

Teaching Reflective Skills in an Engineering Course

David Socha^{†§}, Valentin Razmov[§], Elizabeth Davis[†]
[†]Center for Urban Simulation and Policy Analysis
[§]Department of Computer Science & Engineering
University of Washington

Abstract

One of the most effective tools for lifelong learning is the ability to reflect and learn from experience. Reflection helps to clarify our understanding of the world and to create new distinctions and possibilities for the future. It is a way of creating intention. By putting attention on the perception of what has happened and what one wants to achieve, solutions to problems emerge more easily. We believe reflective skills are among the main characteristics that distinguish excellent engineers from merely good ones. This makes these skills important to teach.

This paper describes a set of reflective practices that we implemented in a 9-week course in software engineering at the junior undergraduate level. These techniques, many of them borrowed from professional leadership training programs, include individual, team, and project practices such as retrospectives (e.g., “What went well and what didn’t?”), informal chats with guest experts (e.g., “Do they really do it that way in industry?”), workshop simulations (e.g., “How do we decide when to ship a product?”), journaling, and some unusual activities (e.g., “Draw a picture of your team”). To gauge student progress we also used weekly reflective writing assignments as well as reflective questions on the take-home final exam. All of these techniques were well received by the students, as evidenced by anonymous, detailed end-of-course evaluations, as well as by feedback many students voluntarily provided four months after the course. Many have continued using several of the techniques after the course. The experience of applying reflective practices appears to have influenced a number of the students into viewing their project, careers, social interactions, and life choices in a different, more positive light.

We believe the practices worked particularly well because we set up the course with ample opportunities for students to make mistakes – a fodder for reflection – and learn from them in a non-threatening (academic) environment. While we recommend the approach to engineering educators interested in teaching “soft skills,” we caution that to successfully apply it, one needs to be comfortable identifying and handling conflict that may emerge.

1. Introduction

This paper describes a set of reflective practices that formed the backbone of a 9-week software engineering course at the junior undergraduate level. We report on our, and our students’, assessments of the effectiveness of these practices. The data were collected during the course, at the end of the course, and four months after the course.

One of the main goals we set for the course was to teach a set of team and project practices necessary for doing engineering projects effectively. Assessments like ABET¹ and our own industrial experience show that being skilled at doing these practices is highly valuable for enabling software engineers to be successful.

We believe experiential learning²³ is one effective way to teach these skills. It requires that students continually go through a learning cycle: practicing, reflecting on the difficulties, discovering new models (or having them introduced by facilitators or other students), and then practicing again.

In order to create an effective experiential learning situation within an academic context, we designed the course around several strategies:

1. *Project-based, a single large team.* To force the students to deal with team and project coordination issues that smaller teams might ignore, the course was designed to revolve around a single project with *all* 22 students working in a single team for the duration of the quarter toward the completion of that project.
2. *Teaching with our mouths shut.* To maximize the chance for student learning, instructors focused on being facilitators within an experiential learning environment, and on teaching by example. Instructors provided some project requirements*, choices, observations, facilitation, and minor guidance. After an outside marketing expert presented the requirements for the product, the students had the freedom and responsibility to run and manage the entire project, including deciding what to do when they did not know what to do.
3. *Reflective practices.* To maximize student learning, we embedded this project within a system of many individual and team reflective practices.
4. *Resembling real life.* To maximize the practicality of what students would learn, the project was done in an environment as close to that in industry as possible within the constraints of an academic 5-credit course. The main exception was that, in the spirit of academia, student learning was emphasized as more important than project success and there was no real customer[†].
5. *Expert practitioners.* To ground our assessments of what an engineering job demands and to help students appreciate the diversity of needs of different constituents, we had eight class sessions in which outside expert practitioners led experiential simulations or told reflective stories of their work.
6. *Need-for over how-to.* To fit within the constraints of a 9-week course, we were more

* We restricted the set of development tools so that (a) students would not spend much time on that choice, and (b) we could provide them with an industrial level set of development tools.

† We would think very carefully before having a *real* customer for such a course, because this would increase the cost of failure, which in turn may prevent students from taking risks and trying something new. Academia is *not* the real world, and it may be best to use that to our advantage by doing things that are not easily done in the real world, such as encouraging students to focus on learning *even if it may lead to project failure*.

concerned with teaching need-for than how-to knowledge. The need-for is about appreciating the need for some type of action, while the how-to is about how specifically to perform that action effectively.

The effect of applying these strategies was encouraging. We were initially surprised by how many students readily provided us with feedback four months after the course was over. University-wide statistics show that typically only one or two students in a class of 20 or more respond to queries after the end of a course. We had a 45% response rate and nearly all students were very positive about their experiences. To us, this indicates that they appreciated the significance of the course for them personally.

Of the wide range of reflective practices we experimented with, several seem to have made a lasting positive impression on students. Nearly all of our respondents said that they continued to write in private journals regularly and found it rewarding, and more than half of them also practiced team conversations, team retrospectives, and the awareness of personality types in their interactions with colleagues.

Since the feedback we received was in response to questions about the techniques we applied in the course and the reflective practices we introduced but not the actual course material, and since nothing about these practices seems domain-specific, we believe they can be successfully applied in courses in other engineering disciplines.

Next, in Section 2 we provide some background and lay out our basic approach to designing this course. Section 3 outlines the reflective practices around which the course skeleton was built, with more details following in Sections 4 through 6. Finally, Section 7 reports the results from the feedback students gave us and concludes.

2. Our Approach

Many courses have taught reflective practices^{7, 17}, of which there are many different types. In our course, we experimented with a few that stand out as being particularly valuable for a wide range of people and circumstances. These practices include journaling, targeted reflective essays²¹, portfolios, retrospectives, and story telling.

