Feedback Techniques for Project-based Courses

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Abstract

Feedback is important for student learning, yet many instructors are rightly concerned about the time they spend giving feedback, especially if they cannot tell whether it is used or ignored by the students. Similarly, instructors can benefit from student feedback, yet to achieve this, effective mechanisms for collecting useful feedback are needed.

This paper sheds light on how to choose feedback mechanisms for a course. We base our analysis upon experiences with the many feedback techniques we use in an undergraduate software engineering course where students learn about team and project work.

Another contribution is the experience report on a variety of techniques we have tried where feedback came from different sources (the student’s own introspection, the instructors, peer students, domain experts, and project artifacts), in different forms (verbal, written, automatic indicators, etc.), and within different contexts (time, frequency, phrasing, etc.). For each technique, we discuss its goals and requirements, and analyze how students and instructors perceived its costs and benefits. We find that feedback that is grounded, unbiased, timely, frequent, and easy to assess tends to work better for students and educators, so we evaluate each covered technique against a set of such desirable qualities.

This type of information can be especially useful for educators planning new courses, as they try to produce low-cost, high-quality feedback that students will listen to and can understand, and as they need corresponding feedback mechanisms that support a variety of learning styles and are easy to use.

1. Introduction

Providing feedback to students is considered beneficial for their learning, and instructors spend much of their time doing that. What instructors often do not know is whether and to what extent students use their feedback, and whether their efforts foster learning.

The literature on the topic is not unanimous about how to maximize the effectiveness of giving feedback. Some authors suggest that instructors increase the number of course assignments to the point where students need to learn how to provide feedback to themselves\textsuperscript{18}, while others advocate a more conservative approach of keeping the number of assignments low so that instructors could successfully handle them all\textsuperscript{18}. 

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Here we report on our experiences with a third approach that combines the benefits of both worlds while suffering from the drawbacks of neither. The idea is to use several sources of feedback – the student herself, other (peer) students, external domain experts, and project artifacts – to augment feedback coming from instructors. The benefit of doing this is that it reduces the time demands on instructors while providing students with additional feedback, often even more trustworthy, to help them learn.

We have implemented this idea in two courses so far, both in software engineering, taught to junior undergraduate students at the University of Washington in 2002 and 2003, respectively.

One contribution of this paper is the experience report on a variety of feedback techniques – some more traditional, some less – that we have employed in our courses to accommodate a multitude of learning styles. For each technique, we discuss its goals, requirements, costs (including time demands), and benefits from both the instructor’s and the students’ point of view.

Secondly, we propose an approach that instructors can use to select appropriate feedback techniques for their courses (from a pool of possible candidate techniques) given a set of constraints (e.g., course objectives, time required, class session length, expert availability, etc.).

While our examples come from a course in software engineering, the set of feedback techniques are not domain-specific and so could be applied broadly to project-based courses in other disciplines.

The rest of this paper is organized as follows. Section 2 discusses what we believe are important qualities of effective feedback. Then, Section 3 presents several categories of feedback techniques and describes our experience with each, pointing out the respective goals, requirements, benefits, and likely costs. Since most techniques can be used independently of the presence of the others, for ease of reference we have confined the discussion of each one to its own subsection. Acknowledging the reality that courses may be able to only employ a subset of the techniques presented here, Section 4 suggests an effective approach to selecting from a pool of possible feedback techniques. We conclude in Section 5, and provide a chart that summarizes the main features of all discussed techniques in the Appendix.

2. What Constitutes Effective Feedback?

An important question related to the tradeoff between the quality of feedback and the time spent giving it is how to maximize the effectiveness of feedback without increasing its cost beyond reasonable limits. This in turn leads to the question of what constitutes effective feedback.

Following is a list of qualities that we believe contribute to the effectiveness of feedback. We use these as a measure to evaluate the extent to which a given technique would achieve its stated purpose and hence to decide if we should adopt it in our repertoire.

- *Sensible, situated, grounded.* The recipient needs to understand the reasoning behind the feedback, or else they may discount its value and not use it. As part of that requirement, the feedback needs to be expressed appropriately in a language that the recipient is
comfortable with. For instance, that expression would differ if it were given to a beginner versus to an expert. A novice may demand explicit recipes for doing things, whereas an expert may be satisfied with a hint or a general direction.

- **Easy to access.** Just as providing feedback would ideally be low cost, the same is true for receiving it – it should not take the recipient extra effort to access the feedback. Computerized ways should be used sparingly, especially with audiences that are not comfortable with computers or if the environment where the feedback is to be used does not readily provide access to computing equipment. In certain circumstances, even if automation were possible, using paper may still be more effective.

- **Perceptible.** People differ in the strength of their senses for perceiving the world. Some digest information from the outside best when it is presented visually, while others tend to rely more on their auditory receptors. Regardless of the specific form it is presented in, feedback needs to be perceptible for the recipient to be able to take advantage of it.

- **Robust.** To maximize the impact of feedback, the provider should take into account the diversity of the audience by giving multiple, possibly redundant, views of the same piece of feedback. This ensures that there is no “single point of failure”, i.e., no reliance on a single method for transmitting the information.

- **Easy to assess.** For feedback to be effective, assessing its relevance and quality should be easy (i.e., be low-cost) for the recipient. Ideally, credible examples (e.g., from the available literature) should be brought in support of the feedback. A possible alternative is to provide ample justification as part of the feedback itself.

- **Unambiguous.** Knowing how to interpret a piece of feedback has value. The presence of possible alternative interpretations may lead to confusion or, even worse, to ill-interpreted suggestions that the recipients put into action, unaware of the trap they are falling into. Novice learners are particularly vulnerable to ambiguity, since they tend to have little experience dealing with it.

- **Unbiased.** Objectivity inspires confidence and encourages students to adopt the suggestions in the feedback. In contrast, the very perception of bias may make it difficult for recipients to untangle the valuable pieces of feedback from those they consider objectionable.

- **Well intentioned.** The perception of a well intentioned instructor can go a long way toward motivating students to learn. Conversely, a (even unfounded) suspicion of indifference or disrespect may ruin the chances of student learning and nullify other efforts by the instructor. Therefore, it is essential that feedback be presented with utmost respect toward individuals and groups both in the classroom and outside. We believe that feedback not accompanied with good intentions would best be withheld.

- **Encouraging.** One of the most effective motivators is an encouraging word. In an academic setting, giving encouraging feedback is a powerful tool that teachers can use – it inspires and empowers students to achieve more than they ordinarily would. Providing encouragement does not mean being dishonest; it means focusing on the positive aspects with the intent of creating more of them.

- **Frequent.** To keep students from straying down unproductive paths, it is necessary to give them frequent feedback. In a different context, the same has been found to be true for the relationship between software developers and their clients. The more frequent feedback is, the less likely it is that valuable time will be spent on some aspect that ultimately brings no value.

- **Timely.** Feedback that comes when it is needed is more likely to make a difference than
feedback that arrives much later (or earlier). For instance, if a sequence of assignments is logically tied together, feedback on the earlier ones should ideally come before the later ones are due. Otherwise, although feedback may still improve learning, some opportunities to reinforce the lessons will inevitably be missed.

- **Iterative.** By nature feedback is about repeatedly using the outputs of a process for informing future inputs to it, with the goal of improving the results of that process. In the context of education, since learning is most effective when it results from acting (as opposed to passively listening or reading), feedback could be tied to subsequent tasks in order to force action on it. For instance, requiring that in their next written assignment students address issues raised as part of the feedback on the previous one, forces them to rethink what they have done and naturally leads to assimilation of the feedback. We have empirically found that students acting on feedback improve substantially during each of at least the first three iterations.

In the next section, we describe our experiences of employing a set of feedback techniques in a software engineering course, and provide examples from interactions with students. We further evaluate each examined feedback technique against the above qualities.

3. Experiences with a Diverse Set of Feedback Techniques

We start by providing context for the discussion on feedback techniques.

3.1. Background on Our Course

The experiences we report on are from two instances of a 9-week long project-based course in software engineering for junior undergraduate students. There were 22 and 29 students, respectively.

The goals of our course are to teach students about “soft” (team and project coordination) skills. For this we created an experiential learning environment where students were in the driver’s seat while we, the instructors, served as facilitators, providing some guidance but largely teaching with our mouths shut. All students were assigned to work in a single large team on a single project. The intent was that in the process of working closely with each other on the project, students would gather sufficient material to reflect upon and learn from. To reinforce the need for practicing reflection as a necessary component of learning, the course devoted considerable time to reflective techniques, including journaling, team conversations, retrospectives, reflective essays, and portfolios – techniques that enhance learning in any domain. Finally, we invited industry experts for several class sessions, and they led experiential simulations – an example of experiential learning in action.

