Empowering Cadets to take Ownership of their Learning Perspectives from the US Air Force Academy

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Abstract

Engineering faculty must not only facilitate learning the specific knowledge embodied by their major field, but also the progression of their students to higher levels of learning. Freshmen generally require significant guidance while learning core subjects of their engineering discipline. As students progress through their undergraduate program, courses require more synthesis of the core subjects to the solution of increasingly open-ended problems. Most engineering programs culminate in capstone design experiences for the students. Such capstone experiences are intended to be the ultimate expression of ill-defined problem solution for the students prior to graduation. A critical element in the student's maturation through the learning process is that they become, to quote ABET, "independent life-long learners". To this end, the Department of Engineering Mechanics at the US Air Force Academy adopted the title phrase as the focus area for their students or cadets as they are known. *Empowering cadets to take ownership of their learning,* when applied to the classroom, has nearly as many interpretations as there are faculty members. The following is a presentation of techniques tried by our department faculty to address the department's focus area and the results. Despite what often may appear as diametrically opposed approaches, each method has its own advantages and disadvantages. All methods provide key insights for engineering educators as they strive to produce the independent life-long learning engineering graduate.

Introduction

As a professional in industry, as a professor about to embark on a research proposal, or as an Air Force officer given a short-suspense (time critical) project, we seldom (if ever) have the opportunity to hear a lecture on our problem, project, or proposal. Instead, we are expected to solve it on our own, using whatever resources we can find! We know from experience to talk to knowledgeable colleagues, dig out relevant information from books and manuals, and perhaps even refer to an old long-forgotten undergraduate text and lecture notes. In short, we have learned the importance of *taking ownership of our learning.* We have learned how to learn.

Think back to your undergraduate days. In how many classes did you almost dare the professor to teach you anything? Remember the required humanities or political science course, taught by a boring professor, who droned on about topics that, you believed, had no relevance to your engineering major or future profession? Sometimes even a required upper-division engineering course fell into this category. Perhaps you felt, as many of our cadets do, that it was up to the instructor to show you exactly what you needed to read, learn, and do in the most efficient manner to maximize your course grade with minimum effort. If his lectures were entertaining, the text was

irrelevant, and homework was not mandatory, so much the better! But who was taking ownership for the (supposed) learning in that course? And how much from that experience can you use now?

At our traditional yearly overnight departmental off-site we all voiced our usual laments: "Cadets never read the text, they only want to learn what is testable, they claim to have forgotten all prerequisite course material, they want me to work more example problems just like those that will be on the midterm, they appear to be fragmented, with too many demands for their time separate from my course, they only average 10 minutes preparation outside of my class, etc., etc."

We all acknowledged the problem; we often had diametrically opposed potential solutions. As a result we decided on a *Departmental Focus Area* for the upcoming academic year: *Empowering Cadets to take Ownership of their Learning.* One of our goals was to have more cadets become, in the language of the ABET Engineering Criteria 2000, "*Independent life-long learners."* We wanted our cadets to be more comfortable with the ill-defined problem nature of engineering design. This paper is a progress report on what was tried, what seemed to work, what didn't, plus some preliminary conclusions and recommendations.

Challenges at the Air Force Academy

We are fortunate to have some of the most talented and academically gifted students in the nation. Average SAT scores are 625 Verbal and 650 Math [1]. However, we place many demands on each one of them, not just academically, but athletically and militarily as well. Cadets can chose to major in one of 30 academic majors ranging from astronautics to humanities. Those cadets who opt for one of our 8 ABET-accredited engineering majors will generally take considerably more individual courses than their civilian counterparts. Every cadet is required to complete an extensive academic core program consisting of 94 semester hours.

In addition to the required core courses, cadets who major in, say, mechanical engineering, will complete 17 majors' courses, for a total of 158 semester hours. Finally, all cadets must take 15 semester hours of physical education, military art and science and Air Force Operations courses, participate in either intramural or intercollegiate athletics, and have significant leadership responsibilities in their squadron. Is it any wonder many cadets appear fragmented when managing their time, and feel they must practice "academic minimalist" survival skills just to graduate? [2]

Unfortunately, this "academic minimalist" mindset runs counter to both our Air Force Academy Faculty Educational Outcomes and specific portions of the ABET Criterion 3 requirements. Both require our engineering graduates to become "life-long learners." In addition, the ability to "frame and resolve ill-defined problems" (USAFA Faculty Educational Outcome 5) and the ability to design (ABET Criterion 4) clearly require students to "take ownership of their learning [3]." It is against this backdrop that we began our academic focus area during the 1999-2000 academic year.