Journaling helps an individual to clarify what has happened and learn about themselves. Targeted reflective essays help the writer derive value from the exploration of a specific question. Portfolios help to build a sense of accomplishment as items accumulate²². Retrospectives help teams to clarify what has happened and learn how to operate better. Finally, story telling helps people learn from the reflections of others.

The teaching style and structure of the course reported on in this paper were strongly influenced by our industrial experiences. Software engineering is about people working in teams on projects to create value for customers. While tools and the “hard skills” are important for software engineering, it is well known that projects almost never fail solely because of technical limitations. Yet, even though the lack of “soft skills” leads to so many project failures, teaching these skills is largely missing from the curricula most engineering students go through. Our goal therefore was to plant the seeds that would enable the students in our course to start and stay on the path toward becoming effective in dealing with real-world projects.

In particular, we consider the following five skill domains to be invaluable for effective engineers:

- Reflective skills (for lifelong learning)¹³
- Team skills (for working with people)³
- Project skills (for navigating projects to success)¹¹
- Value skills (for increasing value in every step of building a product[‡])^{2, 26}
- Design skills (for discovering and building good designs)²⁵

These “soft skills” are necessary to effectively apply the “hard skills” traditionally taught in engineering courses¹. While an individual does not need to be proficient in all of these –that is why there is value in working in a team – the most effective professionals we know are very good at all of them. At the least, for someone to be effective in a team environment, they need to appreciate and respect the need for soft skills in their team.

In some way, reflective skills are the most “fundamental” of the above five types of skills. Reflective skills help one improve in *all* skill domains, whereas the same is not true for the other types of skills. For this reason, we put much attention on reflective skills in our course. However, we caution that while they are necessary, they are not sufficient for lifelong learning in any skill domain.

Creating competence and mastering in these skills takes longer than a single academic quarter. Furthermore, the “right” way to implement them depends on the context, so even if we had taught a right way, that way might not have been applicable to a future situation a student faced. Thus, we were more concerned with teaching students by example to develop an appreciation for these skills than with teaching them the specifics of each skill set. We aimed to create an environment in which students had ample opportunities to practice *and learn from* the mistakes they had made while practicing. Reflection is an essential component of this learning process.

We included a variety of individual and group reflective practices and exercises. A student can apply individual reflective practices in private to help understand what has happened and to create intention in their life. However, that individual view is often limited by what is possible within that student’s set of stories about reality. Team reflective practices leverage the diversity of the group stories about what has happened and what is possible in order to create a much richer design experience and understanding; the cost of this is the higher overhead to the team.

Providing a range of techniques allowed each student to assess which practices worked best for that student’s personality and background, as well as for different situations they might encounter. Different people may learn better through different types of reflective practices. Typical introverts⁸ may prefer the privacy of a journal to participating in team retrospectives, while extroverts may be more effective the opposite way. Writing and talking use different parts of the brain. Many people think better when they are physically active²⁰.

[‡] This includes increasing the value all along the chain from raw materials to finished customer product. While ultimately this increases the value to the customer (by lowering prices), it also increases the value to the company (by bringing higher profits), to the employees (by resulting in higher satisfaction), and to the environment (by producing less waste).

While we experimented with many reflective practices with the goal of covering a wide variety of individual learning styles (our specific choice of techniques being based upon our experience and the limited time in the course), several of these techniques proved to be valuable to many students.

The next four sections discuss the set of choices we made and the practices we implemented in the course. They include background on each of these, as well as our assessments of how well they worked, and results from the student feedback we gathered.

3. Designing the Course around Reflection

For students to learn and for their learning to last, they must be engaged in the material. We expected some resistance to learning “soft skills” because most engineering students had gone through their academic lives largely by working on their own and so had become accustomed to this individualistic style. Thus, we employed several principles to try to awaken the students to the importance of these skills, though in some cases that realization did not come until late in the quarter (or perhaps not at all). Many of the principles we discuss below were motivated by trying to create an environment as close to industry as possible within the constraints of a university class in order to maximize the learning of software engineering in action.

The principles behind our course design were:

- Reflective practices require time and practicing.
- Large teams force students to deal with team and project coordination, which leads to breakdowns and thus creates material for reflection.
- Experiential learning provides material for reflection.
- Reflection supports the development of key skills in all domains.
- For students to benefit from reflective writing, it helps to put them in a situation where they have to struggle enough, but not too much, to collect material for reflection¹⁸.

From these principles we derived the following major course elements that were to promote reflective learning:

1. Pre-course setup
 - a. Increased length of class sessions
 - b. Availability of both a lecture room and a computer lab during class times
2. During the course
 - a. Setting the tone for lifelong learning in the first class session
 - b. Journaling
 - c. Starting and staying on the path to mastery
 - d. A single large team working on the project
 - e. Team conversations
 - f. Weekly reflective essays
 - g. Experiential simulations & Expert practitioners telling stories
 - h. Retrospective sessions
 - i. Grading

3. End-of-course closure
 - a. Personality types
 - b. Portfolios
 - c. Peer reviews
 - d. Final exam

The following sections describe these elements in more detail. Appendix 1 summarizes them and other reflective practices we experimented with in the course.

4. Pre-course Setup

A couple of elements helped structure the course to better accommodate our mix of project work and experiential simulations.

Increased length of class sessions

The first adjustment came before the course started. David changed the course logistics from the usual weekly schedule of three 1-hour lectures and one 1-hour quiz section to three 2-hour sessions so that we could allow sufficient time for simulations.

A simulation is an experiential learning situation carefully crafted for a specific learning outcome and controlled by a facilitator¹⁹. We believe a simulation ideally has at least the following sequence of stages: an introduction, a period of acting in the simulation, a reflective debrief, another period of acting in the simulation, and a final debrief. One hour does not give sufficient time for this. Three hours seems to be the ideal length¹⁶ but for practical reasons we settled on 2-hour periods. Now, given the benefit of hindsight, we suspect that having yet another hour would have further improved the learning process since the level of interaction and engagement tended to still be rising at end of each 2-hour simulation session. This observation was also supported by feedback from one of our students.

