A Case-Study of Assessment in Materials Laboratory

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Materials engineering students are often ill prepared to enter the workforce upon graduation. While students master the content knowledge they often lack critical skills for success. Our industry feedback of internship students indicates weakness in the areas of: technical writing, critical thinking, professional attitude & teamwork, analysis, reasoning and decision making.

We have examined the effectiveness of new teaching and assessment methods in the Materials Laboratory classes. Through our use of new materials and assessment instruments support our thesis that will lead to student improvement in the defined areas of weakness. The integration of peer review strengthens teamwork and professional attitude both in the classroom and later in the students' professional lives. We have used interdisciplinary collaboration as another component to help develop analysis and reasoning skills by utilizing field trips to manufacturers who have quality control and project management programs.

Our feedback system in scoring student reports will likely strengthen their technical writing skills. This works as follows: The group consists of one author and two to three reviewers every week. The roles alternate. The author sends a draft to the reviewers, who in turn review electronically and send the response to both the author and the instructor. This is to make sure the review process can also be graded and the author receives the material in time. The author now makes changes to the report and also responds to the reviewers' suggestions in writing. The entire report is submitted to the instructor for assessment. The grades for the reviewers and the author alike, including the comments on the documents teach the students where strengths and weaknesses lie.

We have exposed the students to professional engineering centers such as MAIC (Major Analytical Instrumentation Center) and PERC (Particle Engineering Research Center) where they develop better insight and can mirror an appropriate attitude in a professional environment.

Current practice vs. our teaching method

The reality of the learning experience in many colleges of engineering is much different from the ideal. Students typically have contact with the instructor only in the classroom sessions. In many cases students rarely if ever truly interact with the professor.

The ‘burden’ of teaching is all too often assigned to teaching assistants. They run the classes; maintain the lab, and grade lab reports, quizzes and orals (such as colloquia). Thus most of the feedback to the students is provided by other students.

Lecture is seen as the fastest way for new teachers to be able to present the information, and deviation from almost 100% lecture is often discouraged since new and radical methods may be rather risky in regards to the student evaluation, a tool used to assess the teaching situation in an institution and its teachers. Poor evaluations will harm the national ranking of a department, but may often not reflect the validity of the teaching methods used, the efficacy of the faculty administering them, or the readiness of students receiving them. This said, classroom time means lecture, even though there is a wide spread use of PowerPoint and videos. Demonstrations are rare. Discussions, if any, are led by instructor, not facilitated.

Bottom line is that the teaching method is not interactive. It is often perceived even by more senior faculty that the amount of information they seem to have to transmit prohibits lengthy discussion. Without open discussion however, the student will stay in a bubble of taking in information and reproducing it at the time of assessment. Furthermore, students get more and more disinterested in the actual subject matter due to the side effects of the system. It is especially dangerous if this mindset is carried into a laboratory class. There, the student is all of the sudden asked to be a creative, critical thinker.

The one, correct answer exists and student creativity and ability to think outside the box is stifled. Labs are only as consistent as the manuals are, and students expect naturally that they will only need to follow perfect procedures with all information given. TAs change every semester which leads to little if any corporate memory engineering classes would benefit from. Technicians are rarely available to fix problems and assist in training the students on equipment. To some degree, the instructor often needs to be the one-stop shop for those reasons.

Our teaching method exhibits a departure from the status quo. People involved have to own the project.

First, the instructor has to buy in. The instructor needs to be willing to give up safety of a lecture method combined with teaching assistants who teach the messy portion.

Second, the department has to buy in. Very often, laboratory classes are given to new faculty, who are concerned with their tenure package down the road. It is suggested to involve tenured faculty who depend less on the ratings for such a core class, or faculty not concerned with the tenure clock such as lecturers. The latter group needs to receive some form of job security if the implementation of cutting edge teaching methods is desired.

Third, the teaching assistants have to buy in. One approach is to see applying new teaching methods for what they are: a project in need of management. The teaching assistants, though they still are students, have to understand themselves as project engineers who reports to the instructor and as coaches and facilitators to the student. They will hence handle equipment, literature and schedules in a project style and will hence learn valuable lessons for their existing and future employment.

Fourth, the students have to buy in. This bullet requires the highest people skill. It can easily be stated that an instructor without the proper people skills will not help develop students with this skill – rather, the students may react in a psychologically understandable, yet for the unknowing instructor incomprehensible and unmanageable way. Students have already signed up and paid for this weekly performance and have as high expectations regarding the class as the instructor has regarding student performance.