What we Tried

Since we had no consensus on what might work, each course director was given the latitude to try what he or she thought might work. In the USAF Academy system, the *course director* (CD) is responsible for day-to-day supervision of all course instructors, establishing assessment instruments and overall course policies. Our only requirement was for the CD to have some documented assessment of results and recommendations for the future. Here is a sample of what was tried:

- Homework – to require or not? To grade or not?
- Clear quantifiable course objectives, published and announced class day one.
- Lectures vs. required reading vs. hands-on demonstrations or a combination.

Homework

Assigning homework was clearly the most controversial. Some instructors believe that forcing a student to complete assigned homework is directly counter to the focus area of making students responsible for their own learning. Other instructors believe that homework assignments are no different from a proposal or project due date. If we miss a submission date, our research proposal cannot get funded. Shouldn't we expect our students to model that same responsibility level while in the classroom learning environment?

Six course directors experimented with homework in an attempt to assist cadets in assuming responsibility for their own learning. Of course, all instructors emphasized the value of homework in mastering the course material. All instructors provided a lesson-by-lesson set of homework problems keyed to the course syllabus. However, the collection and grading methods varied considerably by course. Here are the major subcategories:

- Homework assigned and encouraged, but not collected or counted toward the course grade. Instead, 6 quizzes, announced as exact replicas of homework problems, are given throughout the course (EM350 – Mechanical Behavior of Materials)
- Homework notebook collected twice a semester for 10% of course grade. (EM431 – Introduction to Finite Element Analysis, EM450 – Aerospace Composite Materials)
- Mandatory submission of graded Problem Sets every 10 lessons. (EM330 – Static Analysis of Structures)
- Infrequent collecting of daily homework (about once every 2 weeks, usually announced ahead of time), supplemented with in-class quizzes covering the course material. Homework submissions counted up to 10% of the course points. (EM120 – Fundamentals of Mechanics, a required core course taken by all cadets regardless of major)

- Regular daily homework submissions encouraged and counted toward 10% of the criterion-referenced course grade. (EM320 – Dynamics)

In all courses there was a strong positive correlation between homework submissions and subsequent performance on course exams. The best example comes from EM 450, a senior-level elective majors course, where homework was assigned with a due date for each assignment, but not collected until just before the mid-term exam. Most cadets put off doing any of the homework until the turn-in date. The work received was, in general, of very poor quality, with a number of notable exceptions. As shown in Figure 1 below, the correlation between homework and mid-term GR scores is fairly significant.

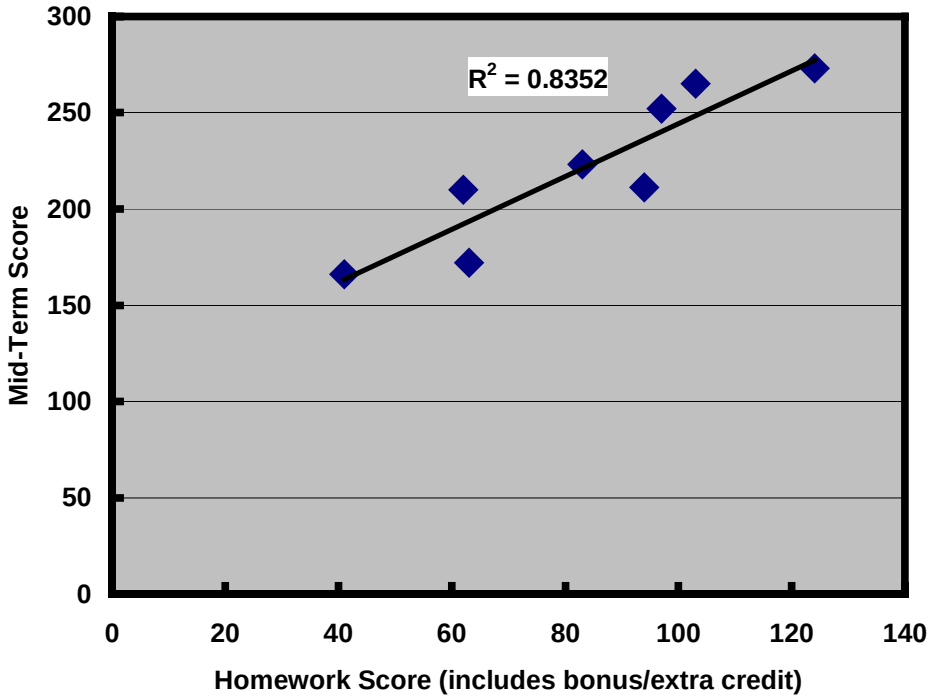

Figure 1. Correlation of Homework scores to mid-term GR scores

On his mid-course critique, the EM450 course director asked his cadets the following question, "If I were the course director, this is how I would handle homework assignments." He received the following somewhat predictable suggestions:

