Multi-source Feedback Processes and Student Learning Styles: Measuring the Influence on Learning Outcomes*

Jack McGourty, Columbia University
and
Larry Shuman, Justin Chimka, Mary Besterfield-Sacre and Harvey Wolfe, University of Pittsburgh

Introduction

With the realization that active and cooperative learning are effective pedagogical modes, and stimulated by ABET's EC-2000, more and more engineering courses are being designed to give students hands-on experiences including working in a team. This trend towards team-based course work has also been influenced by industry where teams have become the prevalent mode of work. In fact, multidisciplinary teams have become an integral part of product development, process improvement, and manufacturing activities. Such management techniques as concurrent engineering, total quality management, and business process re-engineering are based on people effectively working together in teams. Hence, engineering educators, recognizing these trends, are designing more and more courses around teams and providing increased opportunities for students to work in teams. These experiences range from short, decision-making exercises to course-long project management or business simulations, and senior design capstone courses. Such programs as MIT's undergraduate design course and their "New Products Program" make extensive use of teams composed of students, faculty and outside sponsors [1]. That model is currently being replicated across US engineering institutions. Now, almost every accredited engineering program has at least one project-driven course that provides students with the opportunity to experience, as part of a team, design from idea conception to some level of completion. If properly structured, such courses can teach students the skills necessary for being effective team members, including multidisciplinary teams.

Unfortunately, educators frequently incorporate student teams into their courses with little thought given to either learning objectives or the most effective way to introduce teamwork. Minimal guidance is provided to students on group development, soliciting member input, consensus building, resolving conflicts, and team leadership. Evaluation often is subjective, and, at best, may be a piecemeal integration of very rough individual and group level performance measures. Consequently, much learning (and potential learning) of small group dynamics and team behavior is not capitalized upon.

In this paper, we present a review of our research focused on student team learning in relation to their preferred learning style. A multi-source feedback process is used to

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provide students and faculty with feedback on specific team attributes and skills. In addition, the relationship between assessed team behaviors and learning styles are investigated. We also examine the impact of gender on student teams.

Learning Styles

Richard Felder [2] has documented that engineering students have diverse learning styles; i.e., different students take in and process information in different ways. Using theories from cognitive psychology, Felder and Silverman characterized learners according to five different dichotomies [3]. These are: sensing or intuitive; visual or verbal; inductive or deductive; active or reflective; and global or sequential. For example, some students tend to focus on facts and data, while others are more comfortable with theories and models. While certain students prefer learning by obtaining information visually, others learn more effectively by auditory means. Many students prefer to learn by interacting with others people; however, there are individuals who prefer a more introspective approach. The key point is that there are many different ways that students learn best. Each student has a preferred mode that may be quite different than other students in the class. When students work on team projects, this variation in individual learning styles has an impact on learning and the resultant educational experience. Mismatches between an individual's specific learning style profile and that of other team members can lead to dysfunctional behavior, maladaptive learning experiences, and ultimately, poor team performance unless students learn how to recognize these situations and understand that in the long run such heterogeneous groupings can result in a more productive team experience.

For this research, we have used Felder and Silverman's [4] original five learning style dichotomies or dimensions: sensing or intuitive; visual or verbal; inductive or deductive; active or reflective; global or sequential*. Students completed a short learning style inventory developed by Felder that provides a brief overview of each pair of alternatives within each dimension and then asks students to select their preference and indicate where they are in that direction – strong, moderate or minor. For example,

> Visual: remember best what they see - pictures, diagrams, sketches, schematics, flow charts, plots, maps, and demonstrations. If something is said to them, they will probably forget it.
>
> Verbal: prefer written and spoken words; get a lot out of discussions. Prefer verbal explanation to visual demonstration and learn effectively by explaining things to others.