Availability of both a lecture room and a computer lab during class times

We also arranged for the course to have both a standard lecture room and a computer lab available for all class sessions. This allowed us the flexibility to choose the most appropriate environment as needed. Simulations typically benefit from a flexible seating and desk arrangement, while project work sometimes benefits from in-class time spent working on computers where instructors can observe and facilitate.

5. During the Course

This section lists the reflective techniques used throughout the course. Most of these were introduced in the first week of the course.

Setting the tone for lifelong learning in the first class session

The beginning of a course is an important time. Students are fresh from the recent break. How the class starts sets the tone that lasts for the duration of the course. The first session was devoted to the course structure and the reasons behind it. We began with a discussion using some reflective questions from *Teaching with Your Mouth Shut*⁴ to uncover the learning cycle model²³ of experiential learning upon which we based the course. This learning model, very similar to Kolb's¹⁹, explicitly includes reflection as a necessary component of learning. As we

told the students, they would be repeating the cycle of doing and reflecting over and over again, both in sessions with outside experts facilitating simulations and in the project itself. The purpose of this first session was to put reflection foremost in the students' attention.

We informed students that they would be required to make most of the decisions in the class project. It was theirs to organize and run. We, instructors, would largely teach with our mouths shut, primarily acting as facilitators and providing feedback on homework and on the state of the project. We would *not* tell them how to do the project. As expected of people not used to experiential learning (in an academic setting), this disconcerted many of the students, but they gradually got used to this freedom and responsibility.

We also outlined the five skill domains listed above and grounded the importance of these with stories from our own experience in industry as well as using quotes from other industry practitioners.

Of course, these were merely words, and some students did not believe us until the project was well underway and they had experienced the problems of not using the soft skills. In week six, one student apologized to David for not having believed him earlier in the quarter.

One omission from the first session was our grading scheme (see Section 6). We provided this in the second week. It emphasized learning and de-emphasized whether the project would be "successful" in providing value to the customer. Nevertheless, the students acted as if their success would be defined by whether their project worked. It was not until the second to last week that a student asked about our measure of project "success." Our response started with "We've been wondering when someone would ask that..."

Journaling

The first session also introduced journaling – a lightweight and particularly effective mechanism for individual reflection. The act of choosing words to express our thoughts helps to clarify them. Writing in a private journal is a safe and often effective way to get an insight into a situation, since it tends to reduce the emotional load and thus makes it easier to understand the issues. The privacy also reduces the need to prove something or defend one's actions. Instead, it allows a student to focus on creating an honest assessment of a situation. In particular, writing about uncomfortable experiences often reveals that they were not as bad as they felt or uncovers ways to deal with them. This is less likely to be the outcome of talking to someone else unless that person is both a close and wise friend.

We required each student to use a physical journal to record their reflections during the class. We find many good reasons for using a physical journal. Writing by hand uses different muscles than typing and thus promotes different ways of thinking that in turn helps to construct new knowledge. A physical journal promotes writing down (versus continually revising), so students can work more on the concepts and less on reformatting the expression of a concept. Despite the latest advances in technology, the physical page remains a much richer and more accessible medium[§], making it easier to sketch diagrams or draw pictures. Finally, physical journals form a

[§] For a thought-provoking description of the social aspects of paper see Gladwell⁵.

more stable historical record.

We wanted the students to write often enough to start seeing the value of journaling. Since we could not force them to write in journals outside of class, we dedicated the first and last five minutes of each class session to this activity. David led by example, demonstrating the importance of journaling by purchasing an expensive leather-bound journal and writing in it while students wrote in theirs.

We instructed students to “write about whatever is important to write about at that moment.” We do not claim that this is preferable to the more structured approaches other educators have taken but it did not restrict the students’ own choices and so allowed them to develop their own styles. More importantly, it implied that a journal could be used for reflections on anything in their lives, not only on course-related issues. We believe this is essential because school is just one venue for lifelong learning, and a temporary one at that. To us, of higher importance was to instill the practices that would help these people become and stay lifelong learners.

One of the difficulties of using experiential learning in a classroom is judging when to leave students alone and when to intervene. We tended toward allowing them more freedom – something that many appreciated later, even if it caused them some discomfort at the time. By letting them run the entire project, for instance, we allowed students to challenge themselves as they felt appropriate. Another aspect of freedom we allowed had to do with journals.

The journals were private. We considered whether we should ask to read the students’ journals in order to provide feedback and observe their thoughts, but decided against that so that the students could freely express themselves (even if their writings contained criticisms of the instructors). We felt this freedom to write anything without having to think about who would read it was more valuable than the feedback we could provide on their journal entries, especially since we were going to provide feedback on their weekly reflective essays submitted to a public forum. We believed privacy would increase the chance that they write about what matters to them in as open a manner as possible, even if these issues had nothing to do with the class. For instance, one of the students became a “converted” fan of journaling about half way through the course after writing about a sibling’s problems greatly helped both the student and the sibling. The student has kept up journaling ever since and four months later claimed it had changed the student’s life**.

We did not provide example structures to use in reflective writing, like those given in the Reflective Learner²¹ or the critical incident reports used by Jolly and Radcliffe⁷. We felt that a completely unrestrained forum would be the best tool to complement other reflective techniques in maximizing student learning.

Starting and staying on the path to mastery

The first assigned reading was *Mastery*¹⁰. We chose this book because of the value it had provided to us and others we knew, and because of the emphasis it placed on the practice necessary for lifelong learning. The book had an important impact on the tone of the course.

