A Short Guide to Teaching

Greg Wilson

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For Tom Wilkie

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The Rules

1. Be kind: all else is details.
2. Never teach alone.
3. No lesson survives first contact with learners.
4. Nobody will be more excited about the lesson than you are.
5. Every lesson is too short from the teacher's point of view and too long from the learner's.
6. Never hesitate to sacrifice truth for clarity.
7. Every mistake is a lesson.
8. "I learned this a long time ago" is not the same as "this is easy".
9. Ninety percent of magic consists of knowing one extra thing.
10. You can't help everyone, but you can always help someone.

Chapter 1

Introductions

Lesson: **15 minutes**
Challenges: **15 minutes**

is this structure explained anywhere? lesson for reader? lesson in workshop?

There's more to programming than typing in code. Good programmers break their software up into functions, automate repetitive tasks, and keep track of their work using version control. Once they have mastered those basics, they start doing code reviews and writing tests as they go along. They don't invent these techniques for themselves: more experienced programmers teach them (either explicitly or by example), and they in turn pass them on to others.

Similarly, there's more to teaching than talking. Good teachers break subjects up into digestible pieces, design lessons with verifiable goals in mind, check their students' progress at short intervals, and encourage collaboration and improvisation. Like good programming practices, these don't have to be reinvented by every teacher: they can and should be taught and learned. And while they can't automatically make someone a great teacher, they do make people better teachers.

This training course is a fast, wide-ranging, and (necessarily) incomplete introduction to modern evidence-based teaching practices. Its aim is introduce you to what we actually know about teaching and learning, why we believe it is true, and how you can apply it. We will look at:

- how people's thinking changes as they go from being novices to competent practitioners and then to being experts;
- how to tell if your learners are keeping up with you, and what to do or say when they're not;
- how to design and improve lessons efficiently and collaboratively;
- how and why live coding is a better way to teach programming than lectures or self-directed practice; and
- how insights and techniques borrowed from the performing arts can make you a better teacher.

We can't cover everything you need to know to teach well. In fact, we can barely scratch the surface. But we hope that what we show you will be useful, and will convince you that better is possible.

History

I started teaching people how to program in the late 1980s. At first, I was pretty bad at: I went too fast, I used too much jargon, and I assumed that my learners would be interested in the same things I was. I got better over time, but that doesn't mean I was actually very good. And even though I felt I was improving, I had no idea how effective I was compared to other teachers.

My doubts came to a head after I re-launched Software Carpentry in 2010. Its aim was (and is) to teach basic computing skills to researchers from a wide range of disciplines. What I realized then was that, ironically, I was trying to teach people how to build and run software in efficient, repeatable ways, but was mostly ignorant of equivalent techniques for writing and delivering lessons.

Luckily, I discovered resources like Mark Guzdial's blog [Guz17] and the book *How Learning Works* [ABD$^+$10]. These led me to the work of Lemov, Huston, Green, and others [Lem14, Hus09, Gre14], which showed me what would make my teaching better, and why I should believe it.

I started using these ideas in Software Carpentry in 2012, and the results were everything I'd hoped for. Cutting the number of lessons, shifting to in-person delivery, and using live coding all had an impact. What made the biggest difference, though, was creating a training course to turn learners into teachers.

While I originally delivered the course online over multiple weeks, by 2014 I was teaching it in two intensive days, just like our regular software skills workshops. A year later, "I" became "we" as people who had taught regular workshops began training new instructors as well. That same year, I began teaching half-day and one-day versions of the course to people who wanted to help children, recent immigrants, women re-entering the workforce, and a wide variety of others.

Those experiences are the basis of this book. I am grateful to everyone who helped shape the Software Carpentry instructor training course, including Erin Becker, Karen Cranston, Neal Davis, Rayna Harris, Kate Hertweck, Christina Koch, Sue McClatchy, Lex Nederbragt, Elizabeth Patitsas, Aleksandra Pawlik, Ariel Rokem, Tracy Teal, Fiona Tweedie, Allegra Via, Anelda van der Walt, Belinda Weaver, Jason Williams, and the hundreds of people who went through it over the years. I hope you enjoy what follows. If you do, I hope you pass on whatever you find helpful to someone else.

Callout: Who You Are

Section 6.1 will explain how to use *learner profiles* to define who a class is for. Here, we present profiles of two typical participants in a workshop based on this book.

Samira is an undergraduate student in mechanical engineering who first encountered the subject in an after-school club for girls and would now like to pass on her love for it. She has done one programming class and one robotics class, and has been a lab assistant for a couple of weekend introductions to engineering for high school students at her university, but doesn't know if she's ready to stand up and teaching. This class will introduce her to some basic classroom practices and give her a chance to try them out in front of a supportive audience.

