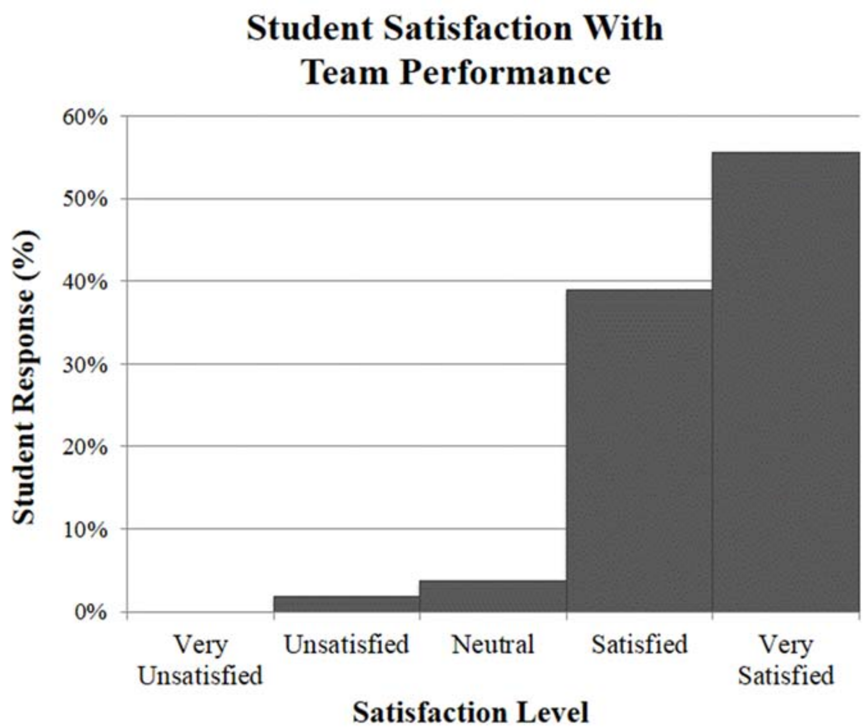


**Figure 2. Part 1 of student peer evaluation forms for overall teamwork satisfaction with the Solar Car Project, answering the question:** ***How satisfied are you that your team is working at its best?***

While Figure 2 summarized overall team satisfaction, Figure 3 shows how students responded to the second part of the peer evaluation survey. Figure 3 illustrates average ratings given to teammates for their contributions to the team. Self-evaluations were excluded from these results to show only how satisfied students were with their teammates, and not how much they felt they themselves had contributed.

The results are also very positive. All teams reported at least a minimal satisfaction with teammates, while most teams reported satisfaction levels in the Very Good or Satisfactory range.

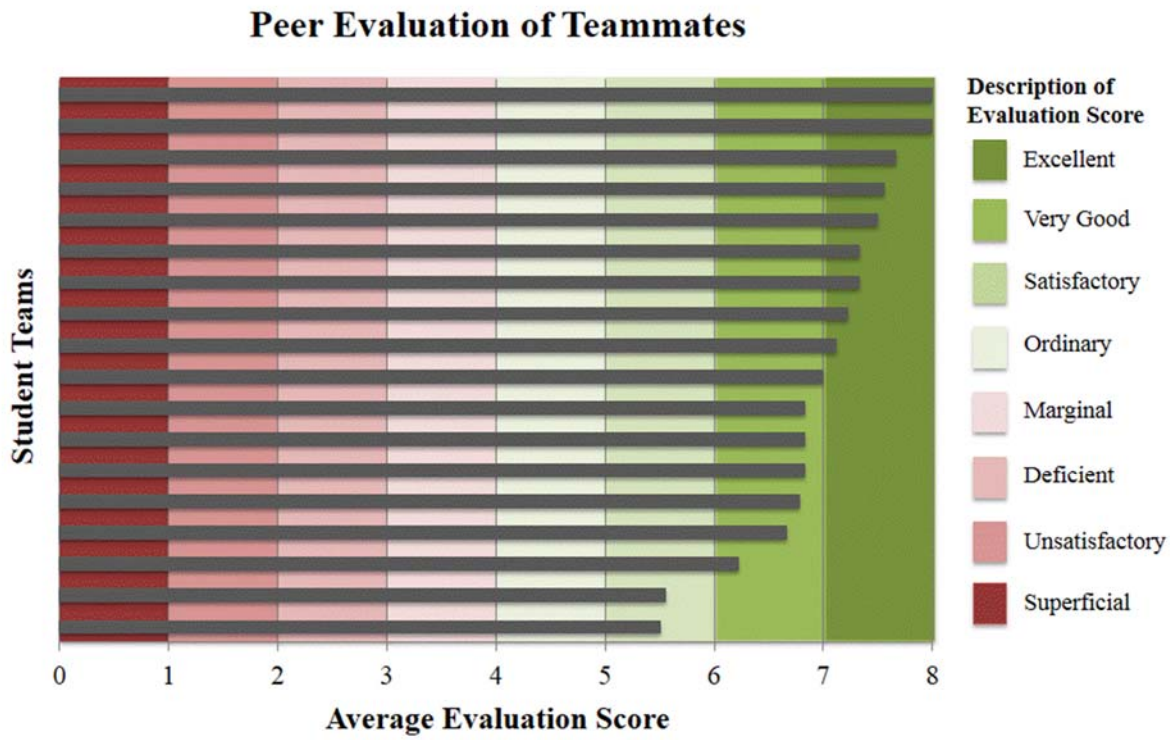


**Figure 3. Part 2 of student peer evaluation forms for teammate performance in the Solar Car Project. Self-evaluation scores were excluded from results shown in this figure to highlight student satisfaction with teammate performance only.**

Table 1 below shows excerpts taken from a selection of different team comments. The selected comments illustrate a correlation between predicted conative behaviors and team participation by members.