More on the general course structure and the rationale behind it we have described elsewhere. Though the details are unimportant for the purposes of this presentation (and some of them have evolved along with our understanding), wherever more background is necessary, we will explicitly provide it below.

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* At the time of this writing we are teaching a third such course with 23 students. Many of the structural components we use are still the same as described here.
3.2. Sources and Targets of Feedback

In a traditional classroom there are two types of players – instructors and students. The better these players understand each other, the better the results from the learning will be. A good way to help students understand their instructors is to give them ample feedback on what is required and how they are doing. The same is true for improving the way instructors understand their students – indeed, some courses try to weave in feedback from students to instructors † in an effort to increase the synergy between the players.

We view feedback to students and feedback to instructors as two parts that intrinsically belong together, informing one player or the other, and ultimately leading to a higher quality of education.

The following figure illustrates sources of feedback for instructors and students, and highlights the similarity in their nature.

![Feedback to students and instructors diagram]

**Figure 1.** Sources of feedback for students and instructors

From this point on, the presentation will focus on feedback to students, while feedback to instructors will be the topic of another paper.

The presentation of each technique below addresses the following factors, albeit not always in that order:

- **source (provider)‡**;
- form (verbal, written, or via automatic indicators);
- context (timing in the course, frequency, phrasing, etc.);
- goals;
- requirements:
  - from the perspectives of both the source and the recipient;
  - cost (in time and other resources), dependence on other techniques or tools, specificity for use in some types of courses only, etc.;
- potential obstacles (e.g., unwarranted assumptions about different roles and responsibilities, etc.);
- indicator of success / acceptance by the recipient;

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† By that we mean more than just the traditional student evaluations at the end of each course.
‡ As mentioned above, the target is always students (for the purposes of this paper), so we do not explicitly say it.
3.3. Feedback Techniques

As Figure 1 illustrates, there are a number of possible sources of feedback for students. Below, we examine each one individually.

Depending on the goals of a given course, instructors may decide to employ certain types of assignments and respective feedback techniques, and not others. One important factor in this decision is the cost of the feedback ideally provided to students for the various assignments. Consequently, our discussion will be structured so as to associate feedback with the specific types of assignments we used in our course.

3.3.1. Feedback from Instructors

The class of feedback techniques where instructors are the source and students are the target is featured in every course we know of, and in ours too. Beyond this, the possible techniques differ in a number of aspects.

On reflective essays. Each student in our course writes 1-page-long weekly essays on a topic assigned by us – one that prompts reflection on their recent readings as well as team and project experiences, including what went well and what did not in the previous week, and how the negative effects may be overcome in the future. We provide written feedback individually to students before their next weekly writing is due. The main purpose of our feedback is to help students change their stories about what is possible for them. To achieve this, we pose questions relevant to the content of their essays and highlight assumptions students are making that might be constraining their progress. We explicitly avoid judging or pointing “the right way”; instead, we suggest alternative paths to solving the problems they chose to talk about. The intent is to have them practice their critical thinking and writing skills, rather than to teach them a set of recipes.

In order to draw student attention away from grades and focus it on their practice and our feedback on it, our grading scale – for all assignments including this one – was simplified to merely give an overall qualitative assessment (0 = ‘not turned in’; 1 = ‘below expectations’; 2 = ‘met expectations’; 3 = ‘surpassed expectations’ with partial scores where applicable), while the essence of our feedback was expressed in words. (The average score that students got on their essays was about 2.4, reflecting the steady upward movement in their understanding of issues.)

On several occasions, students received comments (and grades) from both instructors on the same reflective essay. The fact that these were naturally differing was meant to teach an appreciation for the existence of different, yet all valid, customer (audience) viewpoints. They seemed to grasp that point well.

For students, writing essays took 30-60 minutes. Because essays were the most frequent of all assignments – done so intentionally to force students to reflect upon their experience and thus
learn from it – they were also the most time consuming for instructors. On average, we spent about 15 minutes per essay, reading it and writing comments – usually providing another perspective and asking a couple of questions to prompt students to explore in more depth some idea that they have written about. This may put a limit on the frequency or effectiveness of this exercise for classes over a certain size.

Nevertheless, reflective essays were responsible for some of the most rewarding interactions we have had with our students. After the last session of one course, 4 students came to thank one of us for the written feedback, saying they had been looking forward to it every week. Others wrote about it in their second-to-last essays. One said, “The reflective essays force me to stop and evaluate what I’ve done that week, and the importance and impact of my actions… [The feedback] allowed me to realize the assumptions that I had made… [The questions] caused me to think more about the validity of the statements I had made.” Another one shared, “[The feedback] teaches me to always think of [other] possible alternatives…”

There were problems too that we faced with reflective essays. Initially, students did not understand how writing essays fits in with the course – software engineering. Most of them expressed the urge to start coding, and felt that this reflective exercise was constantly distracting them from their “main task.” Telling them that coding is but a small portion of what software engineers do did not help. Them having to deal with the chaos arising from collaboration without planning did. This was prominently reflected in their writings on the take-home final exam – itself an extended reflective essay. By then students had become appreciative of the value of writing, and their understanding of what a software engineer does had greatly expanded. We believe the practice of reflection had a lot to do with this change.

Also, the effectiveness of our feedback would be increased if students seriously considered the questions we posed in our comments and attempted to address them in their subsequent writings. We were hoping that they would do this – without mandating it – in the courses so far, but only a handful of students took this opportunity. Therefore, we now need a mechanism that naturally leads to a discussion-oriented reflection. It would ensure that students pay attention to and reflect upon our feedback, thus validating our efforts in providing it and increasing the value to themselves. In future courses, we may enforce a second phase for each essay, in which students write responses to the questions we have raised as part of our feedback on their original essays. This would naturally require an adjustment in the number of essays assigned during the term.

Of the criteria outlined in Section 2, our careful feedback on reflective essays meets all except ‘iterative’ to an extent (for the reason just discussed). This deficiency, however, is not inherent in the feedback technique or the type of assignment, and so it could be fixed – something we look forward to trying.

**On student portfolios.** During our course every student creates a portfolio—a representative collection of their best works, each annotated so that it demonstrates how the various items fit together into a single story of who its creator is and what value they have to offer to a particular audience. One of the goals of this assignment is to help students build a sense of accomplishment as the items in the portfolio accumulate. Additionally, the portfolio is a

† usually just one of us, except in the case reported above

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mechanism to link student understanding of the course subject to another domain of their choice. By looking for analogies between two domains students acquire deeper understanding of the material, since they are forced to connect the new knowledge to previously existing mental models. Lastly, students could use their portfolios and the skills acquired in the process of creating those as an effective way to distinguish themselves when interviewing for a job position or applying to graduate school.

In the first offering of the course there was only a single portfolio assignment – due at the very end of the term. Although we were surprised by the creativity of some of the submissions, it was not clear how much value students got from this exercise. So, in the second offering we decided to have three iterations. This change allowed us to provide more feedback and helped students to refine their ideas and improve on subsequent iterations. In addition to the numeric score (0-3) students received written comments on how well their presentation followed the requirements, including guidance on what other factors they might consider to better address their selected audience, to improve the presentation, or to support the overall message of the portfolio.

Through employing this multi-phase approach we also distributed the load on the students – for the first submission they were required to present a single entry in their portfolios, on the second iteration – 3 entries, and in the final version – 6. We wanted students to focus on gaining experience and not worry about their grade on this assignment. To achieve this, we decided that the weight of the submissions would increase as the students acquire more experience in preparing their portfolios, so the three parts represented 10%, 30%, and 60% of the portfolio component of their grade, respectively. The final result demonstrated that instructor feedback with three iterations was more helpful for the students than a single iteration with no feedback. Indeed, one student wrote (in an essay), “It was a great idea to split the portfolio making in three phases because students could use feedback from the previous phase [to create a] better final product.”

Students spent several hours per entry in their portfolios, including deciding on an idea, executing it, and finally “packaging” it appropriately. The time commitment for instructors on this assignment was about 10-15 minutes per portfolio plus some additional (preliminary) time for presenting the assignment itself and explaining its goal to the students. The problems we encountered with this assignment were: (a) students who did not see the purpose of doing portfolios in a software engineering course (despite numerous explanations in class and in writing), and (b) students having difficulty defining and addressing the right audience. While we are still not certain how best to resolve the first issue, we addressed the latter one in the current (third) offering of the course by showing sample portfolios at the very start and by providing a list of possible types of audiences for students to guide them in their choice.