Moshe has been writing accounting software for almost twenty years. His children's school doesn't offer a programming class, so he has volunteered to help put one together. He has never written lessons before, and after reading a dozen different "programming for kids" books, is feeling more confused than ever. This class will show him how to design and deliver lessons tailored for his students (many of whom have hearing disabilities), and how to tell how well those lessons are working.

Teaching Practices

This book can be read on its own, but it is more effective when used as part of an intensive in-person class. We suggest that workshops adopt these three practices right from the start:

- Have a code of conduct (Section 8.1).
- Take notes together (Section 8.2).
- Assess learners' motivation and prior knowledge (Section 8.3).

1.1 Challenges

Challenge: Favorite Class

In the online notes, write down your name, the best class you ever took, and what made it so great.

Chapter 2

Helping Novices Build Mental Models

Lesson:	**20 minutes**
Challenges:	**30 minutes**

The first task in teaching is to figure out who your learners are and how best to help them. Our approach is based on the Dreyfus model of skill acquisition[1], and more specifically on the work of researchers like Patricia Benner, who studied how nurses progress from being novices to being experts [Ben00]. Benner identified five stages of cognitive development that most people go through in a fairly consistent way[2]. For our purposes, we simplify this to three:

- A *novice* is someone who doesn't know what they don't know, i.e., they don't yet know what the key ideas in the domain are or how they relate. They reason by analogy and guesswork, borrowing bits and pieces of their mental models of other domains which seem

[1]https://en.wikipedia.org/wiki/Dreyfus_model_of_skill_acquisition

[2]We say "most" and "fairly" because human beings are variable, and there will always be outliers. However, that shouldn't prevent us from making strong statements about what's true for the majority.

superficially similar. One sign that someone is a novice is that their questions aren't even wrong.

- A *competent practitioner* is someone who has a mental model that's good enough for everyday purposes: they can do normal tasks with normal effort under normal circumstances. This model does not have to be completely accurate in order to be useful: for example, the average driver's mental model of how a car works probably doesn't include most of the complexities that a mechanical engineer would be concerned with.
- An *expert* is someone who can easily handle situations that are out of the ordinary, diagnose the causes of problems, and so on. We will discuss expertise in more detail in Section 4.

One example of a mental model is the ball-and-spring model of molecules that most of us encountered in high school chemistry. Atoms aren't actually balls, and their bonds aren't actually springs, but the model does a good job of helping people reason about chemical compounds and their reactions. Another model of an atom has a small central ball (the nucleus) surrounded by orbiting electrons. Again, this model is wrong, but useful for many purposes.

Novices, competent practitioners, and experts need to be taught differently. In particular, presenting novices with a pile of facts early on is counter-productive, because they don't yet have a model to fit those facts into[3]. Instead, the goal with novices is *to help them construct a working mental model* so that they have somewhere to put facts.

As an example of what this means in practice, Software Carpentry's lesson on the Unix shell[4] introduces fifteen commands in three hours. Twelve minutes per command may seem glacially slow, but the lesson's real purpose isn't to teach those fifteen commands: it's to

[3] In fact, presenting too many facts too soon can actually reinforce the incorrect mental model they've cobbled together.

[4] http://swcarpentry.github.io/shell-novice/

teach learners about paths, history, tab completion, wildcards, pipes and filters, command-line arguments, redirection, and all the other big ideas that the shell depends on. Once they understand those concepts, people can quickly learn a repertoire of commands. What's more, later lessons on how to build functions in a programming language can refer back to pipes and filters, which helps solidify both ideas.

> **Callout: Different Kinds of Lessons**
>
> The cognitive differences between novices and competent practitioners underpin the differences between two kinds of teaching materials. A tutorial's purpose is to help newcomers to a field build a mental model; a manual's role, on the other hand, is to help competent practitioners fill in the gaps in their knowledge. Tutorials frustrate competent practitioners because they move too slowly and say things that are obvious (though of course they are anything but to newcomers). Equally, manuals frustrate novices because they use jargon and *don't* explain things. One of the reasons Unix and C became popular is that Kernighan et al's trilogy [KP82, KP84, KR88] somehow managed to be good tutorials *and* good manuals at the same time. Ray and Ray's book on Unix [RR14] and Fehily's introduction to SQL [Feh08] are among the very few other books in computing that have accomplished this.

One of the challenges in building a mental model is to clear away things that *don't* belong. As Mark Twain said, "It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so."

