The F Word in the Classroom: Fail and Learn

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Introduction

Each semester, I pick one or two bulleted points in our college mission statement and develop new exercises to address them. Five years ago, I chose, “preparation for lifelong learning and professional development.” The behaviors I associate with lifelong learning involve regular reflection on and assessment of failures and successes as well as devising plans for improvement. Students need to examine their own learning and thinking processes, practice learning from failure, and embrace continuous improvement. Such skills are essential in professional practice, but young people are often reluctant to use these opportunities for learning. I searched for a way to encourage these traits and developed an exercise where students explicitly practice these processes. They conduct the exercise after each of two major exams in my courses.

The process consists of three parts. First, students correct their exam. Second, they conduct a “failure analysis” of their mistakes to examine why they made them. Finally, students create an “avoidance strategy” to minimize the likelihood of repeating the same (or a similar) mistake. They submit the corrections along with comments documenting the process. Many instructors use the first step – correction – in their classes. I used to stop there, or sometimes retested on the same material. The real key to improvement, however, has been inviting students to follow through with the failure analysis and avoidance strategy - making the entire self-assessment and improvement process explicit. The exercise is voluntary, but virtually all students participate.

Objectives

In addition to the lifelong learning goals listed above, the exercise addresses two other goals of the college and our petroleum engineering program; improving critical thinking and encouraging leadership behavior.

Implementation

I first used this three-part exam correction exercise in an introductory Statics course. It was so successful that I now use it in all of my courses, including Strength of Materials, Fluid Mechanics, and Thermodynamics. Students majoring in Petroleum Engineering at Marietta College take all four courses and develop reinforced expertise at this kind of self-assessment.

There are two midterms in each of these courses. By completing the exam correction exercise, students recoup as many as one-half of the points lost on the first midterm and a quarter of the lost points on the second. There is no opportunity to correct the final, but students use their analyses of the first two exams for study.

For the first step of the exercise, students need to correct the mistakes on their exam. I allow them to use any resources to find an acceptable answer, including discussions of the problem with other students and asking me for advice. If the problem is not reworked correctly, no credit is allowed as the follow-up steps are likely to be invalid.

The second part of the exercise challenges student performance; finding what "caused" the mistake(s). Students need to recall and reflect on their own thinking during the exam. They also need to think about their study habits and learning styles. There is a tendency for all of us to avoid thinking about our failures. We can help students to be more comfortable about reflecting on their mistakes by taking some of the stigma out of failure. To this end, I give an early reading assignment in Statics - Vicky Hendley's article, "The Importance of Failure."[1] In the article, Hendley lists examples of failures that led to great successes, discusses the importance of learning from failure, and introduces issues in ethics and professional responsibility. By noting that a mistake offers more opportunities for learning than a successful answer, students are less likely to be averse to examining their mistakes.

Henry Petroski writes, "Treating every case of failure as an opportunity to test hypotheses, whether imbedded in design or in theories about the nature and process of engineering itself, makes even the most ancient of case studies immediately relevant for even the most forward looking of technologies."[2] These exercises, in contrast to the studies of structural failures that Petroski discusses, encourage students to examine their own thinking and learning processes to improve their performance. They use their own exam as a case study and can perform a failure analysis on it.

Initially, students tend to develop very shallow analyses. Unless I emphasize the need for a deep analysis of their thinking, their resulting causes for the mistake will be statements like "I didn't study enough" or "I ran out of time." I inform them these represent symptoms rather than causes and they need to examine their thinking, learning styles and study habits closely; that is, they need to find root causes. I advocate the *five whys* [3] technique for examining a cause. Consider an example of inadequate reflection leading to an unhelpful cause - the student response, "I didn't study enough." To help find an avoidance strategy the student needs to dig deeper. Using the five whys technique, the student continues by asking herself the question, "Why didn't I study enough?" Suppose the answer she thinks of is, "I went out on a date the night before the exam." She asks, "Why did I go out on a date the night before the exam when I needed to study more?" She answers, "Bob is good looking. I really wanted to get to know the guy better and thought I could get by on the exam." She asks, "What made me think that?" She answers herself, "I did well on the first two quizzes. Maybe that made me overconfident. I had trouble with the homework

problems in section 5-7 and that is just the material that I messed up on the test. I could have focused my study on that section, used my time more efficiently, and still gone on the date." You can see that the student now focuses on her behavior in enough detail for a meaningful analysis. She may stop with this answer or continue the process to see where it leads. Five is not a magic number, but often five questions are enough for a rich source of information and to discover one or more root causes. Another example of the five whys technique is given in the addendum at the end of this article.

Once the second stage is finished – one or more well considered root causes are uncovered for each mistake - it usually points to good solutions for the third stage - effective avoidance strategies. These may be as simple as a checklist to aid a student's memory in a stressful exam situation or a determination to ask for help the next time the student doesn't understand a concept. A student may find that significant changes in study or work habits are needed.

Results

Since implementing this strategy four years ago, Marietta College students display better mastery of the difficult material in my engineering science courses: Statics, Strength of Materials, Fluid Mechanics, and Thermodynamics. For example, my Statics students seem better prepared for the later course in Strength of Materials. They make fewer sign mistakes, confuse trigonometric functions less often, and sketch less ambiguous diagrams for their work.