Feedback on student portfolios met all criteria for effective feedback except to some extent ‘sensible, situated, grounded’ – the latter for those students who had a hard time understanding the goal of the assignment and to whom our subsequent feedback was no more helpful either.

**On the project.** The vehicle through which students accumulate experiences in our course is a project. Students are responsible for building and delivering a fully functioning piece of software for a given customer by the last week of the term. This includes organizing and
managing themselves into effective teams, gathering requirements, working with the customer (or a surrogate, played by one of the instructors), exploring alternative designs, implementing a solution to the customer’s problem, testing and documenting it, and formally presenting their results to the customer.

The many aspects of the project work offer numerous chances for instructors to give feedback. We believe that by providing specific feedback on the different aspects of the project (rather than solely on the project as a whole) helps students determine in which areas they have succeeded and which need further attention and additional work. The primary form of feedback we used during the project work sessions was in the form of questions. The goal was to guide the students’ attention toward the assumptions they have been making in the course of their team discussions. Additionally, when students struggled with some problem, we suggested specific techniques adopted in similar situations in professional environments. For example, last summer students had a difficult time organizing themselves to create a data flow diagram for their product. The problem was that they assumed that this task had to be done by the class as a whole with everyone participating. Not surprisingly, it was very difficult to work on such an assignment with 30 people each of whom had a different understanding of the task at hand. At the end of the session one instructor provided their feedback including the following observations, questions, and suggestions:

- “There are too many of you here.”
- “Many of you are frustrated today [nods from students; validated their feelings] because you are making assumptions of what you may do; assumptions about control and permission. Question these assumptions.”
- “What is the critical artifact to create? The data flow diagram. What is the fastest way to get that? One team do it? Lead team do it? Volunteers to do it?”

These comments helped the students overcome their initial frustration with the almost fruitless discussion that day (later dubbed by them “Black Tuesday”), and for the next class session they came to class with a prepared agenda. During that project session teams were working on different topics and at the end of the class period they reported the decisions they had made. This session was an enormous success for them – it gave them confidence in their own abilities to manage themselves as a team. One student reflected on that experience, “We managed to form a well-structured and productive [project session]. I was thoroughly impressed and had my spirits raised about the project and the course as a whole.”

In the class sessions following every project-related due date, instructors held a 5-10 minute debrief providing their assessment on the delivered artifacts (including an acknowledgement of the successful components as well as constructive criticism on areas in need of improvement), answering questions students might have, and posing questions to force students to think. One student later wrote, “We would [often] get a question back as an answer... I found this to be an extremely powerful form of feedback [...] to get us thinking in reflective terms.”

Feedback of this type (e.g., debriefing, questioning, etc.) also accompanied the project demo, as well as its final delivery and the customer presentation. In addition to assessing all the components of the milestone deliveries (the time for which varies depending on the depth of evaluation and the project complexity), there were several occasions when instructors provided comments on preliminary versions of project artifacts (e.g., customer reports, the user manual,
and the technical manual). Students considered this feedback when making their improvements to the quality of the final product. Complementing the verbal feedback provided in class, instructors also sent comments, observations, and suggestions to the class mailing list (where they would be stored for future reference).

In a questionnaire at the end of the term we asked students about the usefulness of our feedback on their project work. Most of them indicated that they found our feedback valuable for their progress on the project.

The feedback on project progress met all criteria except ‘timely’ and perhaps ‘encouraging’ in the eyes of many of the students. They would have wanted us to tell them what to do and do so earlier, but our intent was to let them experience managing a project themselves (including dealing with problems that may arise in the process) and learning from that experience.

**Cross cutting issues.** In addition to the specific characteristics of the various types of feedback coming from instructors there are some recurring aspects. In our experience, one of the most effective ways to influence student learning through feedback were the “coaching moments” events. After the students had tried to resolve a particular problem by themselves, instructors would suggest useful approaches or tools. This would be followed by a start-over-and-try-again phase. Often times these moments came about through informal conversations with the students.

One problem we faced was the inability of some students to interpret their scores and tie them to what their final course grade might be. These students were, as expected, fixated on the grade aspect and paid less attention to the learning. They were busy looking for a “formula” on how to get the top score, despite the fact that we had provided both an example of a strong essay and instructions on what constitutes a good essay.

Perhaps the most challenging aspect of employing experiential learning in combination with guidance from instructors was balancing the desire to give suggestions (i.e., feedback on how students could do better on their project) and the desire (and need as we perceive it) to have students “own” the decisions that are made. Our strategy was to keep a middle ground – allowing exploration by not imposing too much fixed structure and guidance, while at the same time not going to the extreme of leaving the students without any help and feedback, which may lead to frustration with the experiential learning approach in general.

An additional requirement for instructor feedback to be effective is the need for instructors to refer back to concepts, techniques, and skills introduced earlier in the course. This repetition of a piece of knowledge in different contexts helps students to connect the knowledge with examples of situations from other domains in which it may be applicable. So when they encounter analogous situations in the future, it would be easier for them to retrieve and apply this new knowledge. Ideally, instructors would use different media for these “reminders” – when giving verbal feedback in class, when writing comments on student homework assignments, etc. – to accommodate the variety of student learning styles. If instructors do not refer back to previous topics from the course, students may not learn them so well (if at all). For example, in the second offering of our course we introduced “card storming” – a helpful technique during the design phase of a product. We did an exercise in class, but it remained a relatively isolated
activity, never repeated or referred back to. Even though some students wrote in their reflective essays how amazed they were with the power that such a simple technique might provide, we doubt that many students learned from it.

3.3.2. Feedback from Outside Experts

To ground our assessment of the broad demands of a software engineering job and to help students appreciate the diversity of needed perspectives and personal skills, we had a number of sessions in which outside expert practitioners led experiential simulations or told their own reflective stories. Some of these sessions were aimed at preparing the students for their encounter with difficult situations while working on their project, and so were scheduled for earlier in the course. Others were meant to help the students overcome current difficulties, and so were included in the schedule dynamically, as the need arose. This type of sessions not only provided guidance on how students could deal with the problems at hand, but also gave them the opportunity to reflect on their prior experience and compare it with their evolved perspective on the same situation after the “consultation” with an expert.

The main requirements for providing students with quality feedback from outside experts are to set aside a portion of the class time for guests to come in, and find experienced practitioners willing to volunteer their time for such an initiative. It is very important for the experts to be not only knowledgeable in their specific domains, but also to have interest (and, hopefully, experience) in working with novices, as well as to be patient and able to adjust their presentation level to that of students. To prepare for each of these encounters, students may need to read a short article introducing the topic and come with questions for the expert.

There could be several potential obstacles to effective expert feedback. One is presenting an expert opinion too early. Some students may not “hear” it – not realize its usefulness – while others may accept expert and/or instructor suggestions as rules that ought to be followed without questioning. The latter would prevent students from exploring different options, or making decisions on their own and subsequently learning from them.

We have seen evidence of both. For instance, one of our guests repeatedly throughout the term (both verbally and in writing) suggested a strategy widely used in industry to increase the predictability of a deliverable product, yet students failed to follow his advice, until they fell into exactly the trap that he had meant to save them from. Only then, towards the end of the term, many of them wrote in their essays about their newly found belief in the usefulness of this strategy: “I feel that our failure to do a 0-function release largely impacted the success (or lack thereof) of our project. I now believe in the incremental release system.” On the opposite end of the spectrum, several students had reflected in their early essays on the ideas from a guest presentation that had opened their eyes to an alternative organization of the project teams. The problem was that these students had not understood the assumptions behind the new model, and did not think to ask. They were eager to apply it in practice, falsely believing that it was applicable to any environment. This increased the tension between the believers and the non-believers within the team, tearing down some of the existing organizational structure without effectively replacing it with any viable alternative.
A different, this time logistical, obstacle arises if on-demand feedback is preferred (e.g., after the students have been wrestling with a problem on their own for some time). In this case, instructors need to be able to flexibly schedule classes as the term progresses, according to the current learning needs of the particular student group. Thus has worked well for us with one of our guest experts – a management consultant who, being a firm believer in what we aimed to teach, eagerly spared time for the class on a short notice.