Note that although the original Felder and Silverman learning style model included the inductive – deductive dimension, and while Felder believes that inductive and deductive

* Such distinctions will be made in the following ways. Whether a learner is sensing or intuitive is referred to as that learner's *SI* style. Whether a learner is visual or verbal is referred to as the learner's *V* style. The *ID* style distinguishes between inductive and deductive learners. Whether a learner is active or reflective is referred to as *AR* style. The *GS* style distinguishes between sequential and global learners.

are indeed different learning preferences and different teaching approaches, he decided to remove this dimension from the resultant ILS instrument that is based on the Felder-Silverman model. According to Felder:

> The "best" method of teaching - at least below the graduate school level - is induction, whether it is called problem-based learning, discovery learning, inquiry learning, or some variation on those themes. On the other hand, the traditional college teaching method is deductive, starting with "fundamentals" and then proceeding to applications.
>
> The problem with inductive presentation is that it isn't concise and prescriptive--you have to take a thorny problem or a collection of observations or data and try to make sense of it. Many or most students would say that they prefer deductive presentation - "Just tell me exactly what I need to know for the test, not one word more or less." Barbara Soloman and I didn't want instructors to be able to give our instrument to students, find that the students prefer deductive presentation, and use that result to justify continuing to use the traditional teacher-centered expository instructional paradigm in their courses and curricula [5, 6]. We therefore chose to omit this dimension from the instrument [7].

Multi-source Assessment and Feedback in Teams

Multi-source assessment is a formal process that collects critical information from several sources including peers, self, and instructors on both student competencies and specific behaviors and skills. As such, it has the capability to provide each student with a better understanding of his/her personal strengths as well as those areas in need of development [8]. For this study, we used the Team Developer™ [9,10] a computer-based survey system designed to provide each student with constructive, developmental feedback regarding his or her effectiveness on several specific cognitive and behavioral skills. The basic application requires each team member to rate both themselves and their teammates on a series items designed to identify skills and behaviors found to be important for engineering graduates and practicing engineers. (See Figure 1 for an example.) An administrative authoring system enables the instructor to quickly create an electronic version of the survey (in disc format). Each student is given a disc and instructed to complete the survey at a convenient time. The computer-collected data is then compiled by the administrative application. Reports are automatically generated, giving each student a confidential, developmental feedback report that presents self and team ratings on each survey item and highlights overall strengths and areas for development.

For this research, a particular emphasis was placed on having students focus on three EC-2000 outcomes [11]:

- 3.d: an ability to function on multi-disciplinary teams (i.e., teamwork)
- 3.e: an ability to identify, formulate, and solve engineering problems (i.e., problem solving)

3.g: an ability to communicate effectively (i.e., communications)

Attributes for these three outcomes were selected from a much larger set of attributes that our colleagues and we and identified and arranged in a hierarchical order [12]. Each selected item was then converted to a statement and entered into the Team Developer™ using its administrative authoring system. Consequently, students were given a subset of 32 items: four related to communication, 24 to teamwork, and four to problem solving. Every item (question) was "positively worded" meaning increasing ordered categories correspond to increasingly positive assessments regarding the item's topic. Five ordered categories were used for rating choices and assigned numerical values 1 (never), 2 (rarely), 3 (sometimes), 4 (frequently), and 5 (always).