- More homework turn-ins throughout the course
- Be able to get help after an assignment is due (To preclude a barrage of the "last-minute unfaithful" cadets, all seeking help on homework due earlier, but not collected until mid-term, the instructor provided help until the due date for that assignment.)
- Homework blocks for individual subjects

- Individual's discretion – no mandatory turn-ins
- Pick up 4 or so at a time, but work more in class to save time. Devote a little time to working problems instead of every-day lectures.
- Leave it as is.

At the other end of the homework spectrum, the course director in EM320 rewarded consistent daily homework completion and submission. To receive the maximum number of points available (up to 10% of the course points), cadets submitted a minimum of 25 daily homework problems. There were usually 4 homework problems assigned for each lesson, and the instructor would announce and collect a specific problem at the beginning of each class for those who chose to hand the problem in. Cadets were encouraged to work together on the homework problems, and the instructor was available for the second hour (essentially a voluntary recitation period) for extra instruction. For the final grade the best 25 homework submissions were used to compute the course points.

At first, the EM320 instructors were concerned about their potentially heavy homework grading load. To streamline grading they adopted and published the following 4-point homework grading criteria:

4 points: Problem is coherently solved, straightforward to grade, and essentially correct, including units.

3 points: Problem is started correctly, correct FBD (free body diagram), etc., but has one or more errors

2 points: Problem is started correctly, correct FBD, but little else.

0 points: Incorrect format, sloppy work, difficult to follow work, more than one problem per page, etc.

Cadets soon realized that there was little value (point or otherwise) to handing in anything other than essentially correct homework solutions. All problems had correct answers posted on the course web page, and those cadets who stayed for the recitation period found they could complete all homework problems for the previous lesson very efficiently. More importantly, they were learning difficult dynamics concepts efficiently.

When questioned at the end of this course, most cadets either agreed or strongly agreed that the daily homework policy was an effective strategy for them to take ownership of their learning. They also evaluated the other "ownership strategies" which were tried in this course. Figure 2 depicts our top 7 strategies:

Ownership Strategies	Student Critiques 5 point Scale
Having the instructor during the voluntary second hour recitation period	4.86
No quizzes or exams other than published in the syllabus (i.e. no pop quizzes)	4.46
Daily homework policy	***4.40***
Boardwork by students during class instruction	4.29
Short Lectures	3.57
Criterion-referenced grading (no curve)	3.38
Reading the textbook prior to class	3.35

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Figure 2. Subjective cadet assessment of EM 320 ownership strategies.

In summary, it appears that learning is enhanced if there is a strong course expectation and incentive for daily homework submissions. Interestingly, even though surveyed cadets agreed that daily homework submissions helped them take ownership of their learning, many instructors oppose daily homework submissions as not giving cadets a real choice to keep up with daily homework. In addition, many instructors are concerned with the increase in their grading workload. While not a panacea, daily homework submissions may be most appropriate for those engineering science courses like dynamics, where practice with example problems is essential to understanding and applying the underlying fundamental concepts.

Course Objectives

With the advent of the ABET Engineering Criteria 2000 requirements for assessable, mission-specific Program Educational Objectives and Program Outcomes, our course directors were expected to develop measurable objectives for his or her course. These course objectives would be clearly stated in the syllabus, briefed to all cadets on lesson one, and used to develop all course exams and projects. In other words, if a proposed exam question or course project could not be traced to a published course objective, it would not be asked or assigned.

Well-written course objectives give the student a clear set of expectations, and provide a guide for mature students to assume responsibility for their learning. Course objectives also provide an important assessment instrument for determining whether the students are receiving the expected “value added” from the course.