** This is grounded by the student’s changes in career and life direction.

(Simply seeing it on the required reading list changed Valentin's initial perspective of this course from being "just another software engineering course" into being something novel and interesting.) The book itself is a profoundly reflective work, so reading it implicitly reinforced the message about the importance of reflection. Writing reflective essays on parts of *Mastery* during the first two weeks forced students to practice reflection themselves, and our written commentary on each of their writings gave them feedback and served as individual guidance. *Mastery* also created a common vocabulary that survived for the duration of the course – something we had not anticipated but which was a welcome success. Students continually reflected upon concepts from the book, such as how different situations related to their own "path to mastery," their tendencies toward being a "dabbler," "obsessive," or "hacker," and seeing "homeostasis" in action. Many students remarked on the value they got from this book. As one student told us three months after the class, *Mastery* helped focus student attention on reflective techniques.

Not all students appreciated *Mastery*. Many were eager to get to the "meat" of the course – the project – which is precisely the reason why we delayed telling them about the project definition, domain, or tool set until half way through the second week. This gave us the time necessary to first lay the foundation for lifelong learning and development of team skills.

A single large team working on the project

During the second session we told the students that they all would work together on a single instance of a project. The motivation was to force them to deal with the coordination and leadership issues of teams, which would support our goal of teaching them the soft skills that are so crucial for effective engineers. The small teams that are more traditional in academic courses can perform well with a much smaller use of formal team and project skills. In some cases, even if the rest of a small team is not performing, a single super-star can "rescue" the team's project. With 22 people in a single team, however, that is hardly possible.

The dynamics of a larger team also provided ample material for reflection. It increased the chance for inter-personal problems as some students assessed that others were not doing their fair share or keeping their promises. Even if some students would work very well together, they still would have to deal with the rest of the class and there was a very high chance that someone would get upset at someone else. While this type of conflict is often viewed as negative, learning to deal with it effectively in a safe academic environment can be an invaluable lesson before the pressures of industry set in¹⁸.

The decision to have a large team disconcerted many of the students. We believe this was partly due to: (a) their unfamiliarity with the new situation due to the common practice of limiting team sizes to at most 5 individuals in virtually all courses taught at our department and at most other universities; and (b) their lacking prior team or project skills, much less exposure to complex environments with larger teams. The decision, however, was critical for creating a more authentic environment where the students could explore the coordination skills necessary for many of the team- and project-related experiences they would encounter in industry. Most students came to realize the value of the large team. Of the ten people who gave us feedback (on our broad question of what we should keep and what we should change in future versions of this course) four months after the course, five of the six who mentioned the large project team said they found it valuable. One student said, "[I] especially found working in a large group

environment to be eye-opening and educational.” Another “particularly liked working in a large group. I found this really taught me the most about group dynamics, and how many people can come together to produce a large product in a relatively small amount of time.”

After the instructors led a class discussion (in that same second session) on potential strategies for effectively organizing many people, students were given one minute to choose their sub-teams. (An alternative would have been to let them take as long as they needed to, but we expected them to learn a lot regardless of which sub-team they were in, and we felt that there were more valuable things to concentrate on especially in light of the very short quarter.) The students decided to organize into five sub-teams of 4-6 students with each sub-team having a lead. Additionally, all leads formed a “Lead Team.”

Team conversations

After forming teams, we introduced the ten conversations that Robert Dunham³ believes constitute a team. He defines a team as a set of ongoing conversations taking place within a community of people. The claim is that teams must have these conversations in order to be effective, even if the conversations are done quite informally. This view provides clear guidance on how to establish teams and keep them healthy.

One of these conversations is about safety. In order to maximize learning, it is important to provide an environment where students feel safe enough to take risks and learn from mistakes. After the class divided into sub-teams, each sub-team spent 30 minutes discussing and writing their collective answers to the following two questions: “What must happen for you to feel safe?” and “What must not happen for you to feel safe?” The answers they wrote on a large sheet of paper. Then, the entire class discussed these. This helped students recognize the similar yet different needs of different groups. Each sub-team’s answers became their established “rules” which the members of that sub-team agreed to abide by in order to foster an atmosphere of safety, and by extension creativity.

Another conversation was about leadership. After it was agreed that sub-teams should have leaders, each sub-team spent 30 minutes choosing its representative. As it quickly became apparent in the weeks to follow, the elected leads had little effective authority vested in them by members of their sub-teams, which indicates a failure in at least one of the conversations. Still, even though their leadership was mostly ineffective – nearly all students felt that way at the end of the course – the reflective essays sub-team leads wrote indicate that these students were able to extract some important lessons from their experience.

One conversation that the students did not appear to have had, which led to misunderstandings as early as the second week of the project, was establishing inter-team rules. Students sometimes acted as if their sub-team was more important than the larger project team.

Weekly reflective essays

Writing reflective essays to which instructors provide feedback enhances student reflective skills and learning²¹. In our course, students had to submit two essays per week, each answering two reflective questions (see below). Instructors returned these with written comments within a week. These essays also provided feedback to the instructors and were a starting ground for conversations between instructors and students.

Students submitted their essays to a web site where they were publicly visible. Our hope was that in allowing public access to this site, students would learn from reading and reflecting on the writings of their peers. Although we know that some of the students read other students' writings, we do not know how prevalent or useful this was.

The questions on the reflective essays were:

1. Describe what you learned in this class during the past week and why it was significant to you.
2. Give an example of your best work from last week and explain why it was a good accomplishment.

We also assigned introspective writings on their required readings. The ones for *The Pragmatic Programmer*⁶ (one of the two required texts for the course) were:

3. What ONE thing will you do during the next week that you would not have done if you had not read this part of "The Pragmatic Programmer"? Why?
4. Reflect upon ONE specific thing that you did last week. How well did it work? Were you satisfied? Why? Did it achieve the result you had expected? If not, was the unexpected better than the expected? Why or why not? What would you do differently to make it more successful next time? Why?

Answers to question #1 provided the most indication of reflection. The examples of best work from the previous week (question #2) were often things mentioned in the answer to question #1. Question #4 did not work so well, since the students almost never kept to what they had said they would do in their answers to question #3 from the previous week. We attempted to discourage this lack of consistency during the course by pointing it out in our feedback to students and by (somewhat) lowering their scores on the writing assignments in which this inconsistency occurred.