Broadly speaking, learners' misconceptions fall into three categories:

- Simple *factual errors*, such as believing that Vancouver is the capital of British Columbia. These are simple to correct, but getting the facts right is not enough on its own.

- *Broken models*, such as believing that motion and acceleration must be in the same direction. We can address these by having them reason through examples to see contradictions.
- *Fundamental beliefs*, such as "the world is only a few thousand years old" or "human beings cannot be affecting the planet's climate". These usually cannot be addressed in class, since they are deeply connected to the learner's social identity and often cannot be reasoned away.

Teaching is most effective when instructors have a way to identify and clear up learners' misconceptions *while they are teaching*. The technical term for this is *formative assessment*, which is assessment that takes place during the lesson in order to form or shape it. Learners don't pass or fail formative assessments; instead, its main purpose is to tell both the instructor and the learner how the learner is doing, and what to focus on next. For example, a music teacher might ask a student to play a scale very slowly in order to see whether she is breathing correctly, and if she is not, what she should change.

The counterpoint to formative assessment is *summative assessment*, which is used at the end of the lesson to tell whether the desired learning took place and whether the learner is ready to move on. Learners either pass or fail a summative assessment. One example is a driving exam, which reassures the rest of society that someone can safely be allowed on the road.

Callout: Connecting Formative and Summative Assessment

One rule to use when designing lessons is that formative assessments should prepare people for summative assessments: no one should ever encounter a question on an exam for which the teaching did not prepare them. This doesn't mean novel problems should never appear, but if they do the preparation should involve practice & feedback on solving novel problems

In order to be useful during teaching, a formative assessment has to be quick to administer and give an unambiguous result. The most

Formative Assessment may deserve own subheading (2.1?); also, it applies to everything learned on path from novice to expert, not only misconceptions (implied by current position)

I don't have an attribution for this but came across recently + really like: "Formative assessment is when the chef tastes the soup; summative assessment is when the guests taste the soup."

widely used kind of formative assessment is probably the multiple choice question (MCQ). When designed well, these can do much more than just tell whether someone knows something or not. For example, suppose we are teaching children multi-digit addition. A well-designed MCQ would be:

> Q: what is 27 + 15 ?
>
> 1. 42
> 2. 32
> 3. 312
> 4. 33

The correct answer is 42, but each of the other answers provides valuable insight:

- If the child answers 32, she is throwing away the carry completely.
- If she answers 312, she knows that she can't just discard the carried 1, but doesn't understand that it's actually a ten and needs to be added into the next column. In other words, she is treating each column of numbers as unconnected to its neighbors.
- If she answers 33 then she knows she has to carry the 1, but is carrying it back into the same column it came from.

Each of these incorrect answers is a *plausible distractor* with *diagnostic power*. "Plausible" means that it looks like it could be right: instructors will often put supposedly-silly answers like "a fish!" on MCQs, but they don't provide any insight and learners actually don't find them funny. "Diagnostic power" means that each of the distractors helps the instructor figure out what to explain to that particular learner next.

Instructors should use MCQs or some other kind of formative assessment at least every 10-15 minutes in order to make sure that the class is actually learning. Since the average attention span is usually only this long, formative assessments also help break up instructional time and re-focus attention. Formative assessments can also be used preemptively: if you start a class with an MCQ and everyone can answer it correctly, then you can safely skip the part of the lecture in which you were going to explain something that your learners already know. (Doing this also helps show learners that the instructor cares about how much they are learning and enough not to waste their time.)

Callout: When to Proceed?

As the instructor, what should you do if most of the class votes for one of the wrong answers? What if the votes are evenly spread between options? The answer is, "It depends." If the majority of the class votes for a single wrong answer, you should go back and work on correcting that particular misconception. If answers are pretty evenly split between options, learners are probably guessing randomly and it's a good idea to go back to a point where everyone was on the same page.

If most of the class votes for the right answer, but a few vote for wrong ones, you have to decide whether you should spend time getting the minority caught up, or whether it's more important to keep the majority engaged. This is just one example of one of the most important rules of teaching: no matter how hard you work, or what teaching practices you use, you won't always be able to give everyone the help they need.

Callout: Peer Instruction

No matter how good a teacher is, she can only say one thing at a time. How then can she clear up many different misconceptions in a reasonable time?