We believe the up-front expectations embodied in the course objectives have helped cadets assume ownership of their learning. There are no surprises in our courses, and cadets seem to appreciate that fact. We often remind cadets to prepare for course examinations by reviewing the appropriate course objectives, and also conduct exam "post mortems" by highlighting the course objectives that were tested. Finally, in the Course Review Package and at the Course Review Meeting, the course director is required to document and brief how well the cadets met the various course objectives.

Lectures

Polished class presentations by instructors have been a hallmark and source of pride for Air Force Academy instructors. Our Center for Educational Excellence continually provides workshops and outside speakers on techniques to improve classroom presentations. Unfortunately, cadets have learned from experience that the important material will be covered in class, and that reading the course text prior to class is unnecessary. So, we appear to be on the horns of a dilemma: the better we present material in class, the less motivated cadets are to learn on their own. Here are three attempts to address the problem:

- Posting instructor lesson notes on a personal web page so those who miss or want to check against their own notes can do so. The idea here is that cadets will use this resource to help fill in the gaps in their learning instead of just asking the instructor for help. There is the potential that cadets will participate more in class discussions instead of just taking notes. The downside is that it could encourage them not to take any notes in class at all and just not pay attention, or skip reading the text entirely and just read the lesson notes.
- Focus in-class instruction on the "why" vs. the "how-to." For example, show/motivate the "why" of shear stress due to a torque ($\tau = T\rho/J$). Let them figure out some of the "how to" (e.g. to calculate J., see reading) on their own.
- Provide the cadets with a readable, commercial text. Use the text as a guide to developing the course syllabus. Limit the lecture to difficult concepts, and clearly state the expectation that students will come to class with specific questions on the reading assignment for that day. Use the cadet questions to guide the "lecture."

All three strategies have been tried. Unfortunately, assessment data is difficult to come by, and is principally subjective by both student and instructor. The strategies also appear to be heavily instructor-dependent, with the third technique requiring a fairly confident, experienced instructor. This third technique is essentially the "Thayer Method," developed by Sylvanius Thayer, the "Father" of the military academy at West Point, where every cadet "recited" every day in every class. While probably not appropriate where class discussion or group design is a major component of the course, the Thayer Method appears to be particularly appropriate in lower-division engineering science courses such as statics, dynamics, and strength of materials. From personal

experience, a quick 10-minute overview lecture, followed by cadet individual boardwork, is a very effective recipe for learning and rewarding cadets who come to class prepared!

Conclusions and Recommendations

As previously observed, implementing what seemed to be a relatively straightforward department focus area spawned a plethora of interpretations. While the implementation methods presented here may seem to contradict each other in teaching pedagogy, each had its successes. In fact, we as educators have one constant fact proven to ourselves time and time again – there are no constants. As engineering educators we work long and hard to help our budding future engineers develop the ability to be true problem solvers.

Here are a few general observations:

- Of the three sample student ownership strategies discussed in this paper, only one (Clear, quantifiable, published and announced course objectives) appears to have useful application independent of either the course or the student cohort. Having students guess what the instructor expects from them is NOT an effective learning strategy.
- Use of daily homework as an ownership strategy appears to work best when used in a "learn by practice" course such as dynamics, where lesson content is usually brief, but students cannot effectively learn simply by vicariously watching the instructor work representative problems. Instead, they must learn by "discovery," that is, by trying many homework problems individually and with peers. In other courses, particularly hands-on courses with considerable design content, the students see mandatory daily homework as a "turn-off." On a related theme, students appreciated having all quizzes and exams announced ahead of time in the course syllabus, presumably so they could plan their study appropriately. There was general disdain for the pop quiz as a coercive way to force lesson preparation.
- Instructor delivery techniques are dependent on a number of variables, including level of student academic maturity, nature of course material, and experience level of the instructor. All of these variables can interact in unusual ways to either enhance or detract from the student's desire to take ownership of his or her learning. What works in an upper-division course might be a failure in a required core course.
- According to cadet survey responses, instructor availability for extra instruction and help with assignments outside of class is one of the most effective ways of empowering cadets to take ownership of their learning.
- The degree to which students are self-motivated toward their chosen field of study makes a significant impact on their interest in taking ownership of their learning.

In conclusion, there is no “one size fits all” technique to empower our students to take ownership of there learning. However, we as engineering educators need to recognize the importance of helping our charges become independent life-long learners.

References

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[2] Curriculum *Handbook 2000-2001,* United States Air Force Academy, 60.

[3] *2000-2001 Criteria for Accrediting Engineering Programs - Engineering Criteria 2000,* Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Inc., 32.