Experiential simulations & Expert practitioners telling stories

During the quarter, industry experts facilitated eight sessions, conducting experiential simulations or interactive sessions in which they told reflective stories from their careers. The simulations were group exercises crafted for a specific type of outcome and facilitated by the guests. This gave students a chance to practice doing, learning, and reflecting under expert tutelage, and provided them with some key lessons.

The first simulation, led by David Schmaltz and Amy Schwab¹⁴, addressed the question of "What do you do when you don't know what to do?" The facilitators introduced the Satir Change Model²⁴ and then had the students play the "Small Change Game" whose explicit goal was to maximize a certain metric. After running the game for a while, the facilitators paused the simulation and asked students if they knew what they were doing. Most students thought that they did, but as the conversation evolved it became clear that none of them did. What looked like a simple "success" criterion turned out to be an extremely vague objective. The students could now look back and see what they were doing when they did not know what to do. Many of them reflected upon this in their later writings. As one student wrote four months later, this question was something that "I'll always keep with me."

In week five Steven Smith led a simulation about “Exploring Tradeoffs: Quality versus Speed”¹⁵. Again, this was a seemingly simple game that required students to make the tradeoffs as would be expected in industry. The difference was that it was done in a safe environment where they could learn from their “mistakes.” On one of the final exam essays one student wrote, “Through my inability to effectively debug [...] in Steve Smith’s marble QA game, I realized and then began making sure I had a reason for doing something before investing time in doing it.”

When James Bullock came in week seven to do an experiential session, he quickly changed gears when it became clear that the students were already overloaded with their project work and had more pressing questions they wished to ask him. He spent the full two hours answering questions about how to handle certain problems students were having and whether such problems really happen in industry. This provided a valuable perspective to help students gauge the relevance and value of the lessons they were learning.

Later that week Bjorn Freeman-Benson talked about how engineers create value. In his session, he randomly chose students and asked them what value they provided to the customer. This caused students some discomfort, because most of them were not prepared to answer this question. One student wrote about how uncomfortable it was when “[I] miserably failed to answer the question.” It is precisely this sort of discomfort that prompted several students to reflect upon this issue in that week’s reflective writing.

Retrospective sessions

Retrospectives⁹ are a mechanism to leverage the design capacity of groups to learn from what has happened, strengthen teams, and create intention for what to do in the future. They also help students to realize how much was accomplished, which brings satisfaction and confidence, and how much was not accomplished, which brings realism and identifies areas for innovation. We had scheduled one 30-minute retrospective session every week, with full 2-hour retrospectives half way through the course and at the end of it^{††}. These retrospectives used a variety of exercises done in groups or by the entire class. Doing group exercises allowed students to see the difference between their individual reflections and those generated by the entire class.

In order to expose students to different ways of reflecting and creating intent for the future, we used several different retrospective formats. For instance, in the Emotions Seismograph⁹ each sub-team drew a chart plotting how each student’s mood (or emotions) changed over a given period of time. This exercise introduced emotions and moods as legitimate aspects of work²⁰, recognizing their strong influence on individuals and others around them. In another retrospective, the class used the whiteboard to list answers to “What happened?”, “What went well?”, “What went poorly?”, and “How can we improve what went poorly?”.

Instead of describing retrospectives in more detail here, we recommend that the interested reader look at Kerth’s excellent book⁹, containing advice on performing retrospectives and many example formats.

^{††} However, due to pressures of working on the project, we did not hold every planned retrospective. See Appendix 2 for our complete course schedule.

Most students appreciated the variety of the retrospectives we used, though one student recommended (in their feedback four months after the course) that these exercises be more focused on how well the previous week's plan had been accomplished.

Grading

In an attempt to make grading as fair as possible, instructors assigned students scores on nine different aspects of their course involvement. Individual performance had six components: reflective essays (0-3)^{‡‡}, class participation (0 or 1), sub-team participation (0 or 1), portfolio (0-3), final exam (0-3), and our level of confidence in that student if we were to hire them (0-3). Team performance had three components, with the same score given to all members of the same sub-team: customer presentation (0-3), project progress (measured three times during the quarter) (0-3), and final project status (0-3). Component scores on a scale of 0-3 (above) were given based on the following criterion: 0=not done, 1=done inadequately, 2=done at the expected level, 3=done above expectations. We then normalized each of these scores and combined them in a weighted average, with higher weights for important measures and lower weights for less reliable measures. The weights, in the same order as the list above, were: 0.2, 0.05, 0.05, 0.09, 0.15, 0.09, 0.07, 0.15, and 0.15^{§§}.

While we consciously de-emphasized whether the project delivered value or even worked – failed projects can teach excellent lessons too – it is not clear if the students believed us on this aspect. We were pleasantly surprised that the students pulled together after a period of chaos and delivered a functional product and an excellent customer presentation demonstrating the project status and options for further work.

6. End-of-course Closure

We ended the course with several elements designed to bring closure and to help students recognize their individual and group achievements.

Personality types

We had not planned to discuss personality types until a student recommended it. By that time, it had become clear that many students were not respecting some of their colleagues. Recognizing that other people *really do* think differently and have different perceptions of what is “best” makes it easier to respect others despite differences of opinion. We adjusted the original schedule to cover personality types in the penultimate session.

In that session, the students first took an online version of the Myers-Briggs Personality Type Indicator⁸ test and then proceeded to the classroom to discuss the results. Because of the danger that people might put too much emphasis on being of a particular type, we were careful to state that the measures reflected current preferences, *not* definitions of who the test taker is and always will be. They measure a person's “strengths” for that day in that setting, but can change over time as well as across different contexts (e.g., at home versus at work). In retrospect, it may

^{‡‡} Numbers in parentheses represent the range of points awarded for each specific component.