The best solution developed so far is a technique called *peer instruction*[5]. Originally created by Eric Mazur at Harvard, it has been studied extensively in a wide variety of contexts, including

✱ look for Peter Newbury (UCSD)'s flowchart/quick ref. for P.I.

programming [PGMS13]. Peer instruction combines formative assessment with student discussion and looks something like this:

1. Give a brief introduction to the topic.
2. Give students an MCQ that probes for misconceptions (rather than simple factual knowledge).
3. Have all the students vote on their answers to the MCQ.

    a) If the students all have the right answer, move on.
    b) If they all have the same wrong answer, address that specific misconception.
    c) If they have a mix of right and wrong answers, give them several minutes to discuss those answers with one another in small groups (typically 2-4 students) and then reconvene and vote again.

As this video[6] shows, group discussion significantly improves students' understanding because it forces them to clarify their thinking, which can be enough to call out gaps in reasoning. Re-polling the class then lets the instructor know if they can move on, or if further explanation is necessary. A final round of additional explanation and discussion after the correct answer is presented gives students one more chance to solidify their understanding.

Peer instruction is essentially a way to provide one-to-one mentorship in a scalable way. Despite this, we usually do not use it in our workshops because it takes people time to learn a new way to learn—time that we don't have in our compressed two-day format.

Callout: A Note on MCQ Design

- A good MCQ tests for conceptual misunderstanding rather than simple factual knowledge. If you are having a hard time coming up with diagnostic distractors, then either you need to think more about your learners' mental models, or your question simply isn't a good starting point for an MCQ.

- When you are trying to come up with distractors, think about questions that learners asked or problems they had the last time you taught this subject. If you haven't taught it before, think about your own misconceptions or ask colleagues about their experiences.
- You can generate plausible distractors by asking same Q open-ended (collecting data).

&

Callout: Concept Inventories

The Force Concept Inventory[7] is a set of MCQs designed to gauge understanding of basic Newtonian mechanics. By interviewing a large number of respondents, correlating their misconceptions with patterns of right and wrong answers to questions, and then improving the questions, it's possible to construct a very precise diagnostic tool. However, it's very costly to do this, and students' ability to search for answers on the internet is an ever-increasing threat to its validity.

Callout: We Know Less Than We Think

Brown and Altadmri's "Investigating Novice Programming Mistakes: Educator Beliefs vs Student Data" [BA14] compared teachers' opinions about common programming errors with data from over 100,000 students, and finds only weak consensus amongst teachers and between teachers and data.

Designing an MCQ with plausible distractors is useful even if it is never used in class because it forces the instructor to think about the learners' mental models and how they might be broken—in short, to put themselves into the learners' heads and see the topic from their point of view.

It is valuable to try to think through, but due to expert blindness there is no substitute for asking novices directly (tests, surveys, interviews)

Teaching Practices

sec:novice-practices

If you haven't done so ~~already,~~ you should start using these three teaching practices in your instructor training workshop:

- Use sticky notes as status flags (Section 8.4).
- Use sticky notes to distribute attention (Section 8.5).
- Use sticky notes as minute cards (Section 8.6).

Is this an aside for just training? Then belongs in Appendix.

2.1 Challenges

Challenge: Your Mental Models

What do you do for a living? What is one mental model you use to frame and understand your work?

Challenge: Symptoms of Being a Novice

What are the symptoms of being a novice? I.e., what does someone do or say that leads you to classify them as a novice in some domain?

Challenge: Modelling Novice Mental Models

Create a multiple choice question related to a topic you intend to teach and explain the diagnostic power of each its distractors (i.e., what misconception each distractor is meant to identify).

When you are done, give your MCQ to a partner, and have a look at theirs. Is the question ambiguous? Are the misconceptions plausible? Do the distractors actually test for them? Are any likely misconceptions *not* tested for?

Challenge: Other Kinds of Formative Assessment

Describe another kind of formative assessment you have seen or used and explain how it helps both the instructor and the learner figure out where they are and what they need to do next.

Challenge: Icebergs

An example of how solving problems can help people correct broken mental models, consider this problem from [Eps02]. Imagine that you have placed a cake of ice in a bathtub and then filled the tub to the rim with water. When the ice melts, does the water level go up (so that the tub overflows), go down, or stay the same?

FIXME: FIGURE

The correct answer is that it stays the same; figuring out why helps people build a model of the relationship between weight, volume, and density.

Challenge: chal:minute-cards Write one thing you learned this

morning that you found useful on your green sticky note, and one question you have about the material on the red. Do *not* put your name on the notes: this is meant to be anonymous feedback. Add your notes to the pile by the door as you leave to get coffee.

Chapter 3

Teaching as a Performance Art

Lesson:	**20 minutes**
Challenges:	**45 minutes**

Many people assume that teachers are born, not made. From politicians to researchers and teachers themselves, reformers have designed systems to find and promote those who can teach and eliminate those who can't. But as Elizabeth Green explains in *Building a Better Teacher* [Gre14], that assumption is wrong, which is why educational reforms based on it have repeatedly failed.