The idea is therefore to regard this portion of engineering student education as a project, and all parties involved as a team. Done right, this open class design with obvious outcomes will reflect on the potential and desired goal: a student who not only learns the material in a tangible from as this is a lab, but also a future employee, co-worker and even employer who understands teamwork and compartmentalization due to abilities and interests. Some supporting literature can be found here. [12345]

Our idea is best described in the following:

Contact with instructor is extensive and open, even online on a daily basis when possible. Teaching assistants stay longer than one semester to minimize retraining. Even if they do not, the instructor most certainly stays. Continuity is hence established by an involved instructor and carefully written material. Reports from previous years are being collected and lead to improvements: the instructor learns what the students have understood and are capable of, and the future students will have the resource of a pool of very good reports reflecting all possible styles. All possibilities of plagiarism are noted and can be counteracted against: the students will not obtain copies but rather be able to take a look, and software helps distinguish original work from that which is not.

Teaching assistants get small projects they can manage themselves. However, since projects are the 'in' thing to do in teaching, students do get overwhelmed by the vast number of projects on top of homework, quizzes and the likes. One student mentioned that a project adds a course on top of the courses, with students being ill able to coordinate their busy schedules and interests. And they do not like other students to have influence on their grade! Feedback between the professor and students is ongoing and dynamic, and flexible to protect the students while challenging them sufficiently.

Our classrooms are interactive; technology is used, but not overused. Discussions are facilitated by the instructor though driven by students. Occasional guest speakers will usually lecture; often give demonstrations which kick off discussions. Care has to be taken to select the guest speakers and the time commitment following this invitation. While the students often find a different angle interesting, another academic view may not be what broadens their scope. Wisely chosen industrial representatives, from a famous knife maker to production engineers, will positively add to the laboratory experience in relationship to the real world. It is absolutely necessary to give students the idea of purpose. Most engineers are 'made' in the lab and through internships. If they dislike that environment it is safe to say engineering is not for them.

The major assessment part in our laboratory class is the writing of technical communication, laboratory conduct and team interaction. While they will create a poster in their teams and later present it to the class and interested faculty, the main part of their grade stems from laboratory notes, laboratory and field reports, their student reviews, and the extend to which the students can implement reviewers' ideas.

Students can resubmit improved reports. This allows for the development of greater understanding by giving the students the opportunity to learn from their mistakes. All activities are assessed, and students receive personalized feedback. Students work in teams where they will fulfill changing roles on a weekly basis. More in-depth information to laboratory quality can be found in Ratliff. [6]

The Instructor functions not only as a fountain of knowledge but also as mentor to each student. The instructors are actively engaged with each student and monitor their progress throughout the course.

Summary of what has been achieved in our materials lab

A detailed plan for development of a prototype product or practice has been prepared. Educational practices generally regarded by the community as effective in enhancing learning are being incorporated into the prototype, or new approaches are being developed. An assessment instrument and/or an approach to evaluate the prototype's impact in improving student learning has been developed.

A prototype of a product or practice has been developed and made ready for testing. The prototype has been tested in a pilot program at the instructor's home institution. Documentation is being prepared so that others can test prototype. Presentations have been given (at professional meetings or other institutions) or articles have been published about the prototype and its potential uses, and/or it has been cited by others.
An outline of a plan has been developed for:
- developing the prototype into a full set of materials, including beta testing and evaluation of the product at diverse types of institutions and with diverse student populations, and
- commercial or other self-sustained distribution of a fully developed product or practice.

To satisfy ABET requirement that engineering graduates have an ability to function on multi-disciplinary teams, a 5 factor behaviorally anchored rating scale developed by Ohland et. al. was employed as a method for assessing team skills by peer review.[7]

Status of Data Collection and Preliminary Results

Our data was collected through the end of the fall 2004 semester. We are currently beginning both qualitative and quantitative analyses. Preliminary results indicate an increase in students' perception of their learning experience. Also preliminary results of the peer review indicate a low variability among student self ratings and ratings of team members.

Grade changes over the course of the semester: We are considering three major groups: students with significant improvement, students with significant decline of their grades, and students whose performance was stable. The grades issued included grades for four reports, partial grade for group performance, two group projects, lab notes, instructor evaluation, peer evaluation and the better one of two exams.