**Table 1. Excerpts of peer evaluations Part 2.**

| | FF | FT | QS | IM | Commentary |
|---|---|---|---|---|---|
| A | 3 | 3 | 7 | 7 | made the project easier and more fun |
| B | 6 | 5 | 1 | 8 | without XX we would have really struggled building our car |
| C | 2 | 2 | 7 | 8 | great team player, has a good understanding of the project and concepts and is **a natural builder** |
| D | 8 | 7 | 2 | 3 | he sometimes didn't know what to do and sat back and waited to be instructed |

The team member described in Row A is an insistent Quick Start and insistent Implementer suggesting an inclination for innovation and need to construct quality objects; this person is also resistant in Fact Finder and Follow Thru suggesting a need to simplify and seek out short cuts. This unique index made a teammate who was viewed as making the project easier (preventing problems through resistance in FF and FT) and more fun (finding innovative solution through insistence in QS).

The team member described in Row B is an insistent Implementer indicating a need to construct quality objects using the correct tools and materials; this person is also resistant in Quick Start suggesting a need to stabilize and avoid risk. This unique index made a teammate who was viewed as indispensable in the car construction (using their innate hands-on approach to problem solving through insistence in IM).

Similarly, the team member described in Row C is also an insistent Implementer suggesting a need to construct quality objects using the correct tools and materials; this person is also insistent in Quick Start suggesting a need to innovate. This unique index made a teammate who was recognized as a natural builder (using their innate hands-on approach to problem solving through insistence in IM).

The team member described in Row D is an insistent Fact Finder and an insistent Follow Thru suggesting a need to clearly define and understand the problem before moving forward and only moving forward with an organized plan; this person is also resistant in Quick Start suggesting a need to avoid risk. This unique index made a teammate who was unfortunately misunderstood as lazy when what they really needed was more information and an actual plan.

The introduction of conation and the Kolbe System™ gave students new vocabulary to use in cooperative situations. They were able to better understand their own strengths and what they could offer to a team scenario as well as better understand their classmates and teammates. This was illustrated in an additional comment on one of the peer evaluation forms (directed to the course instructor):

> "You were hesitant about our group's Kolbe Index combination which I now think was astute. XX and I worked well together on the proposal but clash heavily during production. It is interesting to see how some people complement each other in some areas and clash in others. We all do our part, just in different ways." – FSE100 Student comment to instructor on peer evaluation form.

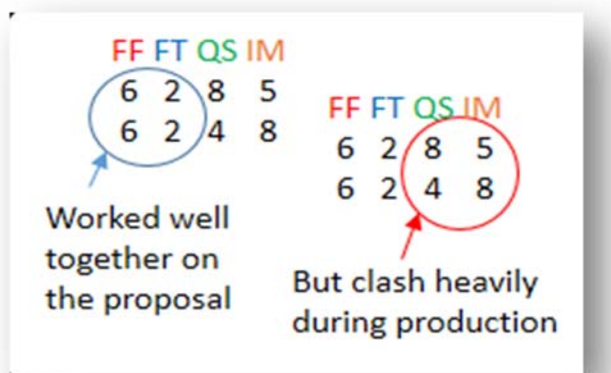


**Figure 6: Comparison of team member Kolbe A index results, validating the student quote to the left about team dynamics during project execution.**

Discussion

The inclusion of this module resulted in an overwhelmingly positive experience for students and instructors. Students report appreciating the validation of their individual strengths and the appreciation of their uniqueness. The information has contributed to the students' development

of self and will continue to affect them beyond this course. Comments from course student evaluations (answering the question, *What did you like most about this course?*) show that:
(1) students were able to grow personally from the experience

> I enjoyed the lab and exposure to different engineering modalities that I had previously not understood. Being able to use all of those skills to produce a final project was rewarding. I was really proud of myself that I could put together a working electrical system for a solar car when electrical has always been my weakness**. *I learned a lot of valuable things about myself and my core strengths*** and weakness. The course was a nice blend of team building, system building, and learning about technical systems. (emphasis added)

And that,
(2) students were highly satisfied with the team experience

> "Got to do actual team projects that required teamwork."

These responses are illustrative of how including conative methods for instructing team work are effective and can result in positive team experiences.

From the instructor's perspective the conation module and team work discussions that follow create an equally positive experience. It provides an opportunity to get to know the students as individuals, and an opportunity for the students to see the instructor as a conative individual as well. The classroom environment became more open to diversity in how people behave and learn – in a way wholly unrelated to GPA or sex or cultural background [22]. Instructors report a positive experience based on the success of the students. The openness and harmony realized in the classroom during the semester Solar Car Project, resulted in students feeling encouraged and respected and responding by taking responsibility for their learning and being accountable to their teammates.

Teaching engineering students to be effective team members is critically important to their success in the workforce. While the authors of this paper understand that conation is not the only factor in creating successful working relationships and teams and that there are many methods incorporating cognitive and affective attributes into team formation that are a step in the right direction [4], this study illustrates how the inclusion of conation in the classroom can have a significant impact on students and teamwork experience.

Providing students the opportunity to have a positive teamwork experience shows them that such an experience is possible. Ultimately, introducing these concepts at the freshman level is intended to assist students with forming strong relationships with solid, team-based foundations that have a positive impact on student retention and persistence in engineering.

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