^{§§} When introducing the grading scheme to the students, we listed eight components and said that we expected to give these equal weights, but that we reserved the right to modify the grading scheme as necessary. When doing the final grading, we added the hire-ability and adjusted the weights.

have been better to cover this topic much earlier in the course so that students could practice using this information.

Portfolios

Portfolios¹² are a mechanism for students to gain an appreciation of how much they have accomplished and can be valuable to present at job interviews. On the last day of class, each student handed in a hard-copy portfolio of examples of their best work related to the class. Each example had to have a short description of it. Although we were surprised by the creativity of some of these, it remained unclear how much value students got from this exercise. Perhaps one reason for this is that portfolios were never a central aspect of the course design.

Peer reviews

Peer reviews are a valuable technique for learning how your peers see you. In order to provide this benefit to the students, and to emulate yet another aspect present in industry, we had each student fill out (on the last day of class) an anonymous peer review of all the students in the class. (To alleviate concerns about grading, we stated that we would not use the results of the peer review for grading purposes even though we would have those results at that time.) The instructors compiled the feedback and sent each student their results after the quarter had ended. Only one student wrote back acknowledging the receipt of the results, so it is hard to gauge the effectiveness of this practice. We suspect that if the practice had been more tightly integrated into the course – perhaps performed several times during the quarter – it might have positively affected student behavior and caused learning.

Final exam

The take-home final exam consisted of four questions intended to force the students to consolidate their learning and create intention for the future:

1. Of the things that you did in [this course] which would you do again and why?
2. Of the things that you did in [this course] which would you *not* do again and why?
3. Describe your current assessment of what a “software engineer” does and how.
4. From the customer’s point of view, what value did you add to this project?

In order to help students focus on building their reflective skills and on learning during the quarter, we had told them the first two questions in the first week of class and had repeated those a few weeks later.

The final exam essays on the above questions (each essay limited to half a page) demonstrated a variety of lessons students were able to derive. Most students claimed they would continue journaling. Many had much clearer answers to the “value” question (question #4) on which they had previously stumbled in Bjorn Benson’s session.

Most importantly, we saw signs of students not fearing mistakes, but appreciating the learning experience: “That period of prolonged chaos we went through was useful... That’s where we started asking ourselves some tough questions, and reevaluating our previous decisions.” “There were a lot of things all of us in the class did that didn’t work so well, but we learned from it, and I wouldn’t want to change that.”

7. Results and Conclusions

Our goal in this course was to get the students to appreciate the need for “soft skills” so that they would spend the time and effort honing their people skills. While the reflective essays and final exams gave us some indication of what the students had learned, these could be biased by their desire for a good grade, especially since they knew that the practice of reflective techniques was a main factor in determining their grades. Similarly, how they rated various parts of the course does not necessarily indicate what they learned. To assess what students have actually learned we asked them the following questions four months after the course had ended:

1. If we teach this course again, which aspects of it would you recommend that we keep and which ones may need to be changed? Some things did not go as well as we all wanted. Others went better than we had expected. What is your take on this?
2. Do you find yourself now applying some of the practices/lessons you learned in [the class] and if so, which ones (of the following): journaling, team conversations, team retrospectives, thinking of the path to mastery, portfolio, personality types, learning cycle [...], Pragmatic Programmer lessons, peer review feedback?

Eight of the 22 students replied to the second question, while we received ten responses to the first. The key points from the feedback are:

- Of those eight respondents, the number of students who reported having continued to use a particular technique is as follows: journaling (5), thinking of the path to mastery (4), team conversations (3), team retrospectives (3), personality types (3), learning cycle (2), Pragmatic Programmer lessons (2), portfolio (1), peer review feedback (1).
- Five of the six people who mentioned the large team believed it was valuable. One student wrote, “I especially found working in a large group environment to be eye-opening and educational.” Another wrote, “I particularly liked working in a large group.”
- Several students mentioned the value of the experiential simulations. One remarked on how they liked the “variety of the exercises,” though they would have liked more of them to be closely linked to the project material.
- Five students said they would have liked more direction from the instructors, though one of these also mentioned that they had not believed us when we spoke of the need for a detailed project plan and that “If we hadn’t faltered as we did, I don’t think we would have fully realized the importance and need for these tools.” We believe it may have helped to provide the students with more concrete examples of good tools, such as project tracking spreadsheets, from which they could choose or design their own. Even so, we doubt that they would have adopted any of those until they were forced to by having failed to achieve the desired results otherwise.
- Journaling was the favorite practice. As shown above, 5 of the 8 students had continued journaling. One student wrote, “I think that [journaling] is the most valuable thing I picked up from this class.” Another one, with many years of executive experience, said, “I was not in the practice of journaling everyday. I use this now and find it useful.”

In the end-of-course questionnaire, students also rated journaling as the most valuable technique: 75% of all students in the class rated journaling as giving them ‘value’, while 32% qualified it as one of ‘high value’. In the final exams, journaling was the most commonly mentioned practice students said they would continue doing.

- Half of the respondents continued thinking of the path to mastery. One said, “I think of the following when I run into some difficulties: thinking of the path to mastery, learning cycle.”
- Three of the respondents continued to use team conversations.
- Several of the students noted the benefit of the challenges they faced. “I absolutely enjoyed the class better because of the difficulties we had. It made the project much more challenging, and it made it feel like a much bigger accomplishment when we were finished.”

Finally, we have received unrequested emails from some students after the course. In one of them, a student had the following to say about the impact of this course on their career: “The team conversations and retrospective methods have been highly effective in building strong and creative communications within the team... Nevertheless, the tool I have found to be the most effective has been journaling, it has helped me to manage and track my learning experiences, converting goals into reality and ideas into actions.”

From their reflective essays and the post-course feedback, it appears that we were successful in teaching reflection and in raising the importance of team and project practices. As one student put it, “This simulated corporate scenario in a controlled environment was the best learning experience in all my 4 years at the UW. More important than learning out of a book, I learned about myself.”