In our courses this type of just-in-time coaching occurred during some of the project (lab) sessions as well as during the final project presentation. In the former case, an expert observed students working as a team and, whenever an important pattern emerged that students failed to notice, the expert highlighted it, and then suggested and explained methods that professionals would use in a similar situation. This demonstrated to students the need to stay detached from the process, monitoring and questioning their own approach. In a different situation, a guest abandoned his originally planned presentation in favor of an open question and answer period as soon as he realized that the students were overwhelmed with their project and had many questions about “how it really is done in industry.” Another coaching opportunity presented itself during the final project presentation, when experts acknowledged the students’ own findings and encouraged the successful application of skills that students had acquired during the term. They also gave concrete examples of how to “conditionalize” that knowledge (in the terminology of How People Learn). One problem that we did not anticipate during that session (but that we acknowledged in our post-course retrospective) was that students appeared overwhelmed by the wave of feedback directed at them, which was further exacerbated by the numerous interruptions of the flow of their presentation.

Some guest experts chose to be involved in other ways too. Several led experiential simulation sessions in which iterations of doing, followed by debriefing, and then doing again were the main learning tool. Others provided helpful comments on some of the project deliverables (e.g., user and technical documentation, status reports, etc.). Finally, one of the students helped organize a tour of Microsoft where a panel of program managers and developers gave short presentations and answered questions. At the time of this writing, our host has graciously agreed to provide a similar experience to the current class too.

Guest feedback came primarily in verbal form, and was provided during the respective class sessions. In several notable cases the experts willingly engaged students additionally by posting follow-up emails to the class mailing list as well as by individually mentoring some of them afterwards.

The main measure of success for the outside expert feedback was what students wrote in their weekly reflective essays and on a questionnaire we asked them to anonymously fill out at the end of the course. Many of them not only indicated an appreciation for being introduced to new perspectives (“The workshop in class […] opened me up to a new perspective on organization… I had become so engrossed in [the old] model that considering other models is very unnatural.” or “[He] discussed a topic that was already familiar to us from a different perspective.”), but also reported on personal experiences of applying in other classes or projects what they had learned here (“While I was at work manually marking corners plotted by a GPS, I realized the process should probably be automatic. I think these incidents demonstrate that the material I’ve read is
being internalized as something I really know rather than just data I’ve memorized…”). Just-in-time coaching was highly valued by students (“What I actually liked best about this course was when [instructors and experts] would […] critique how we were doing things. I particularly found the process comments useful.”) and the fact that some of them sought additional advice and coaching from the experts is yet another evidence for the warm reception of this type of feedback. Finally, the success of employing feedback from experienced practitioners as part of the course manifested itself in the “thank you for the life changing experience” emails and in-person conversations with the guests during the final class session (to which those experts were invited again and a few came). Several of the experts found the experience during their respective sessions so gratifying that they gladly accepted to come – and came indeed – in the following course offerings too.

Expert feedback satisfied most of the criteria we set for effectiveness of feedback. The qualities ‘timely’ and ‘frequent’ were among the few that were not always met, largely due to occasional scheduling constraints. Despite this, we were happy to see that even sporadic expert feedback made a difference for students. Another criterion that left something to be wished was ‘sensible, situated, grounded’ – some of the experts phrased their advice in ways that students with less domain experience could not grasp well. In such situations, the instructors attempted to subsequently provide alternative explanations, where possible.

Finally, although from a certain angle it may look like the instructors primarily acted as coaches (something that Peter Denning argues is undesirable⁷), while guest practitioners were the experts, in reality guests were only there for a small percentage of the course time and the rationale behind their presence was to reinforce our messages and add their own wisdom. As Sally Fincher points out⁸, students listen to practitioners differently and appear more willing to believe them.

### 3.3.3. Feedback from Peer Students

Peer feedback is a widely adopted technique in professional environments (especially in the software industry), but only recently gaining in popularity in academic settings. The goal of this technique is to increase student awareness and appreciation for the existence of different interpretations of the same situation – an essential skill when it comes to working together as a team. Peer feedback also ensures the presence of shared understanding among teammates; it reveals if such understanding lacks, indicating the need for discussion to create one.

We chose to include this form of feedback in our course not only to introduce students to more techniques used in real work environments, but, more importantly, because it reinforces reflection and hence improves learning.

The course structure we built included a variety of techniques for providing feedback to peers. These may be grouped in two categories – feedback to teams (of students), and feedback to individuals – each one addressing different aspects of the course.

The feedback technique that concentrated on the team dynamics was team rankings.
Team rankings. The goal of team rankings is to provide a glimpse of how each team’s work is perceived by other teams. To this end, we collected the students’ individual assessments of the contribution of each team (including their own) to them personally and to the project as a whole, and then disseminated the aggregated results after removing any information identifying individual students.

This was done 4 times during the term, at regular intervals. The intent of doing it iteratively was to give students the opportunity to consider what they need to change, then act on their decision, and see the results in the next iteration. We explicitly told them at the very start that the ranking process was not meant to be competitive and the results from it would not be used for grading purposes. The idea was to encourage them to give their honest assessment by removing the pressure they would feel if an instructor were assessing their assessments.

The mechanics of the ranking process were as follows. Each student would provide a numeric rating for each team (where the team with the highest contribution during the current phase of the project would get a rating of 1, the second highest contributor – 2, and so on) and no two teams could be given the same rating. For each team (X), in addition to the rating, students would write comments using the following format: (a) “I like ____ about team X”, and (b) “I have problems with ____ about team X.”

From a student’s standpoint, providing such feedback takes only a 3-5 minutes per team, and this is done once every 2-3 weeks. To cut down on the time instructors need to spend in order to administer this technique, we created an online form (using a readily available university-administered tool) that we reused across all 4 iterations. The only additional cost for instructors came from aggregating and anonymizing the results. This took one of us just under 2 hours per iteration.

We noticed that many students wanted to see their own team rated high, which motivated them to be more cooperative and help their teammates. For instance, after the first iteration, the students from the team that was rated last overall felt a bit discouraged, but did not give up. After analyzing the results, they concluded that they were rated mostly based on their team’s (lack of) visibility in the class, not on the actual work they had put into the project. So, they designated the more vocal people among themselves to become the “voice of the team,” actively presenting the position of the team in class discussions. The more shy members also made a conscious effort to improve their communication skills and participate in inter-team communications. One of them wrote, “I am very happy, satisfied, and also surprised because I did not know that I could speak in front of people confidently.” Not surprisingly, at the end of the course this team’s overall rating had not only climbed to second best, in large part owing to their synergy and collaboration, but individual students were satisfied with the results of their changed behavior and what they had learned about teamwork. Here is what one student wrote: “[My team] came to support me on the demo. I could not appreciate everybody enough for such support… I was in a great team.”

We found that student feedback provided as part of team rankings was not always ‘sensible, situated, grounded’, rarely ‘unbiased’, and sometimes not ‘well intentioned’ and ‘encouraging’. Comments from some students seemed to have an arbitrary nature. We see two plausible reasons
for this. One is that students had not been trained to provide constructive criticism and act like professionals. The other, on a psychological level, is that they feel the urge to compete and perceive it as fair to use all means possible in order to get an edge over everyone else.

Feedback to individual students was provided in several different forms: in a peer review, through an appreciation exercise, on the class wiki web, and through the class mailing list.

**Peer reviews.** Peer reviews are similar in spirit to team rankings and widely used as part of regular performance appraisals in industry. The goal here is to allow each student to see themselves through the eyes of everyone else with the hope that this will result in students reflecting on (and maybe changing) their own behavior and its impact on others. For this form of feedback to be effective, it needs to be conducted after participants have accumulated sufficient experience of working with each other. We did it once at the end of the first two course offerings.

We assured everyone that results from the peer review would not be used for grading purposes and made the submission of peer reviews anonymous (even to instructors) by conducting the exercise on paper and requesting that students not put their names – only their teams – on the sheet. One reason for doing it this way was to encourage honest assessments by removing the possibility of instructors identifying who gave a particular assessment. However, this choice resulted in several unforeseen drawbacks as we discuss further below.

Students gave a numeric rating** (in our case between 1 and 5, where 5 is the highest) and wrote brief comments to each of their classmates. In the end, each student received a spreadsheet containing only the ratings and comments others had written about them. These ratings and comments were grouped by team; individual “reviewers” remained anonymous.

In the first two offerings of the course, we conducted the exercise in class on paper and allowed up to 30 minutes for it. While this may have limited the usefulness of the comments students gave, it also limited the cost in terms of time they spent doing it – a conscious decision on our part and (what seemed like) a practical constraint. For instructors, however, the time commitment was high due to the use of paper, which meant that we had to read handwritings, then enter the data, and finally aggregate it. This process took one of us many hours. Because of that high cost we could not afford to have several iterations of the peer review during the term – something we would have wanted to do in order to give students a chance to improve their interactions and, hopefully, see the improvement during the term itself.