The book is written as a history of the people who have put that puzzle together in the US. Its core begins with a discussion of what James Stigler discovered during a visit to Japan in the early 1990s:

> Some American teachers called their pattern "I, We, You": After checking homework, teachers announced the day's topic, demonstrating a new procedure (I)... Then they led the class in trying out a sample problem together (We)... Finally, they let students work through similar problems

> on their own, usually by silently making their way through a worksheet (You)…
>
> The Japanese teachers, meanwhile, turned "I, We, You" inside out. You might call their version "You, Y'all, We." They began not with an introduction, but a single problem that students spent ten or twenty minutes working through alone (You)… While the students worked, the teacher wove through the students' desks, studying what they came up with and taking notes to remember who had which idea. Sometimes the teacher then deployed the students to discuss the problem in small groups (Y'all). Next, the teacher brought them back to the whole group, asking students to present their different ideas for how to solve the problem on the chalkboard… Finally, the teacher led a discussion, guiding students to a shared conclusion (We).

It's tempting but wrong to think that this particular teaching technique is some kind of secret sauce. The actual key is revealed in the description of Akihiko Takahashi's work. In 1991, he visited the United States in a vain attempt to find the classrooms described a decade earlier in a report by the National Council of Teachers of Mathematics. He couldn't find them. Instead, he found that American teachers met once a year (if that) to exchange ideas about teaching, compared to the weekly or even daily meetings he was used to. What was worse:

> The teachers described lessons they gave and things students said, but they did not *see* the practices. When it came to observing actual lessons—watching each other teach—they simply had no opportunity… They had, he realized, no *jugyokenkyu*. Translated literally as "lesson study", *jugyokenkyu* is a bucket of practices that Japanese teachers use to hone their craft, from observing each other

> at work to discussing the lesson afterward to studying curriculum materials with colleagues. The practice is so pervasive in Japanese schools that it is. . . effectively invisible.
>
> And here lay the answer to [Akihiko's] puzzle. Of course the American teachers' work fell short of the model set by their best thinkers. . . Without *jugyokenkyu*, his own classes would have been equally drab. Without *jugyokenkyu*, how could you even teach?

So what does *jugyokenkyu* look like in practice?

> In order to graduate, education majors not only had to watch their assigned master teacher work, they had to effectively replace him, installing themselves in his classroom first as observers and then, by the third week, as a wobbly. . . approximation of the teacher himself. It worked like a kind of teaching relay. Each trainee took a subject, planning five days' worth of lessons. . . [and then] each took a day. To pass the baton, you had to teach a day's lesson in every single subject: the one you planned and the four you did not. . . and you had to do it right under your master teacher's nose. Afterward, everyone—the teacher, the college students, and sometimes even another outside observer—would sit around a formal table to talk about what they saw.
>
> [Trainees] stayed in. . . class until the students left. . . They talked about what [the master teacher] had done, but they spent more time poring over how the students had responded: what they wrote in their notes; the ideas they came up with, right and wrong; the architecture of the group discussion. . .
>
> . . . By the time he arrived in [the US], [Akihiko had] become. . . famous. . . giving public lessons that attracted hun-

> dreds, and, in one case, an audience of a thousand. He had a seemingly magical effect on children... But Akihiko knew he was no virtuoso. "It is not only me," he always said... "*Many* people." After all, it was his mentor...who had taught him the new approach to teaching... And [he] had crafted the approach along with the other math teachers in [his ward] and beyond. Together, the group met regularly to discuss their plans for teaching... [At] the end of a discussion, they'd invite each other to their classrooms to study the results. In retrospect, this was the most important lesson: not how to give a lesson, but how to study teaching, using the cycle of *jugyokenkyu* to put...work under a microscope and improve it.

Putting work under a microscope in order to improve it is commonplace in sports and music. A professional musician, for example, will dissect half a dozen different recordings of "Body and Soul" or "Smells Like Teen Spirit" before performing it. They would also expect to get feedback from fellow musicians during practice and after performances. Many other disciplines work this way too: the Japanese drew inspiration from Deming[1]'s ideas on continuous improvement in manufacturing, while the adoption of code review over the last 15 years has done more to improve everyday programming than any number of books or websites.

But this kind of feedback isn't part of teaching culture in the US, the UK, Canada, or Australia. There, what happens in the classroom stays in the classroom: teachers don't watch each other's lessons on a regular basis, so they can't borrow each other's good ideas. The result is that *every teacher has to invent teaching on their own.* They may get lesson plans and assignments from colleagues, the school board, a textbook publisher, or the Internet, but each teacher has to figure out on their own how to combine that with the theory they've learned in

[1]https://en.wikipedia.org/wiki/W._Edwards_Deming

education school to deliver an actual lesson in an actual classroom for actual students.