One way I see leadership behavior involves engineers visualizing a desirable future, considering strategies for making changes, and converting their thinking into action. By creating and implementing avoidance strategies, students practice thinking about future behavior and convert the thinking to action.

According to the Foundation for Critical Thinking, "Critical thinking is, in short, self-directed, self-disciplined, self-monitoring, and self-correcting thinking."[4] These self-reflecting exercises contribute to the students' growth as critical thinkers. They take responsibility for evaluating and changing their own thinking and behavior.

I don't have quantitative assessment data, but I regularly seek student reactions to these exercises in class evaluations, reflection papers, and informal question sessions. The response is unanimously positive. Students start out motivated by the extra points, but many come to appreciate the learning that the exercise creates, a few apply this method in many of their courses with other instructors.

Though I end up grading each exam twice, the second time goes quickly as there is less test material to evaluate and few mistakes at this stage. The failure analyses and strategies for improvement also need to be evaluated. This takes significant time in the beginning because there is a learning curve for these analyses. Efforts to reduce the time expenditure resulted in refined written instructions and oral explanations. Explaining these correction processes requires

significant class time in addition to the extra homework. You could argue that this time could be used for covering additional subject material but I believe that it is a valuable investment in lifelong learning.

Conclusion

With practice, students learn to provide a very thorough analysis of their mistakes and offer highly creative avoidance strategies. Their oral feedback remains positive and enthusiastic. Remarks in their reflection papers lead me to believe that they take these opportunities to examine their own thinking seriously. I believe that the exercises promote habits for lifelong learning and the skills learned translate into more effective professional development in the students' careers.

Addendum - An example of student handouts

Exam Corrections – Guidelines

Habits for Lifelong Learning - Form the habit of learning from your own mistakes and those of others. Develop and practice strategies to improve your learning processes. These techniques will enhance your career as an engineer/scientist/problem-solver.

We all make mistakes when we solve engineering problems. Why? Lack of attentionto method, misunderstanding the problem, confusion about the theory behind the possible solutions, aresome of the reasons. Practice helps. Practice, with close examination of our mistakes is one of the richest sources of learning. Recall Vicky Hendley's article on the importance of failure.

To examine your performance and reclaim credit on the two midterm exams in this course: correct the mistakes you make, perform a specific "failure analysis" for each mistake, and develop strategies to avoid each of them in the future. You may earn back one-half of the points you lost on the first exam and one-fourth of the points lost on the second.

First **correct** your mistakes. You will receive no credit if you make further mistakes in the process of correction. The original exam needs to be turned in along with the corrections, analyses, and strategies.

In addition to the corrections, **analyze** your studying and test taking behavior to understand why you made each mistake. You need to analyze what you were thinking at the time andwhy you were thinking it. Be thorough. Many students short-circuit the thinking process and come up with inadequate reasons for their mistakes. "I didn't study that," "I didn't study hard enough," and "I didn't have enough time" are some examples of responses that will not help to devise avoidance strategies.

Dig deeper. Did you think that the subject would not be covered on the exam because the professor said that this would not be covered? Did you miss a class and one of your classmates tell you that this section would not be covered on the exam? Did you make a sign mistake on the problem because you misinterpreted the drawing illustrating the problem? Why did you misinterpret the drawing? What was there about the drawing that confused you?

Analysis is a difficult but critical step. A technique called "the five **whys**" may help. Ask yourself, "**Why** did I make the mistake?" The answer might be, "I ran out of time." Continue. Ask yourself,

"**Why** did I run out of time?" The answer might be, "I spent too long working on problem three." Keep digging. Ask yourself, "**Why** did I spend too much time on problem three?" You might reason, "I thought problem three looked hard and I was determined to get an answer." Continue in this vein until you come to one or more *root causes* of the mistake. It may be that you need to schedule a certain amount of time for working on problems and if you haven't finished, move on. Ask as many questions as you need to come to a reason that you recognize as a root cause. Often five whys will get you there. Engineers call this process *failure analysis*. If you don't get to the root cause, your proposed cure is likely to be superficial and ineffective.

Once you discover the root cause, you are ready to think about ways of avoiding similar mistakes in the future. **Create** an avoidance strategy. For example, suppose you have made sign mistakes on the exam. One avoidance strategy would be to reserve time to go back and double check for signs in your calculations. Another possibility might be to put a check list on your formula sheet that included a reminder to check signs.

Corrections, failure analyses, and strategies are due the first class meeting after the graded exams are returned.

Bibliography

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4. Richard Paul and Linda Elder, *The Miniature Guide to Critical Thinking: Concepts and Tools*, The Foundation for Critical Thinking, Dillon Beach, CA, 2001, p.1.

Biography

David Cress has degrees in Physics, Metallurgy and Environmental Science. He is Associate Professor in Petroleum Engineering at Marietta College and has been teaching there for more than twenty years. In addition to engineering courses, he teaches a course in science, technology and society. He has research interests in systems of technological innovation, methods of encouraging students' creativity, and intellectual property issues.