One way to correct this would be to conduct peer reviews online. In the last session of the course, several students, not knowing that we had been contemplating such a change too, suggested using online peer reviews as an alternative that would allow them to provide more careful feedback to peers. They had found the peer review results to be useful, but would have appreciated it even more if it had been done at least twice and conducted electronically (as was done with the team rankings).

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**For those cases in which students felt that they did not know someone enough to give them a rating, we provided the possibility of choosing an “N/A” rating. (In our experience, the most useful comments typically go to members of the same team.)**
With online peer reviews, the time to fill them out would be approximately the same (1-2 min per person reviewed), while the time to aggregate the results would be cut substantially, perhaps even automatically if the right tools are available.

Another drawback of the process was that, as with team rankings, there was scarcity of constructive comments. To improve in that area we now plan to make the peer review submissions non-anonymous from instructors (but still anonymous from all other students). Doing it online makes that easy.

As a result, we have now built (reusable) scripts to automate the process of collecting and aggregating the results of peer reviews. This tremendously lowers the time demand on instructors, allowing us to conduct multiple iterations during the term; it also does not artificially constrain the time students spend giving useful feedback to their peers, and creates an incentive for them to provide constructive feedback by allowing instructors to associate reviewers’ comments with those who wrote them. This system is used at the time of this writing.

The peer review feedback was not always ‘sensible, situated, grounded’, rarely ‘unbiased’, and sometimes not ‘well intentioned’ and ‘encouraging’ for the same reasons as those mentioned in the discussion of team rankings. In addition, peer review feedback was not ‘frequent’ and ‘iterative’ in the first two offerings due to its high cost, but this is now changing.

**Peer appreciation.** The goals of the peer appreciation technique are several: to reinforce the value of approaching people positively and treasuring them even over disagreements; to remind us that disagreements are rarely to be taken personally; to reconcile differences and heal relationships between individuals working in a team; to promote civility, restore, and increase mutual respect; and to create a shared sense of accomplishment\(^\text{13}\).

In contrast with the other peer feedback techniques discussed so far – all of which are in a written format – the appreciation exercise was the only verbal peer feedback that we enforced in our course\(^\dagger\). Participation was required, but the exercise was, understandably, not graded.

While the exercise is very low on cost from the instructors’ (and students’) perspectives, it was highly appreciated and warmly accepted by many students\(^\text{19}\). It requires only about 10-15 minutes of class time, and is usually best done at the end of the term. No special preparation is required. The instructor leads by example, turning to someone in the class with the words “*Name*, I appreciate you for …” It is important to be very specific with the reasons provided – having to find something appreciative for a person helps focus people on the many good things that have happened. Then, that person responds in like style. After that demonstration, students do the appreciations within their own teams (although they are free to give their appreciation to anyone in the class).

Doing this exercise at the end of our first course became a memorable experience for many. In a class where the levels of conflict ran high\(^\text{19}\), the appreciation helped to put students on the path to healing from their negative emotions, and allowed them to refocus on the lessons they had

\(^{\dagger}\) The students may have provided other verbal feedback to each other, but none of it was enforced.

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learned. It was especially gratifying to see some students come unprompted to us, at the end of each course, expressing their sincere appreciation for our help in what they had learned in the course.

Peer appreciations are inherently not ‘unbiased’ and so may leave lingering doubts in the recipient if passions run deep. They should not be considered a “silver bullet”, but rather a step in the right direction. Also, we did not make the exercise ‘frequent’ or ‘iterative’. Doing so may be warranted if early and serious conflicts threaten to disrupt the course environment.

Other techniques. In addition to the above techniques, students also used more conventional ways to provide feedback to peers: via the class mailing list, in intra-team or inter-team conversations, and via a wiki web. These were not as strictly and constantly monitored by instructors.

Cross cutting issues. Even though the presented peer feedback techniques are applicable in different contexts, and may differ in their specific goals, they share some of the potential obstacles and indicators for acceptance and success.

The main potential obstacle we see with the use of peer reviews and team rankings comes from the fact that they are not traditional mechanisms for providing feedback in academic environments. As a result, some students question the approach and resist their use at first. To overcome this, instructors have to be very explicit about the motivation for introducing these feedback tools.

Another possible problem is students who are uncomfortable dealing with critique from peers. This situation, too, can be alleviated by explicitly addressing those concerns and carefully explaining the motivation behind such unconventional techniques.

Yet another potential obstacle is the need for an enforcement mechanism to ensure that students provide useful, grounded, and concrete feedback to their peers. We have not experienced serious problems like this, but others report on the need for such a mechanism.

Finally, if feedback provided via peer reviews or team rankings is made to be non-anonymous, some students may not be sincere in what they say, especially if they feel they have a problem. In that case their feedback would lose its value as a driving force for reflection and learning.

In terms of indicators for acceptance of the different types of peer feedback, the main resource were the students’ reflective essays as well as the anonymous end-of-course questionnaire designed specifically for this class, in which students gave ratings for how useful they found the different types of feedback.

3.3.4. Feedback from Self

Perhaps the most unconventional type of feedback that we use in our course is the feedback coming from a student’s own retrospection. By including experiential sessions and various

‡‡ A web-based collaborative system that allows flexible creation and editing of web content by multiple users (in contrast to the standard Web where each page is controlled by a single person).
exercises that focus on self-observation and reflection our goal is to help students discover analogies between what they have learned and observed while working on the project and other experiences they have had in different domains. Through the process of relating new knowledge to already established mental models students are able to deepen their understanding of the subject matter and forge connections between already existing (but likely perceived as separate) factoids and pieces of knowledge. We believe that meta-cognition and the ability to consciously monitor one’s approach to problem solving are a necessary first step in crossing the gap between the novice level (in which learners need exact instructions to be followed without questioning) and the next level up (in which learners look for parallels, questioning alternative approaches to a given problem, and expressing interest in the tradeoffs between alternatives)\textsuperscript{6,3}.

An inherent characteristic of the feedback from self is that it is very difficult to measure its real effectiveness because it depends mainly on the person and their own motivation. The only way for us to have a glimpse at how well the different techniques worked was through the student reflective essays. Alternatively, a more general idea of how well these reflective tools were accepted we could obtain through a questionnaire or survey. To capture this, we had devoted a separate section on this aspect of the course in the final anonymous questionnaire. In addition, four months after the first course we conducted a survey, which showed that several students had continued practicing reflection and journaling (discussed below) in their everyday lives. Since feedback from self is new to traditional academic environments, most students have not had prior exposure to self-reflection as part of a course. This requires that instructors explicitly clarify why a particular technique is used, how and when to apply it, and how it relates to the subject matter. Furthermore, we believe that for students to accept this type of feedback it is essential that instructors teach it by setting an example themselves.

To teach students an appreciation of the influence of self-reflection on the way they think, organize, represent, and interpret information in the surrounding environment we employ a variety of techniques to practice this type of reflection. Our hope is that if we introduce several approaches to reflection students will find some among them that suite their personal learning styles well. While in the first course we offered a more limited set of reflective techniques (journaling and reflective essays), in the second offering of the course we broadened the collection with experiential sessions on centering practice and effective conversations, as explained below.

Since reflective essays were discussed earlier, here we will present our experience with the rest of the techniques.

**Journaling.** Journaling is similar in spirit to reflective essays in its main goal of enforcing the practice of reflection\textsuperscript{20}. In each class period students write in a personal physical journal about what they feel is important for them at that moment. They are assured from the very start that journals will be kept private, i.e., instructors will not ask to read them. The idea is that students feel comfortable to express what matters the most to them and in the process focus on the important aspect – practicing reflection – rather than trying to write something that instructors might give a higher grade for. In keeping with the strategy of teaching by example, instructors also have their own journals and write in them while students do so. This gives instructors a chance to capture and reflect upon their observations of the course – what works and what
aspects may need to change for future classes.

Since the journaling assignments are not graded, this technique is very light in terms of time commitment from instructors. With class sessions being 2 or 3 hours long, students wrote in their journals for 5-10 minutes at the beginning and at the end of every class period. (In the course we teach at the time of this writing, class sessions are limited to 50 minutes, so we reduced the journaling time to 5 minutes and only at the beginning of each class.)

Journaling was the practice that many students from the first course had kept when we asked them 4 months after the course had been over. 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.” We also received an unprompted email from one student after the end of the course. It said, “… 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.”