Demonstration lessons, in which one teacher is in front of a room full of students while other teachers observe, seem like a way to solve this. However, Fincher and her colleagues studied how teaching practices are actually transferred using both a detailed case study [FT07] and analysis of change stories [FRF+12]. The abstract of the latter paper sums up their findings:

> Innovative tools and teaching practices often fail to be adopted by educators in the field, despite evidence of their effectiveness. Na ive models of educational change assume this lack of adoption arises from failure to properly disseminate promising work, but evidence suggests that dissemination via publication is simply not effective... We asked educators to describe changes they had made to their teaching practice and analyzed the resulting stories... Of the 99 change stories analyzed, only three demonstrate an active search for new practices or materials on the part of teachers, and published materials were consulted in just eight of the stories. Most of the changes occurred locally, without input from outside sources, or involved only personal interaction with other educators.

Barker et al found something similar [BHG15]:

> Adoption is not a "rational action," however, but an iterative series of decisions made in a social context, relying on normative traditions, social cueing, and emotional or intuitive processes... Faculty are not likely to use educational research findings as the basis for adoption decisions. Faculty become aware of innovative practices either because a problem leads them to intentionally seek them out, or

> they hear about them through funded initiatives, conferences and journals, or from colleagues. They experiment (or not) for several reasons, depending on institutional expectations and policies, perceived costs and benefits for themselves and students, and the influence of role models. Faculty tend to trust other faculty whose work and institutional context is more like their own. The choice to try out practices competes with the need to "cover" material, as well as with classroom layouts. Positive student feedback is taken as strong evidence by faculty that they should continue a practice.

This phenomenon is sometimes called *lateral knowledge transfer*: someone sets out to teach X, but while watching them, their audience actually learns Y as well (or instead). For example, an instructor might set out to show people how to do a particular statistical analysis in R, but what her learners might take away is some new keyboard shortcuts in R Studio. Live coding makes this much more likely because it allows learners to see the "how" as well as the "what".

3.1 Feedback

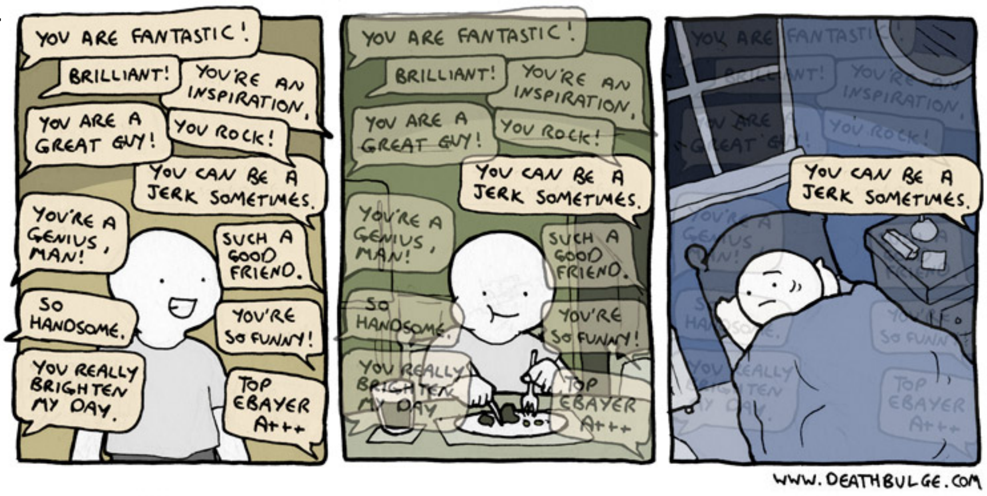
As Figure 3.1 suggests, sometimes it can be hard to receive feedback, especially negative feedback. The process is easier and more productive when the people involved share ground rules and expectations. This is especially important when they have different backgrounds or cultural expectations about what's appropriate to say and what isn't.

There are several things you can do to make feedback more effective:

1. *Initiate feedback.* It's better to ask for feedback than to receive it unwillingly.
2. *Choose your own questions*, i.e., ask for specific feedback. It's a lot harder for someone to answer, "What do you think?" than to answer

Check conditions on re-use of this

Figure 3.1: Feedback Feelings



either, "What is one thing I could have done as an instructor to make this lesson more effective?" or "If you could pick one thing from the lesson to go over again, what would it be?"