The assumption is that a very good student will perform well in any environment due to excellent adaptive skills, superior intellectual and analytical skills, and an enormous drive. On the same token, a student with significant and persistent poor performance will falter in even the most nurturing of environments due to self-imposed issues and problems outside the scope of the class or curriculum. Of interest here is the student between those two groups: they are the ones we need to address as here the teaching methodology makes a difference.

Of 28 students, there were x students with the following characteristics in addition to the ones named above: they provided their team with perspective, help and organization, and helped them identify with a certain team pride. Weaker students most definitely improved with this A+ student on their team.

Table 1: Student interaction leading to grade changes

Groups with x also contained y	A+	B (students benefits from setting)	I (independent)	S (stable)	D (could do better, resistant)	F (does not care, personal problems)
A+	1	3	1	0	2	2
B	3	1	1	0	2	1
I	1	1	0	0	1	0
S	0	0	0	2	1	0
D	2	2	0	1	0	0
F	2	1	0	0	0	1

Table 2: Extend to which grades changed: report grades

Number of students	Average	Improvements	Stability	Deterioration or Fluctuation
28	10% (one letter grade)	12	13	3

Table 3 is a summary of the following tables 4 through 8.

Table 3: Overall statistics utilizing the BARS tool

Statistics

		Contribution	Interaction	TRACK	Expecting	SKILL
N	Valid	9	9	9	9	9
	Missing	0	0	0	0	0
Mean		4.0333	4.2333	4.0889	3.9778	4.2556
Median		4.0000	4.0000	4.2000	4.1000	4.3000
Mode		4.00[a]	5.00	4.20[a]	3.00[a]	4.30[a]
Std. Deviation		.62249	.75498	.66792	.55403	.56593
Minimum		2.80	3.30	2.80	3.00	3.30
Maximum		4.80	5.00	4.80	4.70	5.00

a. Multiple modes exist. The smallest value is shown

Table 4: Contribution to the team

Contributing to the Team's Work

		Frequenc	Percen	Valid	Cumulativ Percen
Valid	2.80	1	11.1	11.1	11.1
	3.50	1	11.1	11.1	22.2
	3.90	1	11.1	11.1	33.3
	4.00	2	22.2	22.2	55.6
	4.20	1	11.1	11.1	66.7
	4.30	1	11.1	11.1	77.8
	4.80	2	22.2	22.2	100.0
	Total	9	100.0	100.0	

66.7 % of teams had an average rating above 4.0 for Contributing to Team's Work. A majority felt the team members did their fair share. This seems to be a major concern for some students as only an equal level of work by all team members offsets the fear of being dependent on others.

Table 5: Interaction

Interacting With Teammates

		Frequenc	Percen	Valid	Cumulativ Percen
Valid	3.30	1	11.1	11.1	11.1
	3.40	1	11.1	11.1	22.2
	3.60	1	11.1	11.1	33.3
	3.80	1	11.1	11.1	44.4
	4.00	1	11.1	11.1	55.6
	5.00	4	44.4	44.4	100.0
	Total	9	100.0	100.0	

55.5 % of teams had an average rating above 4.0 for Interacting with Teammates. A majority felt the team members interacted successfully with other teammates. Here, the personalities of the students had the greatest impact: who wants to go the extra mile for an A, who respects others for their skills and potential, who communicates even in high stake situations with pressing deadlines effectively. While no engineering class teaches any of this as a core principle, our students still have to learn to interact with others. There has to be space and time for these important learning experiences. According to our data, these students acquired and applied these skills comparatively well.

Table 6: Keeping Team on Track

Keeping the Team on Track

		Frequenc	Percen	Valid	Cumulativ Percen
Valid	2.80	1	11.1	11.1	11.1
	3.50	1	11.1	11.1	22.2
	3.70	1	11.1	11.1	33.3
	4.10	1	11.1	11.1	44.4
	4.20	2	22.2	22.2	66.7
	4.70	1	11.1	11.1	77.8
	4.80	2	22.2	22.2	100.0
	Total	9	100.0	100.0	

66.7 % of teams had an average rating above 4.0 for Keeping the Team on Track. A majority of teams felt the team members were keeping the team on track. The most effective students were especially praised for this ability by their teams, hence acting as peer role models.