Finally, journaling meets all the criteria for effective feedback that we identified earlier.

**Centering Practice.** Centering is the practice of aligning one’s body, mind, and spirit, so that one’s intentions can easily be transformed into effective actions. The goal of the practice is to help people focus on the present moment and what they care about the most.

In our second course we had an experiential session during which students and instructors practiced focusing on their current state of mind and body in a variety of situations. The idea was to demonstrate the importance of detaching oneself from the process in order to analyze and evaluate it objectively, as well as the value of self-awareness for achieving one’s goals. At the end of the class, one student wrote: “The most important things from [this class] that I’m trying to put into action are awareness and observation.” Through the exercises we did in class students gained personal experience on how to regain control over their actions after falling in a difficult situation and being unable to reach their goal (e.g., when they are under stress because of a close deadline). They would switch their attention from the current worrisome thoughts to the state of their body, and after finding its “center,” they would refocus back on what they were doing and consider how it was distracting them from reaching the goal.

Despite the fact that this session was non-traditional for an engineering course, students seemed to resonate with its message. One of them wrote at the end of the term, “I paid more attention to states that people were in… It really made a big difference in dealing with a conflict in a group situation.” Another one said, “The exercises on state and learning how to center ourselves mentally put us in a better position to change our reactions to things we didn’t like.”

The centering practice may be problematic for novices as suggested by many of the criteria – it may appear to not be ‘sensible, situated, grounded’, not ‘easy to assess’, or not ‘unambiguous’, all due to inexperience of the person doing it. This emphasizes the need for practice to get to a

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§§ We chose them to be longer than the traditional 1-hour periods in order to accommodate for longer experiential sessions.
higher level of self-awareness.

The centering practice usually requires about 90 minutes of class time to cover adequately, especially when taught to novice students. (There is no required preparation from students.) Having 50-minute-long class sessions in the third offering of the course made us reconsider using that practice, despite its success with students in the previous offering (in which, however, they had 3 hours to split between centering and the next technique described here).

**Effective Conversations.** One of the most needed skills in the professional world, yet perhaps the one that was until recently most often overlooked in academic engineering curricula, is communication\(^1\). Effective communication is at the center of building trust among team members, decision making, coordination, and almost any collaborative activity. The job of a software engineer is no exception to this norm, so we dedicate course time to the topic of communication.

An experiential session introduced students to four types of conversations: pretense, sincerity, accuracy, and authenticity. After our guest lecturers explained the differences between them, students were paired up and had conversations concentrating on one particular type at a time. Eventually, students tried out every type of conversation from both sides of the “conversation meter” (e.g., being the one who presented an idea while the other person pretended that they agreed with everything said even if they had a “better” idea themselves; then reversing roles). After each conversation, there was a short debrief on what students had observed (e.g., how they felt being on each side) and what the possible implications of such a conversation might be for both participants (e.g., level of mutual trust, openness in future conversations, willingness to share one’s ideas, etc.).

After this session some of the students wrote in their reflective essays how they started catching themselves thinking about the effect of the different styles of conversation outside of class and how that knowledge had empowered them and helped them understand why people had problems communicating effectively, especially when under pressure. One student wrote about how they handled a situation when someone confronted them reporting a problem in that student’s part of the project: “I found that asking myself ‘Why is he or she asking me to do this?’ really helps because […] it takes my mind off the criticism.”

Since outside experts led both the centering practice and the effective conversations session, those did not require special preparation time from instructors except handling the session organization. The class time required for adequate coverage of this practice is about 90 minutes. No special preparation is required from students. As with the journaling exercise, the instructors did participate in all activities and discussions along with the students. After the end of the session the responsibility for further practicing and applying these new techniques was left up to the students, though themes of that session were regularly brought up in subsequent class discussions.

While telling one type of conversation from another may be hard (and so not ‘unambiguous’) for an inexperienced eye, revisiting these topics often in the course teaches students an awareness of the different conversation types so that they could practice recognizing them outside of class.
3.3.5. Feedback from Project Artifacts and Tools

While the process of providing feedback of the types presented in the previous sub-sections depends primarily on human involvement, and so is more subjective, the feedback coming from project artifacts and tools used in the development process does not rely exclusively on people, and consequently is more objective in nature. (Artistic representations related to the project are an exception discussed in more detail below.) Another feature that distinguishes this type of feedback from the rest is that it tends to be discipline-specific, and hence many techniques that fall into this category may not be directly transferable to courses in other domains. Only one of the techniques presented here (namely, artistic representations) is an exception, i.e., it may be adopted across disciplines without modifications.

Automatic Indicators. By employing feedback from project artifacts and tools our goal was to introduce students to techniques and tools used by professionals in their daily work. In addition, we hoped that this type of feedback would direct the students toward a deeper understanding of the value of working as a community on large-scale projects.

In the computer area, perhaps the most popular type of feedback from a project tool comes from compilers in the form of warnings and error messages emitted when a program code is compiled. Since the students have experience with compilers from previous programming classes and are used to it, this part did not present any interesting evidence, so we will not further dwell on it.

Another form of project feedback with which students are familiar is the use of application programming interfaces (APIs). Even though APIs were not a new concept to students in computer science, they did not have a deep understanding and appreciation for the type of feedback coming from APIs. The reason we see for this is that before taking our class most students had been working on projects either on their own, or in small teams (of 2-3 students) – an organization whose success does not critically depend, unlike a bigger team does, on a high level of commitment to the accuracy of the interfaces. After several misunderstandings between teams (due to misinterpretation of the problems to solve or duplicating effort for something already accomplished by another team), students realized the value of not only having formal and up-to-date APIs, but also of checking those and discussing the misleading assumptions when one team’s API did not work for other teams.

An important part of a software developer’s work is ensuring the quality of the product. As part of the course students were introduced to test-first development. From other programming classes they were already familiar with the value provided by the testing process, but for many of them this was the first time when formal automated testing was required. Test writing was enforced by requiring that students deliver their test cases as part of the project delivery; also, test coverage was considered as a factor in determining the project grade.

As part of their development process students used an automated build system. If a problem occurs during the build, it is reported by the build system through a virtual traffic light accessible online. In addition, the results from the build and automated tests are visualized by a physical traffic light located in the lab where students work. If all is right, the light is green; a yellow
signals that the next build is in process, while a red means that some component has failed.

The feedback from the project artifacts and tools discussed so far was very well accepted by most students – the reliable tools (both as an objective measure of quality and as professional-level development tools) were what students gave the highest ratings for in the end-of-quarter questionnaire. Between 50% and 90% of the students were very happy with the tools, while under 20% reported that they did not like some aspect of at least one of the tools. Through their experience with the tools students became more conscious about the quality of software products and realized that it was much easier to maintain a product’s quality from the very start – making one step at a time, in an incremental fashion – than to try to prove that everything works correctly shortly before the delivery deadline.

The only problem we encountered with this type of feedback was in the case of unsuccessful project builds close to the delivery deadline. Then, in the heat of the moment, some students started blaming the “poor soul” who had created the chaos, not realizing that this is precisely the moment when it is most important to collaborate and help fix the problem faster.

In addition to the objectiveness of the feedback coming from project artifacts and tools, these techniques are very lightweight in cost. While instructors need to be familiar with the tools and be able to provide a short introduction or demo, once set up at the start of a term, the tools provide automatic feedback and require little if any maintenance. The exact time demand on instructors depends on the project domain. From students, the effective use of automatic indicators requires continuous use of the (domain-specific) tools.

The feedback provided by automatic indicators meets all criteria, except perhaps ‘encouraging’ (from the perspective of some students, at least).

**Artistic Representations.** As part of the student feedback to the teams we had a session dedicated to the current state of the project as perceived from the different teams. As an alternative approach to the standard short slide/oral presentations students were given big sheets of paper, color markers, and the freedom to choose the form of the presentation of their team’s current project assessment. They had about 20 minutes to work in teams and about 3-5 minutes after that for each team to present their work to the rest of the class. Some teams used diagrams, others drew pictorial representation: cartoons, a puzzle, a “project monopoly” game. Students had fun creating these artistic presentations, and in the subsequent reflective essays some of them acknowledged that this exercise helped them see where the teams had misunderstandings or completely different views on the project they have all been working on. The cost for the instructor associated with this type of feedback is in using some of the class time, as well as providing materials and an environment for the students to express themselves. At the end of the exercise, instructors typically take 5-10 minutes to debrief.