Acknowledgments

We thank the many colleagues who helped us design and deliver this course: Jonathan Bach, Bjorn Freeman-Benson, James Bullock, George Engelbeck, Angela Linse, Dan Rawsthorne, Vibha Sazawal, David Schmaltz, Amy Schwab, Steve Smith, Stani Vlasseva, Skip Walter, and Sharon Whiting. We are grateful to the many students who gave us post-course feedback, and to the anonymous reviewers who provided helpful comments on the presentation of this material. This research was supported in part by NSF Grant numbers EIA-0090832 and EIA-0121326.

References

- [1] *ABET Criteria*. <http://www.abet.org/>
- [2] Peter J. Denning, Robert Dunham. *The Core of the Third-Wave Professional*. CACM 44(11): 21-25, 2001.
- [3] Robert Dunham. *Constitutive Conversations of Teams*, Handout in the “Action in Management” course, Enterprise Design, Inc., <http://www.enterprise-design.com>, 2001.
- [4] Donald L. Finkel. *Teaching With Your Mouth Shut*. Boynton/Cook Publishers, Inc., 2000.
- [5] Malcolm Gladwell. *The Social Life of Paper: Looking for Method in the Mess*. The New Yorker, 2002. (Retrieved 24 Mar. 2003 from http://www.newyorker.com/critics/books/?020325crbo_books)
- [6] Andrew Hunt and David Thomas. *The Pragmatic Programmer: From Journeyman to Master*. Addison-Wesley, 1999.

- [7] Lesley Jolly and David Radcliffe. *Strategies for Developing Reflexive Habits in Students*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 2000.
- [8] David Keirse. *Please Understand Me II*. Prometheus Nemesis Book Co., 1998.
- [9] Norman L. Kerth. *Project Retrospectives: A Handbook for Team Reviews*. Dorset House Publishing, 2001.
- [10] George Leonard. *Mastery: The Keys to Success and Long-Term Fulfillment*. Plume Publishing House, 1991.
- [11] Steve McConnell. *Rapid Development: Taming Wild Software Schedules*. Microsoft Press, 1996.
- [12] Barbara M. Olds. *Reflection as an Assessment Measure*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 2000.
- [13] Donald A. Schön. *The Reflective Practitioner: How Professionals Think in Action*. Basic Books, 1983.
- [14] Amy Schwab. *The Small Change Game*. True North pgs, Inc., <http://www.projectcommunity.com>, 2002.
- [15] Steven M. Smith and Gerald M. Weinberg. *Exploring Tradeoffs: Quality versus Speed*. Simulation at the 3rd Annual Amplifying Your Effectiveness (AYE) Conference, <http://www.ayeconference.com> (wiki), 2002.
- [16] Steven M. Smith. Personal communication, 2002.
- [17] Durward K. Sobek II. *Use of Journals to Evaluate Student Design Processes*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 2002.
- [18] David Socha, Valentin Razmov, and Elizabeth Davis. *When Conflict Helps Learning*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 2003.
- [19] Robert K. Tener, Michael T. Winstead, Edward J. Smaglik. *Experiential Learning from Internships in Construction Engineering*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 2001.
- [20] Kenneth L. Thompson. *Learning as a Biological Process*. Pegasus Communications, Inc., 2002. (Retrieved 24 Mar. 2003 from <http://www.pegasus.com/levpoints/learnbio.html>)
- [21] Jennifer Turns, Wendy Newstetter, Janet K. Allen, and Farrokh Mistree. *Learning Essays and the Reflective Learner: Supporting Reflection in Engineering Design Education*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 1997.
- [22] Richard L. Upchurch, Judith E. Sims-Knight. *The Learning Portal*. In Proc. American Society for Engineering Education (ASEE) Annual Conference and Exposition, 2001.
- [23] Daniela Weinberg and Gerald M. Weinberg. *Learning by Design: Constructing Experiential Learning Programs*. Readings for Problem Solving Leadership, Weinberg & Weinberg, 1985.
- [24] Gerald M. Weinberg. *Quality Software Management: Anticipating Change (Vol. 4)*. Dorset House Publishing, 1997.
- [25] Terry Winograd (Ed.). *Bringing Design to Software*. ACM Press, 1996.
- [26] James P. Womack, Daniel T. Jones. *Lean Thinking: Banish Waste and Create Wealth in Your Organization*. Simon & Schuster, 1996.

Biographical Information

DAVID SOCHA, Ph.D.

David Socha studies the human side of software development. He currently is a Software Engineer on the UrbanSim project, and a Lecturer at the Computer Science & Engineering department, both at the University of Washington, Seattle where he received his Ph.D. in 1991. After that, he spent 11 years in industry, 6 of those managing teams of software developers, before returning to academia.

VALENTIN RAZMOV

Valentin Razmov is a Ph.D. candidate in Computer Science and Engineering at the University of Washington (Seattle). He obtained a Bachelors degree with honors in Computer Science from Sofia University (Bulgaria) in 1998 before receiving his Masters degree in the same area from the University of Washington in 2001. Valentin enjoys interacting with students through courses and direct counseling.

ELIZABETH DAVIS, Ph.D.

Elizabeth Davis most recently spent 15 years as a full-time family therapist. During that time, she also taught University courses in family relations and experiential, post-graduate courses in family therapy. Before that, she raised three sons while teaching Zoology and organizing science materials for a public school. She currently is enjoying retirement.