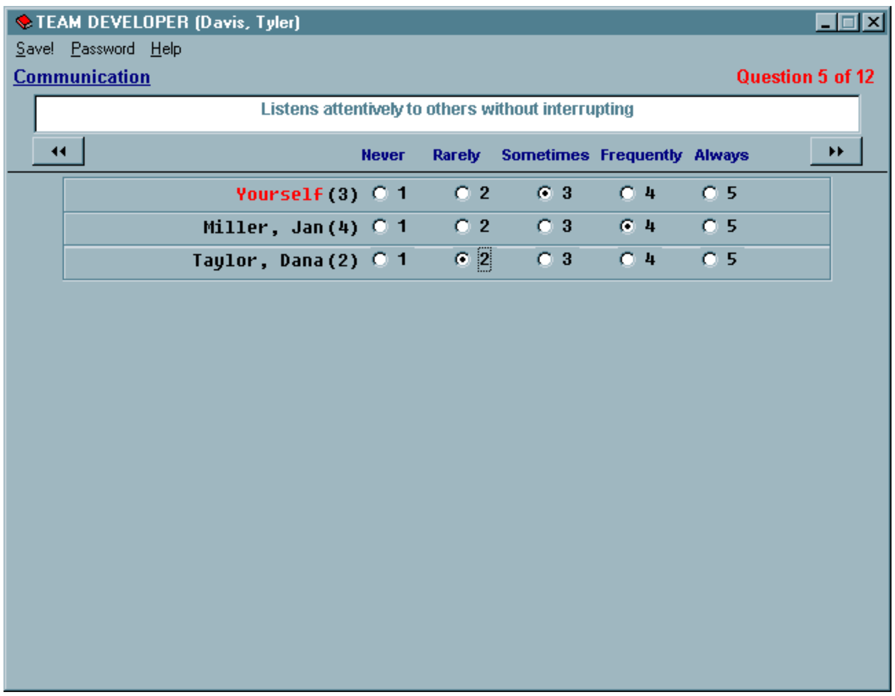

Figure 1: Team Developer Example Item

Classroom Research

Investigators from University of Pittsburgh and Columbia University have been applying a series of assessment methods and processes to a cohort of engineering students for validation purposes [13]. Specifically, we have been conducting a longitudinal triangulation experiment [14] involving students from the University of Pittsburgh, Department of Industrial Engineering. The experiment began in the fall of 1999 when the students were in their first semester, sophomore year and has continued through the fall of 2000 when the students complete the first semester of their junior year. A second cohort was started for fall 2000 enabling us to replicate the experiment. The experiment is part of a larger research project in which we are evaluating the information obtained when multiple methods are used to assess the learning process and outcomes.

Specifically, this experiment involves following two cohorts of approximately 50 students each through a three-course sequence in industrial engineering. The first course, *Modeling with Computer Applications*, was taken by the first cohort in the fall 1999 (and by the second cohort in the fall 2000) and provided an introduction to mathematical modeling, problem solving, and teamwork. The second course, *Productivity Analysis*, is taken in the second semester of the sophomore year (spring 2000 and 2001) and provides an introduction to industrial engineering concepts and thought processes. The last course, *Human Factors Engineering*, is taken the first semester junior year (fall 2000 and fall 2001) and focuses on the study of human abilities, characteristics, and behavior in the development and operation of systems designed for human use. Each course requires the use of open-ended problem solving (outcome “e”), oral and written communication skills (outcome “g”), and relies heavily on teamwork (outcome “d”) in and out of the classroom. Thus, these three outcomes were chosen for the study: problem solving abilities, teamwork, and communication skills.

For the first cohort (fall 1999) 51 undergraduate Industrial Engineering students were initially exposed to teamwork skills as part of *Modeling with Computer Applications*; the first course in the experimental series. At the beginning of the course, Felder’s original learning style inventory (described above) was administered, measuring student’s preferences across five dimensions: sensing or intuitive; visual or verbal; inductive or deductive; active or reflective; and global or sequential. Students completed the inventory during the first session of the course.

Students were assigned to three different teams over the duration of the course. The instructor randomly selected the first set of teams. The second and third sets were determined by student-developed algorithms that attempted to create heterogeneous teams using the learning style data (with names removed). The Team Developer was administered to the students during the second half of the semester following their second team assignment, and again at the end of the course following a third team assignment and a team final. During their second course, *Productivity Analysis*, students were randomly assigned to nine teams for a longer duration project. One class was devoted to the importance of performance assessment and the value of critical, but realistic feedback prior to repeating the Team Developer measurements. In the third course, *Human Factors Engineering*, students again worked in teams. A final multi-source assessment was administered at the conclusion of this course.

The investigators have begun to analyze the effects of gender and learning styles on self- and peer ratings, the difference in ratings according to specific learning styles, and a review of how gender influences student perceptions of behavior.

Results

As noted, we are following a cohort of 51 students over a series of three courses, typically taken during the third, fourth and fifth semesters of the Industrial Engineering

Curriculum. We are specifically looking at three EC-2000 outcomes – teamwork, problem solving and communications. For our analyses, the dependent variable was the Team Developer rating; independent factors included the following learning style dimensions in addition to gender.