Directing feedback like this is also more helpful to you. It's always better to try to fix one thing at once than to change everything and hope it's for the better. Directing feedback at something you have chosen to work on helps you stay focused, which in turn increases the odds that you'll see progress.

3. *Balance positive and negative feedback.* One method is a "compliment sandwiches" made up of one positive, one negative, and a second positive observation. Another (which we discuss below) is to ask for at least one point in each of several categories.
4. Use a feedback translator. Have a fellow instructor (or other trusted person in the room) read over all the feedback and give an executive summary. It can be easier to hear "It sounds like most people are following, so you could speed up" than to read several notes all

saying, "this is too slow" or "this is boring".

5. Most importantly, *be kind to yourself.* Many of us are very critical of ourselves, so it's always helpful to jot down what we thought of ourselves *before* getting feedback from others. That allows us to compare what we think of our performance with what others think, which in turn allows us to scale the former more accurately. For example, it's very common for people to think that they're saying "um" and "err" all the time, when their audience doesn't notice it. Getting that feedback once allows instructors to adjust their assessment of themselves the next time they feel that way.

The technique we find most useful for giving feedback is to create a 2×2 grid and put each piece of feedback in one of its four squares. The vertical axis divides positive from negative; the horizontal divides content from presentation, i.e., what was said from how it was said. Even this little bit of structure helps people figure out what to say, and to separate those who have good ideas that they can't communicate from those who are eloquent but don't actually have anything to say.

> **Callout: Studio Classes**
>
> Architecture schools often include studio classes, in which students solve small design problems and get feedback from their peers right then and there. These classes are most effective when the instructor critiques both the designs and the peer critiques, so that participants are learning not only how to make buildings, but how to give and get feedback [Sch84]. Master classes in music serve a similar purpose, and a few people have experimented with using live coding at conferences or online in similar ways.

> **Callout: Tells**
>
> Everyone has nervous habits. For example, many of us become "Mickey Mouse" versions of ourselves when we're nervous, i.e., we

* Opportunity in feedback section to tie back to formative assessment. Teaching is a complex activity (Ch 1) and you learn much more effectively w/ formative assessment (Ch 2).

talk more rapidly than usual, in a higher-pitched voice, and wave our arms around more than we usually would.

Gamblers call nervous habits like this “tells”. While these are often not as noticeable as you would think, it’s good to identify ways to keep yourself from pacing, or fiddling with your jewellery, or not looking at the audience.

If you are interested in knowing more about giving and getting feedback, you may want to read Gormally et al’s “Feedback about Teaching in Higher Ed” [GEB14] and discuss ways you could make peer-to-peer feedback a routine part of your teaching. You may also enjoy Gawande’s essay “Personal Best” [Gaw11], which looks at the value of having a coach.

3.2 Challenges

Challenge: Giving Feedback

1. Watch this video[2] as a group and then give feedback on it. Organize feedback along two axes: positive vs. negative and content vs. presentation.
2. Have each person in the class add one point to a 2×2 grid on a whiteboard (or in the shared notes) without duplicating any points that are already up there.

What did other people see that you missed? What did they think that you strongly agree or disagree with?

Challenge: Feedback on Your Teaching

1. Split into groups of three.

2. Have each person introduce themselves and then explain, in no more than 90 seconds, the key idea or ideas from the Carpentry lesson episode they chose before the start of the training course to another person in the group while the third person records it (video and audio) using a cell phone or some other handheld device.
3. After the first person finishes, rotate roles (she becomes the videographer, her audience becomes the instructor, the person who was recording becomes the audience) and then rotate roles again.
4. After everyone in the group of three has finished teaching, watch the videos as a group. Everyone gives feedback on all three videos, i.e., people give feedback on themselves as well as on others.
5. After everyone has given feedback on all of the videos, return to the main group and put all of the feeback into the notes. Again, try to divide positive from negative and content from presentation. Try also to identify each person's tells: what do they do that betrays nervousness, and how noticeable is it?

Chapter 4

Expertise and Memory

Lesson: **20 minutes**
Challenges: **20 minutes**

The previous chapter looked at what distinguishes novices from competent practitioners. Here, we will look at expertise: what it is, how people acquire it, and how it can be harmful as well as helpful. We will then see how concept maps can be used to figure out how to turn knowledge into lessons.

To start, what do we mean when we say someone is an expert? The usual response is that they can solve problems much faster than people who are "merely competent", or that they can recognize and deal with the cases where the normal rules don't apply. They also somehow make this look effortless: in most cases, they just know what the right answer is.