Appendix 1. List of Reflective Practices and Techniques Used in the Course

Technique	Brief Description	Reflective Purpose
TWYMS test ^{***}	<ul style="list-style-type: none"> • What were your most significant learning experiences in life? • Was an instructor directly involved? 	<ul style="list-style-type: none"> • Gets students to reflect in first class session
Learning cycle	<ul style="list-style-type: none"> • Do; reflect; introduce new models; do again 	<ul style="list-style-type: none"> • Identifies reflection as an integral part of learning • Discourages looking for quick solutions
Journaling	<ul style="list-style-type: none"> • Students wrote in journals for the first and last five minutes of each class session 	<ul style="list-style-type: none"> • Builds the habit and discipline for practicing • Promotes individual reflection
Team conversations	<ul style="list-style-type: none"> • 10 types of conversations that effective teams regularly have 	<ul style="list-style-type: none"> • Emphasizes the importance of teams • Provides tools for running teams
Safety exercise	<ul style="list-style-type: none"> • What must happen for you to feel safe? • What must not happen for you to feel safe? 	<ul style="list-style-type: none"> • Gets students to do a group reflective exercise
Teaching with our mouths shut	<ul style="list-style-type: none"> • Instructors created an environment for experiential learning, used facilitation, and avoided lecturing 	<ul style="list-style-type: none"> • Provokes students to not fear the difficulties and practice • Forces students to make their own choices and construct their knowledge
Emphasis on learning	<ul style="list-style-type: none"> • Instructors made it clear that they were most interested in student learning • Reflective exercises were a major grading component 	<ul style="list-style-type: none"> • Fosters a culture of lifelong learning
Staying on the path to mastery	<ul style="list-style-type: none"> • Students read the Mastery book and wrote about it 	<ul style="list-style-type: none"> • Gets students to reflect upon <ul style="list-style-type: none"> o their learning style o how mastery relates to the subject matter (software engineering) • Connects reflection to something bigger (the student's path to mastery)
Reflective writings	<ul style="list-style-type: none"> • Weekly 1-page essays directed by questions • A take-home Final Exam 	<ul style="list-style-type: none"> • Forces practicing reflection • Helps instructors gauge learning and guide students individually
Simulations	<ul style="list-style-type: none"> • Experiential workshops each aimed at a specific learning outcome 	<ul style="list-style-type: none"> • Forces practicing reflection under the guidance of an expert facilitator • Demonstrates how the learning cycle works • Creates material for reflection
Operating as one large team with sub-teams	<ul style="list-style-type: none"> • All 22 students worked together on a single project 	<ul style="list-style-type: none"> • Provides reflective material by forcing students to deal with team and project coordination
Project retrospectives	<ul style="list-style-type: none"> • Group reflective exercises 	<ul style="list-style-type: none"> • Gives students practice in a variety of group reflective exercises
Stories from expert practitioners	<ul style="list-style-type: none"> • Sessions where outside industry experts told work-related stories 	<ul style="list-style-type: none"> • Exposes students to many reflective stories in an interactive setting

^{***} A set of questions drawn from *Teaching with Your Mouth Shut*⁴

Technique	Brief Description	Reflective Purpose
Personality type test	<ul style="list-style-type: none"> Took and discussed the Myers-Briggs personality type test 	<ul style="list-style-type: none"> Promotes reflection on how a personality type changes one's perceptions and actions
Individual student portfolios	<ul style="list-style-type: none"> Each student prepared an end-of-term portfolio of the student's best work 	<ul style="list-style-type: none"> Forces a reflection on the value of the individual's contribution to the team and on the learning that the experience led to
Challenging students	<ul style="list-style-type: none"> Instructors provided assessments of student and project performance, including challenging students' own assessments 	<ul style="list-style-type: none"> Provokes students to reflect
Individual feedback on student writings	<ul style="list-style-type: none"> Instructors provided ample individual feedback on reflective essays 	<ul style="list-style-type: none"> Provides material for reflection Helps teach techniques for reflective writing
Openness of student writings	<ul style="list-style-type: none"> Weekly student essays were stored digitally in a public-domain site 	<ul style="list-style-type: none"> Enables learning from peer reflections
Public presentations	<ul style="list-style-type: none"> Presentation #1: Each sub-team presented the architecture of their respective component Presentation #2: Final official customer presentation to instructors and an outside marketing person 	<ul style="list-style-type: none"> Forces students to objectively evaluate their product and put those assessments in the perspective of what brings value to the customer

Appendix 2. Our Course Calendar

This appendix shows what we did on each day of the course. This schedule was part of our course plan that we initially presented to the students as our substitute for a course syllabus. Note the frequent workshops and retrospectives, and the weekly project-planning meetings.

Week	Monday	Wednesday	Friday
Week 1	Welcome Why are we here?	Join the company Form sub-teams	Project meeting Team conversations Retrospective (last 30 min)
Week 2	<u>Workshop</u> : Managing Change	Project meeting Meet a marketing person Introduce project & development system	<u>Workshop</u> : Use Cases Retrospective (last 30 min) <i>Due</i> : Project plan v.1 at 5pm
Week 3	<u>Workshop</u> : Supporting Work in Distributed Organizations <i>Due</i> : Project plan v.2 at 5pm	Project meeting Work on the project <i>Due</i> : Project plan v.3 at 5pm	Finish architecture specification <i>Due</i> : Project plan v.4 at 5pm (arch + schedule)
Week 4	<u>Workshop</u> : Testing <i>is</i> Science	<u>Workshop</u> : About Business	Project meeting Work on the project Retrospective (last 30 min)
Week 5	<u>Workshop</u> : Exploring Tradeoffs: Quality versus Speed	Project meeting Work on the project	Retrospective (first 30 min) Work on the project
Week 6	Work on the project	Project meeting Work on the project	In-class sub-team presentations
Week 7	<u>Workshop</u> : Development Systems	Project meeting Work on the project	Guest Retrospective (first 30 min) Work on the project
Week 8	Work on the project	Project meeting Work on the project	Practice customer presentation Retrospective (last 30 min) <i>Due</i> : Project CD-ROM at 5pm
Week 9	Customer presentation and Project demo Customer feedback	Personality Types	Peer appreciation Fill in peer reviews <i>Due</i> : Portfolios, take-home final exam, questionnaire