- Whether the rating is a self rating or a peer rating
- Gender of the rater
- Gender of the student being rated
- *SI* (sensing/intuitive) style of the rater
- *SI* (sensing/intuitive) style of the student being rated
- *VV* (visual/verbal) style of the rater
- *VV* (visual/verbal) style of the student being rated
- *ID* (inductive/deductive) style of the rater
- *ID* (inductive/deductive) style of the student being rated
- *AR* (active/reflective) style of the rater
- *AR* (active/reflective) style of the student being rated
- *GS* (global/sequential) style of the rater
- *GS* (global/sequential) style of the student being rated

Because of the non-parametric nature of this data, a Mann-Whitney test was used rather than a t-test or analysis of variance when significance testing was done.

Table 1: Summary of Peer and Self Ratings – Three Courses

Overall	**Course**	**Com Peer**	**Com Self**	**Team Peer**	**Team Self**	**Prob Peer**	**Prob Self**
	1a	3.98	4.06	3.93	4.09	4.06	4.24
	1b	4.11	4.13	4.13	4.16	4.12	4.10
	2	3.53	3.54	3.64	3.71	3.73	3.79
	3	3.81	3.87	3.68	3.85	3.85	3.99
Male		**Com Peer**	**Com Self**	**Team Peer**	**Team Self**	**Prob Peer**	**Prob Self**
	1a	4.01	4.05	3.97	4.06	4.06	4.19
	1b	4.12	4.14	4.15	4.16	4.10	4.09
	2	3.57	3.64	3.67	3.71	3.77	3.83
	3	3.98	3.96	3.74	3.87	3.91	4.02
Female		**Com Peer**	**Com Self**	**Team Peer**	**Team Self**	**Prob Peer**	**Prob Self**
	1a	3.93	4.07	3.88	4.14	4.06	4.31
	1b	4.09	4.13	4.11	4.17	4.14	4.13
	2	3.48	3.41	3.60	3.72	3.69	3.73
	3	3.61	3.76	3.61	3.83	3.79	3.95
Com: Communications; **Team**: Teamwork; **Prob**: Problem Solving							

Table 1 and Figures 2, 3 and 4 summarize the results for all students, males, and females over the three courses and four applications of the Team Developer. (Note that the first semester sophomore course includes two applications of the Team Developer – 1a and 1b; with one application each for the second semester sophomore and first semester junior courses.) Of particular note is the consistent pattern in the magnitude of responses for both male and female students across the three-course sequence, for both peer and self ratings, and for all three outcomes. Specifically, first semester sophomores rated both themselves and their peers relatively high after their second teamwork assignment, and even higher after the third assignment. However, the next semester, after they had a more involved teamwork assignment (with somewhat larger teams), all ratings were relatively lower. These ratings then rose by the end of the third course (first semester juniors), but not to the same levels that they originally rated themselves and their peers the previous year. These changes are particularly pronounced for female students.