This technique meets most of the criteria for effective feedback, but due to the human involvement it may not be ‘unambiguous’ or ‘unbiased’. Other qualities that may or may not be associated with this technique are ‘frequent’ and ‘iterative’ – those depend on the emphasis that instructors choose to place on artistic representations in the particular course.
3.4. Feedback We Missed

Even though we used a wide variety of feedback techniques to improve the learning process in the course, our own course retrospectives showed that we had missed some opportunities in the first two offerings of the course. This section discusses the omissions we have discovered and reports on the changes we have made to the course schedule in order to address these issues in our latest course.

**On reflective essays.** Since the reflective essays that students write and the feedback that we provide on them are a key aspect of the course, we would like to know if students find our feedback useful for their learning. While we gathered student feedback on their general perception of the usefulness of our feedback on the essays, the course did not have an established enforcement mechanism to turn the essays and the feedback on them into an interactive conversation. If such a mechanism was employed, students would be forced to consider and act on the feedback coming from instructors; moreover, it would help the instructors to better gauge the students’ level of engagement and their learning.

In both terms when we previously taught the course, there were students who came up with a simple way to create a bidirectional feedback channel – in their subsequent essays they were addressing some of the questions raised as part of the instructors’ feedback on the previous ones. These students found such a “conversation” very inspiring and were always impatient to receive our comments on their next assignment. One of them wrote, “The part [of this class] I looked forward to the most besides coding was getting my reflective essay back. [The feedback I got] inspired new thinking.”

For the current offering of the course we considered various possibilities on how to create an iterative conversation. In the end, we chose the simplest alternative – reducing the number of reflective essays in exchange for requiring a written response from students on the questions we raise in our feedback to their previous essays. (We considered using a web-based tool\textsuperscript{5} to simplify the mechanics of the iterative conversation, but in the end decided against it, because its latest version had no provision for allowing multiple instructors to provide feedback on the same student essay, while we wanted to teach students to appreciate different perspectives by doing just that, albeit not for all essays. We currently plan on developing a similar tool that would satisfy our specific requirements.)

**Others.** In the two courses so far instructors did not sit in to observe the meetings of student teams. The reason was rather pragmatic – although the instructors’ input on team dynamics may have a lot of positive impact on students (e.g., by suggesting more effective ways to conduct a meeting), it would require a much higher time commitment and so would be at the expense of some other form of feedback. In the future we plan to assess the impact of this technique by experimenting with impromptu drop-ins on student meetings.

Another feedback technique previously missing in our course – feedback on the state of the project from a competing team – is included in the current version. The idea is to have the class split in two large teams that work on the same project. On each delivery date (of which there are several for reasons already discussed) each of the two teams would hand over their current
milestone release to the other team for testing and overall feedback. We hope that such an approach will help students learn from each other, in addition to developing an end product of higher quality.

3.5. What Surprised Us

Having taught the class once, we came into the second offering armed with expectations and big plans. But the second course was unlike the first in several aspects. The differences took us by surprise.

First of all, there was not as much (inner) conflict as we had expected the class structure to encourage. Inner conflict, when carefully controlled, can be beneficial for learning – it prompts students to discover and reexamine assumptions that have constrained their potential (“Why can I not achieve what I want?”), it encourages them to become open to new models (“How can I achieve what I want?”) and ultimately to adopt (learn) these more effective models. That students did not experience as much inner conflict as their peers in the first course we attribute to both the different mix of personalities in the class (some of the students in the first course were more aggressively pushing, while others had prior management experience) and the fact that instructors intentionally did not enforce a deadline for any project-related component until well into the second part of the course. We had hoped that students would heed our suggested strategies and steer their project clear of problems without much intervention on our part. They would not listen. Only when they actually failed to deliver a full-fledged product did many of them make a step toward learning by questioning their existing models.

Another surprise for us was that despite having spent more time to prepare and improve the second course, in the end most students did not appreciate it as much as their peers had liked the first course. We believe this could be due to (a combination of) several factors:

- The learning moments came quite late in the course (due to the late failure to deliver the promised product), which meant that we had less time to refocus the students’ attention on the positive aspect – the learning that had occurred. Moreover, there was no time left in the course to do another (this time hopefully successful) project iteration and bring back their optimism. This experience has since led us to change the course structure by enforcing several short iterations, each one ending with the delivery of some “slice” of the project. The intent is that students could fail early but still have a chance to improve their process and succeed on later phases, resulting in a higher sense of accomplishment.

- Students in the second course came less often unprompted to us to informally discuss issues they were having (perhaps because they experienced less conflict and so felt that the project was cruising smoothly). In the end, we had directly interacted with fewer students and so had less chance to help as many of them as we had been able to in the first course. We expect this to be an issue in large classes too, where an instructor’s attention is necessarily split among more students.

- The instructors did not give students sufficient encouragement and positive feedback on their project work. Several students noted this in the anonymous end-of-course questionnaire we conducted. Unfortunately, we were unaware of this perception until after

** We discuss elsewhere in detail the aspects of conflict and how to handle it in a classroom environment.††† Some of the agreed upon features were there, but others were missing.
the course was over. We would have liked to capture such feedback earlier and address the need, but the message was not there halfway through the course when we did a short anonymous questionnaire specifically on how our feedback was being accepted by students. We have now decided to make an extra effort to catch students doing things right and encourage more of that, in addition to the constructive criticism we provide on their work. For students in the beginning stages of their development such encouragement is especially important.

4. Selecting Appropriate Feedback Techniques for a Course

One might ask: given the multitude of feedback techniques to choose from, how can we decide which ones to use in a course and which ones to forgo. Are some of the techniques redundant or is each one adding a valuable piece to the big picture? In the latter case, which techniques might be more important to keep?

This section attempts to shed light on how we do the technique selection during the design of our courses. Below we briefly outline a simplified version of our approach while a more elaborate version is described in detail elsewhere.

We list all feedback techniques (and possibly other important course elements) in a table with several columns: technique, level, type, and priority. For each of the dozen or so feedback techniques, we list its level – whether it relates to an individual, a team, or the project. For instance, journaling and peer reviews are individual techniques while team rankings and conversation meters are team-related. For each technique we also indicate its type – whether it is going to be an experiential session or assigned as homework. (Increasing the variety of candidate feedback techniques may require a richer definition of their types too.) Finally, we assign a priority level to each technique (on a scale of 0-3, where 3 = ‘we must use it’), reflecting how much we believe this technique fits with the specific goals of the course, whether an expert would be available to teach it (if we believed this would be better than us teaching it), whether we could devote the time to make it effective, as well as other contextual information.

With the table filled out, we proceed to assign techniques to particular dates on our calendar by following a few simple rules that reinforce the diversity of employed techniques with attention to the pragmatics of course scheduling too.

- Techniques are assigned to dates on the course calendar until the instructor believes they have exhausted the number of slots they want to devote to these techniques (but not necessarily exhausting the list of all techniques).
- Techniques are drawn from the list in descending order of their priorities.
- An attempt should be made to create a mix of techniques from all levels.
- An attempt should be made to create a mix of techniques from all types.

It is worth mentioning that the above rules may lead to ambiguous situations such as, for example, having to choose between a high-priority technique and a technique that solely “covers” a level to which no other candidate technique belongs. The existence of such cases may indicate that some of the priorities do not correctly reflect the importance that the instructor has placed in the corresponding techniques. Adjusting those appropriately will make the decision easier.
We used a version of the above approach to map the entire course structure (with about 40 different practices that we wished to convey to students) onto our course calendar. While this required the introduction of more complex types, the main idea remained the same. Since the above method is not specific to any one domain, it could be applied to scheduling courses in a variety of disciplines.

5. Summary and Conclusions

This paper is an experience report that attempts to shed light on the following questions:
• What (categories of) feedback techniques may be applicable to project-based courses?
• What are the requirements and costs of each technique and how might we assess its effectiveness?
• How might instructors balance the effectiveness of feedback they give to students with the time they spend providing that feedback?
• How can instructors choose which techniques to include in a course and which to forgo?

To maximize the effectiveness of student learning, we recommend that instructors employ fewer techniques that can be practiced regularly and enforced throughout the course, rather than a large number of techniques many of which will necessarily have only cursory coverage, likely resulting in no lasting effect. We suggest a simple, practical approach for mapping a set of candidate techniques onto a course calendar.

While the examples come from our experiences teaching software engineering, the discussed techniques are domain-independent and so could be applied broadly to project-based courses in other disciplines too.