Table 7: Expecting Quality

Expecting Quality

		Frequenc	Percen	Valid	Cumulativ Percen
Valid	3.00	1	11.1	11.1	11.1
	3.30	1	11.1	11.1	22.2
	3.70	1	11.1	11.1	33.3
	4.00	1	11.1	11.1	44.4
	4.10	1	11.1	11.1	55.6
	4.20	1	11.1	11.1	66.7
	4.30	1	11.1	11.1	77.8
	4.50	1	11.1	11.1	88.9
	4.70	1	11.1	11.1	100.0
	Total	9	100.0	100.0	

66.7 % of teams had an average rating above 4.0 for Expecting Quality. This indicates a majority of teams felt it important to do good work. Here the students who like to improve and achieve were a great reinforcement to the lessons taught: in their own teams and even beyond they were especially helpful. It was interesting to see that the quieter, more analytically thinking students often stepped up to the plate.

Table 8: Task related Knowledge Skills and Abilities

Having Task Related Knowledge Skills and Abilities

		Frequenc	Percen	Valid	Cumulativ Percen
Valid	3.30	1	11.1	11.1	11.1
	3.50	1	11.1	11.1	22.2
	4.00	1	11.1	11.1	33.3
	4.30	2	22.2	22.2	55.6
	4.50	1	11.1	11.1	66.7
	4.70	2	22.2	22.2	88.9
	5.00	1	11.1	11.1	100.0
	Total	9	100.0	100.0	

77.8% of teams had an average rating above 4.0 for Having Task Related Knowledge, Skills and Abilities. This indicates the teams were confident in the KSA's of their team members. Most students had the abilities to perform the experiments and analyze the data, and it is evident that the students had confidence in one another regarding skills and abilities.

Data shown and other more anecdotal evidence infer that the randomly chosen teams worked well together. Most of this comes from a sensible approach to dealing with this specific group of learners. The more controlled the environment, in the lab that is, the better the results. One weakness is the interaction of teammates which mostly happens outside the space and realm of the class. But even so, a majority of students felt they could interact effectively. The tool itself reportedly reinforced what students already knew, and helped put the team learning experience into a new light.

Table 9: Descriptive Statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Contribution	9	2.80	4.80	4.0333	.62249
Interaction	9	3.30	5.00	4.2333	.75498
TRACK	9	2.80	4.80	4.0889	.66792
Expecting	9	3.00	4.70	3.9778	.55403
SKILL	9	3.30	5.00	4.2556	.56593
Valid N (listwise)	9				

This represents the average rating and standard deviation across teams for each factor of the BARS scale. This shows certain variability among team scores indicating that students were giving each other feedback on team skills. This is suitable to support the anecdotal evidence of what students told the instructor about their building teamwork. The peer feedback indicates that teams are not just glossing over the ratings. From the Max-Min numbers it can be deducted that there is a significant variability among team averages. The team communication that some teams learned and maintained is exactly what is needed not only in the lab but more so later in the workplace.

Discussion and Outlook

Our study has shown that the proposed teaching methods and techniques foster teambuilding and a sense of ownership and responsibility for the projects. Students reported that the labs were more interesting and the use of the peer review instrument helped each student and team improve beyond the usual laboratories they have experienced.

Based on our results we would like to give an outlook on how we see the changes to the course curriculum develop.[89] One of the most important yet least quantifiable strategies is the implementation of mentoring. Mentoring requires people skills which cannot be placed on a CD. It will always require a person who interacts with another in a nurturing fashion. The following can only be a short list of suggestions to an instructor of what helped in this class:

1. Do not give out one single true answer. It does cause student frustration early on, but they will adapt if enabled to learn the necessary skills and if encouraged to apply them. As the instructor, you are helping create a student who cares about the answer and understands the problem. This student will be curious and motivated and will also refrain from black and white thinking.
2. Do help where appropriate. Let them think of at least two possible solutions. Give feedback. Let them work on the best possible solution, and do not dismiss an idea. Instead, give your student the chance to investigate and present a more grounded version to you.
3. Be there, and be ready and willing to help.
4. Know the students, their strengths, weaknesses and potential. If you treat them like numbers, that is what they are going to be.

We fully appreciate that this approach takes time. Most students will pick up on it quickly. Some will even assist in the process as senior students, while others will require more TLC.

Summary

This paper describes a complex approach to laboratory teaching combined with advanced team techniques, yet is rather qualitative in nature. This is especially due to the small number of students. The strength is the weakness: success mostly depends on the instructor and requires an intuitive approach. With experience, actual laboratory modules can be smoother, and with a sensible selection of teaching assistants the instructor will no longer have to wear as many hats. Overall, we find the approach demanding and fulfilling.

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