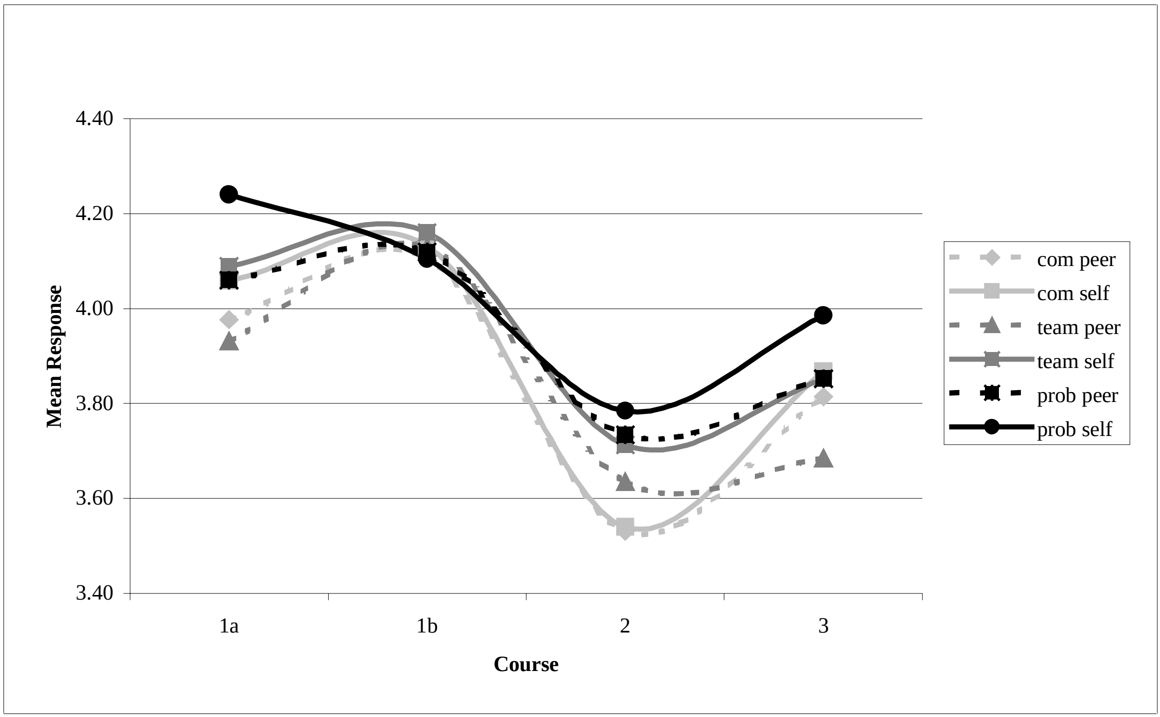

Figure 2: Self and Peer Team Developer Scores – All Students

Although females tend to show more pronounced changes relative to peer and self assessments for the teamwork assignments over the three courses, in only one instance were gender differences significant. This was for the "Communications" outcome for the third course (first semester juniors). As shown in Table 2, for this case males gave significantly higher ratings to females, themselves and other males in comparison to females rating themselves, males and other females. As shown in the Table, the highest ratings were given by males to female team members (4.20). In contrast, females rated their male team members lowest of the six comparison groups (3.53). In addition, females rated themselves (self ratings) significantly lower (3.76) than their male peers rated the same group of females.

However, it should be noted that this was the only one of the four sets of ratings, and the only one outcome where significant gender differences were observed. For the other eleven comparisons, no significant gender differences were found. That is, for the other two outcomes ("Teams" and "Problem Solvings") for juniors, and for the three sophomore year ratings, no significant gender differences were observed.