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References


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Stani Vlasseva obtained a Masters degree with honors in Computer Science from Sofia University (Bulgaria) in 1999. After working as a research scientist at the Bulgarian Academy of Sciences, she moved to Seattle where she has since acted as a volunteer on research projects and in undergraduate courses in Computer Science and Engineering at the University of Washington. Stani’s interests are in software engineering and team management.
Appendix: Feedback Techniques in a Nutshell

The chart below summarizes the main features of all feedback techniques discussed in the paper. The semantics of each column are self-explanatory. The order in which techniques are presented is the same as that in the body of the paper.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Brief description</th>
<th>Goals</th>
<th>Requirements and Time Demands</th>
</tr>
</thead>
</table>
| on Reflective Essays | • written feedback individually to students before the next essay is due  
• poses 2-3 questions relevant to the content of the essays  
• highlights assumptions made that might be constraining student progress  
• numeric score (0 = not turned in; 1 = below expectations; 2 = met expectations; 3 = surpassed expectations) | • helps students change their stories about what is possible for them  
• practices critical thinking and writing skills | • avoid judging or pointing “the right way”  
• suggest alternative paths to solving the problems students chose to talk about  
• instructors: takes about 15 min per essay  
• students: takes 30-60 min per essay |
| on Student Portfolios   | • written comments on how well the presentation follows the requirements  
• guidance on what other factors might be considered to better address the specific audience, improve the presentation, or to support the overall message of the portfolio  
• numeric score (0-3) | • helps students to build a sense of accomplishment  
• students link their understanding of course subject to other domains  
• students learn to address a specific audience | • provide examples of good portfolios  
• multiple submissions (3 iterations, containing 1, 3, and 6 artifacts, respectively)  
• instructors: takes about 10-15 minutes per portfolio  
• students: takes several hours per artifact |
| on Project          | • poses guiding questions  
• suggests specific techniques / tools / approaches for dealing with current problems  
• provides assessment of the status of the project during project sessions and after each milestone delivery | • guides students’ attention toward the assumptions they are making  
• provides encouragement and constructive criticism | • provide specific feedback on all aspects of the project (e.g., design documents, product proposal, customer reports, documentation, testing, presentation)  
• refer back to concept / techniques / tools introduced earlier  
• instructors: give verbal feedback (5-10 min debrief) and written feedback (time depends on the depth of evaluation and the project complexity)  
• students: time required varies |
<table>
<thead>
<tr>
<th>Technique</th>
<th>Brief description</th>
<th>Goals</th>
<th>Requirements and Time Demands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guest Sessions</td>
<td>• experiential simulation sessions</td>
<td>• prepares students for encountering difficult situations while working on the project</td>
<td>• find willing experienced practitioners</td>
</tr>
<tr>
<td></td>
<td>• just-in-time coaching</td>
<td>• helps students overcome current difficulties</td>
<td>• set aside a (portion of a) class period for guests to come</td>
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<tr>
<td></td>
<td>• follow-up emails to the class mailing list</td>
<td>• grounds the broad demands of a software engineering job</td>
<td>• experts must be interested (hopefully experienced) in working with novices</td>
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<tr>
<td></td>
<td>• individual mentoring</td>
<td>• helps students appreciate the diversity of needed perspectives and personal skills</td>
<td>• instructors: handle organization; bring guests up-to-date on course</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• students: sometimes read a short paper ahead and come with questions</td>
</tr>
<tr>
<td>Feedback from Outside Experts</td>
<td></td>
<td></td>
<td>---------------------------------------------------------------------------------------------</td>
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<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Feedback from Peer Students</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Team Rankings</td>
<td>• assessments of the contribution of each team</td>
<td>• provides a glimpse of how each team’s work is perceived by other teams</td>
<td>• multiple iterations (4 times over 10 weeks)</td>
</tr>
<tr>
<td></td>
<td>• numeric rating for each team (no two teams could be given the same rating)</td>
<td>• suggests areas that need improvement</td>
<td>• results are anonymous to the students</td>
</tr>
<tr>
<td></td>
<td>• written comments using the following format: (a) “I like ____ about team X”, and (b) “I have problems with ____ about team X.”</td>
<td></td>
<td>• results are not used for grading purposes</td>
</tr>
<tr>
<td>Peer Reviews</td>
<td>• written brief comments to each of the classmates</td>
<td>• allows students to see themselves through the eyes of their peers</td>
<td>• instructors: takes about 2 hours per iteration for aggregating the results</td>
</tr>
<tr>
<td></td>
<td>• numeric rating (1-5, where 5 is the highest; N/A also available)</td>
<td>• this hopefully results in students reflecting on (and maybe changing) their own behavior and its impact on others</td>
<td>• students: takes 3-5 min per team ranked</td>
</tr>
<tr>
<td>Peer Appreciation</td>
<td>• “Name, I appreciate you for ...” specific reasons provided</td>
<td>• reinforces value of treasuring people even over disagreements</td>
<td>• conducted after participants have accumulated sufficient experience of working with each other</td>
</tr>
<tr>
<td></td>
<td>• verbal exercise</td>
<td>• restores and increases mutual respect</td>
<td>• more iterations (at least 2) work better</td>
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<tr>
<td></td>
<td></td>
<td>• reconciles differences, heals relationships</td>
<td>• results may or may not be used for grading purposes</td>
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<tr>
<td></td>
<td></td>
<td>• creates a shared sense of accomplishment</td>
<td>• instructors: time for result aggregation depends on the media used for collecting the feedback (e.g., online vs. on paper)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• students: 1-2 min per person reviewed</td>
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<table>
<thead>
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<th>Brief description</th>
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<tbody>
<tr>
<td>Feedback from Self</td>
<td></td>
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<tr>
<td>Journaling</td>
<td>• students write in their physical journals about whatever they find important for themselves at this moment</td>
<td>• enforces the practice of reflection</td>
<td>• journals are private</td>
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<tr>
<td></td>
<td></td>
<td>• helps them find parallels between the subject matter and previous experiences and knowledge from other domains</td>
<td>• instructors also write in journals</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• instructors and students: first 5-10 min of class (and last, if classes are long)</td>
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<tr>
<td>Centering Practice</td>
<td>• experiential session</td>
<td>• demonstrates the importance of self awareness for achieving one’s goals</td>
<td>• outside expert may be needed</td>
</tr>
<tr>
<td></td>
<td>• aligns mind and body, so that one can easily transform their intentions into effective actions</td>
<td>• helps students to focus on the present moment and what they care about most</td>
<td>• instructors participate in the exercises along with the students</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• set aside a full class period (about 90 min) for the session</td>
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<td></td>
<td></td>
<td></td>
<td>• instructors: handle organization</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• students: no preparation required</td>
</tr>
<tr>
<td>Effective Conversations</td>
<td>• experiential session</td>
<td>• emphasizes the importance of effective communication in a team</td>
<td>• outside expert may be needed</td>
</tr>
<tr>
<td></td>
<td>• practices different styles of conversations</td>
<td></td>
<td>• instructors participate in the exercises along with the students</td>
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<tr>
<td></td>
<td>• debrief after each exercise</td>
<td></td>
<td>• set aside a full class period (about 90 min) for the session</td>
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<td></td>
<td></td>
<td></td>
<td>• instructors: handle organization</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• students: no preparation required</td>
</tr>
<tr>
<td>Feedback from Project Artifacts and Tools</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Automatic Indicators</td>
<td>• discipline-specific</td>
<td>• introduces students to professional techniques and tools</td>
<td>• discipline-specific requirements</td>
</tr>
<tr>
<td></td>
<td>• provides objective measures</td>
<td>• directs students toward deeper understanding and enforcement of the value of working as a community on large-scale projects</td>
<td>• instructors: setting the tools once at the beginning of the term</td>
</tr>
<tr>
<td></td>
<td>• tools: Eclipse, JUnit, automated build system, traffic light, etc.</td>
<td></td>
<td>• students: continuous use of the tools</td>
</tr>
<tr>
<td>Artistic Representations</td>
<td>• teams create project status assessment using big sheets of paper and color pens</td>
<td>• presents a team’s current assessment of the project status to the other teams</td>
<td>• provide materials and environment for students to express themselves</td>
</tr>
<tr>
<td></td>
<td>• teams present their creations in front of the class</td>
<td>• checks if teams have similar perceptions on what works and what does not</td>
<td>• 20-30 min in-class retrospective exercise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• sharing of learning experiences</td>
<td>• instructor: 5-10 min debrief at the end</td>
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<td></td>
<td></td>
<td>• helps to determine areas that need improved communication channels</td>
<td>• students: no required preparation</td>
</tr>
</tbody>
</table>