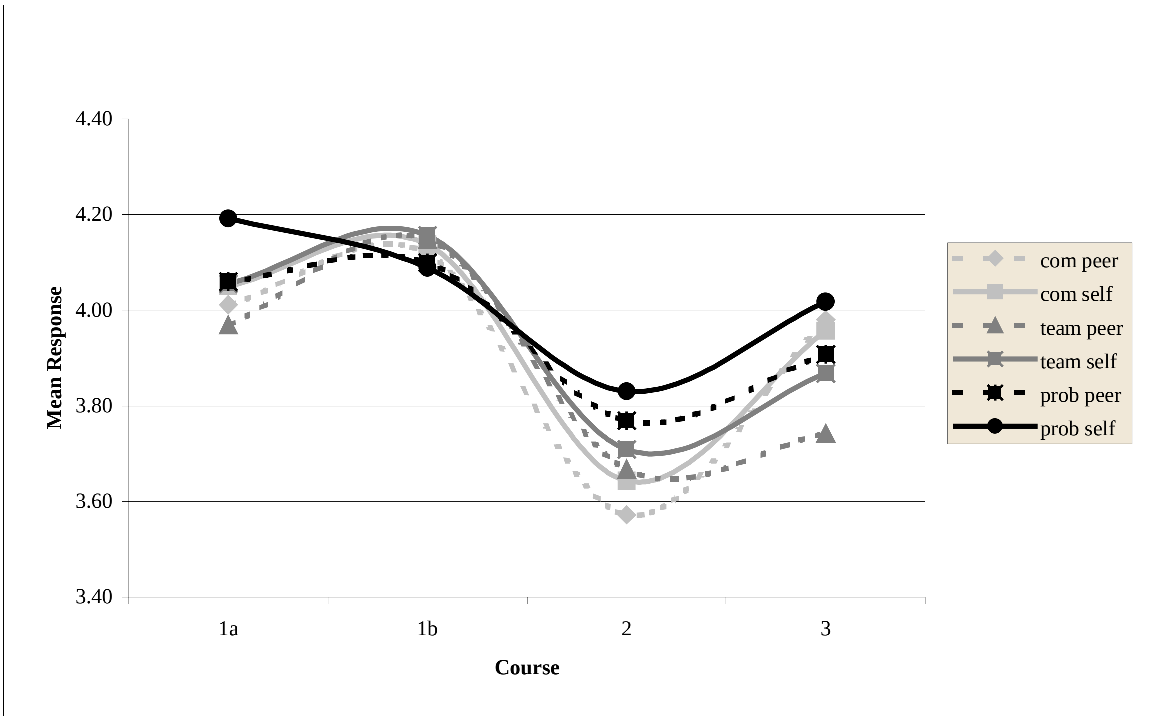

Figure 3: Self and Peer Team Developer Scores – Male Students

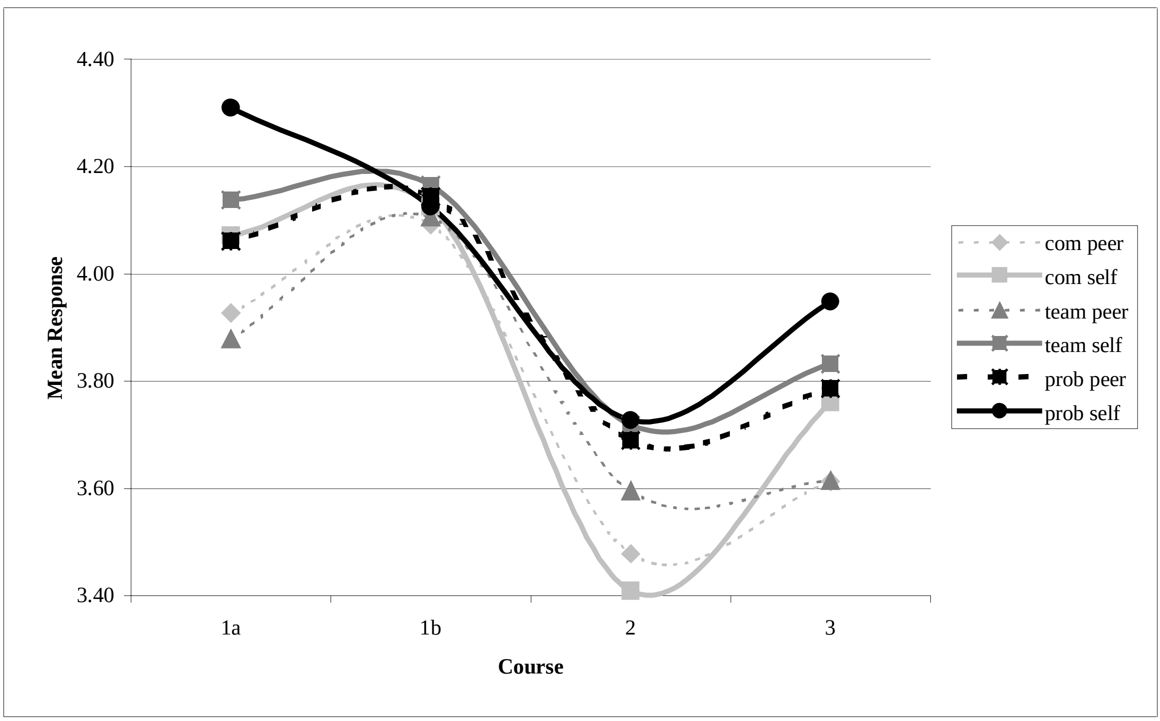

Figure 4: Self and Peer Team Developer Scores – Female Students

Table 2: Significant Gender Differences – Juniors - Communications

Communications						
Rater	**female**	**female**	**female**	**male**	**male**	**male**
Rated	male	female	self	male	self	female
Obs	35	47	24	67	29	33
Mean	3.53	3.68	3.76	3.87	3.96	4.20
Std. Dev.	0.86	0.77	0.68	0.54	0.55	0.63

With respect to the learning styles significant differences were found for three of the five dimensions. These results are summarized in Table 3 (where the shaded cells represent significant differences) and discussed below.

Table 3: Significant Learning Styles Differences

Learning Style	**Communications**		**Teamwork**		**Problem-Solving**	
Sensing	1a	1b	1a	1b	1a	1b
Intuitive	2	3	2	3	2	3
Visual	1a	1b	1a	1b	1a	1b
Verbal	2	3	2	3	2	3
Induction	1a	1b	1a	1b	1a	1b
Deduction	2	3	2	3	2	3
Active	1a	1b	1a	1b	1a	1b
Reflective	2	3	2	3	2	3
Sequential	1a	1b	1a	1b	1a	1b
Global	2	3	2	3	2	3

Specifically, as shown in the Table there were no differences for either raters or those rated between sensing and intuitive learners and between visual and verbal learners. However, inductive learners tended to give higher ratings to themselves, other inductive learners and deductive learners compared to deductive learners rating themselves, other deductive and inductive learners. As indicated, this trend was apparent for sophomore students (1a, 1b and 2) for both the "Teamwork" and "Problem Solving" outcomes. For three cases, active learners tended to rate themselves higher than reflective learners rated themselves, and in these three cases, active learners tended to give higher ratings than did reflective learners.

The most pronounced differences were observed between sequential and global learners. In eight of the twelve cases, sequential learners rated themselves higher than did global learners, and in three of these cases sequential learners also rated other sequential learners and global learners higher compared to global learners rating other global learners and sequential learners. That is, sequential learners tended to give higher ratings than global learners, and global learners tended to receive lower ratings, especially from other global learners and themselves. These differences were observed for all three outcomes.

Conclusions

The following are some initial conclusions.

- With regard to gender, few significant differences were found, and females exhibited a rating pattern similar to males.
- Ratings given by sensing and intuitive learners were not significantly different.
- Ratings given by verbal and visual learners were not significantly different.
- Deductive learners' gave significantly lower ratings than inductive learners, particularly for teamwork and problem solving outcomes.
- Regarding AR styles, active learners gave higher ratings for only one case.
- Sequential learners tended to give significantly higher ratings than did global learners for all three outcomes. Global learners gave lower self ratings than did sequential learners. Global learners also tended to rate other global learners lower than sequential learners rated other sequential learners.

The results reported here begin to inform the instructor on how student teams are affected by gender and learning style. This data is from only our first cohort of students. As more data is collected, these preliminary findings should become more conclusive, enabling faculty to better form and train student teams in order to maximize learning and team effectiveness. In doing this, instruments such as the Team Developer™ should prove useful for assessment by enabling faculty to track students' self- and peer-ratings over time. Finally, ratings may be correlated to specific assessment surveys to further validate those surveys and the Team Developer as assessment tools.

What one sees when viewing the overall longitudinal results of the cohort is real learning in action. All three learning outcomes - communication, teamwork, and problem solving – follow the same trend. Early ratings tend to be inflated. In other words the students perceive their own skill levels and that of others higher than the actual competency they possess. Once they become an active member in the feedback process, they begin to reflect on each of the skill sets and how they are defined. Most importantly, they begin to have a more accurate perception of their own skill level as well as what they observe in others. This leads to a natural lowering in the multi-source ratings as is seen in the second semester results. In this case, a better understanding of the skills and behaviors and the rating process was precipitated by a special class session on the importance of accurate peer and self-assessment that was presented during the second course. By the third course, the student ratings are now founded on a more realistic base. Therefore students are able to assess their skill levels more accurately. Now if real learning occurs, the self and peer ratings should reflect the increase level of competency. In our experiment, this is the case across all three skills.

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