What makes someone an expert? The answer isn't only that they know more facts: competent practitioners can memorize a lot of trivia without any noticeable improvement to their performance. Instead, imagine for a moment that we store knowledge as a graph in which facts are nodes and relationships are arcs. (This is emphatically *not* how our brains work, but it's a useful metaphor.) The key difference between experts and people who are "merely competent" is that experts have many more connections, i.e., their mental models are much more densely connected.

This metaphor helps explain many observed aspects of expert behavior:

1. Experts can jump directly from a problem to its solution because there actually is a direct link between the two in their mind. Where a competent practitioner would have to reason "A, B, C, D, E", the expert can go from A to E in a single step. We call this *intuition*, and it isn't always a good thing: when asked to explain their reasoning, experts often can't, because they didn't actually reason their way to the solution—they just recognized it.
2. Experts are frequently so familiar with their subject that they can no longer imagine what it's like to *not* see the world that way. As a result, they are often less good at teaching the subject than people with less expertise who still remember what it's like to have to learn the things. This phenomenon is called *expert blind spot*, and while it can be overcome with training, it's part of why world-famous researchers are often poor lecturers.
3. Densely-connected knowledge graphs are also the basis for experts' *fluid representations*, i.e., their ability to switch back and forth between different views of a problem [PvdHQ16]. For example, when trying to solve a problem in mathematics, we might switch between tackling it geometrically and representing it as a set of equations to be solved.
4. Finally, this metaphor also explains why experts are better at diagnosis than competent practitioners: more linkages between facts makes it easier to reason backward from symptoms to causes. (And this in turn is why asking programmers to debug during job interviews gives a more accurate impression of their ability than asking them to program.)

Callout: The J Word

Experts often betray their blind spot by using the word "just" in explanations, as in, "Oh, it's easy, you just fire up a new virtual machine and then you just install these four patches to Ubuntu and then you just re-write your entire program in a pure functional language." As we discuss later in Section 7, the J word (also sometimes called the passive dismissive adjective) should be banned from classrooms, primarily because using it gives learners the very clear signal that the instructor thinks their problem is trivial and that they therefore must be stupid.

The graph model of knowledge explains why helping learners make connections is as important as introducing them to facts. To use another analogy, the more people you know in a group, the more likely you are to remain part of that group. Similarly, the more connections a fact has to other facts, the more likely the fact is to be remembered.

Callout: Repetition vs. Deliberate Practice

The idea that ten thousand hours of practice will make someone an expert in some field is widely quoted, but reality is more complex. Doing exactly the same thing over and over again is much more likely to solidify bad habits than perfect performance. What actually works is *deliberate practice*[1], which is doing similar but subtly different things, paying attention to what works and what doesn't, and then changing behavior in response to that feedback to get cumulatively better.

A common progression is for people to go through three stages:

1. They *learn how to do something given feedback from others*. For example, they might write an essay about what they did on their summer holiday, and get feedback from a teacher telling them how to improve it.

2. They *learn how to give feedback.* For example, they might write an essay about character development in *The Catcher in the Rye*, and get feedback on their critique from a teacher.

3. They *apply what they've learned about feedback to themselves.* At some point, they start critiquing their own work in real time (or nearly so) using the critical skills they've built up in steps 1 and 2. Doing this is so much faster than waiting for feedback from others that proficiency suddenly starts to take off.

A meta-study conducted in 2014 [MHO14] found that "...deliberate practice explained 26% of the variance in performance for games, 21% for music, 18% for sports, 4% for education, and less than 1% for professions." One explanation for this variation is that deliberate practice works best when the rules for evaluating success are very stable, but is less effective when there are more factors at play (i.e., when it's harder to connect cause to effect).

4.1 Concept Maps

Our tool of choice to represent a knowledge graph (expert or otherwise) is a *concept map*. A concept map is simply a picture of someone's mental model of a domain: facts are bubbles, and connections are labelled arcs. It is important that they are labelled: saying "X and Y are related" is only helpful if we explain what the relationship *is*. And yes, one person's fact may be another person's connection, but one of the benefits of concept mapping is that it makes those differences explicit.

Callout: Externalizing Cognition

> Concept maps are just one way to represent our understanding of a subject. For example, Andrew Abela's decision tree[2] presents a mental mode of how to choose the right kind of chart for different kinds of questions and data. Maps, flowcharts, and blueprints can also be useful in some contexts. What each does is *externalize cognition*, i.e., make thought processes and mental models visible so that they can be compared, contrasted, and combined.

To show what concept maps look like, consider this simple `for` loop in Python:

```
for letter in "abc":
    print('*' + letter)
```

whose output is:

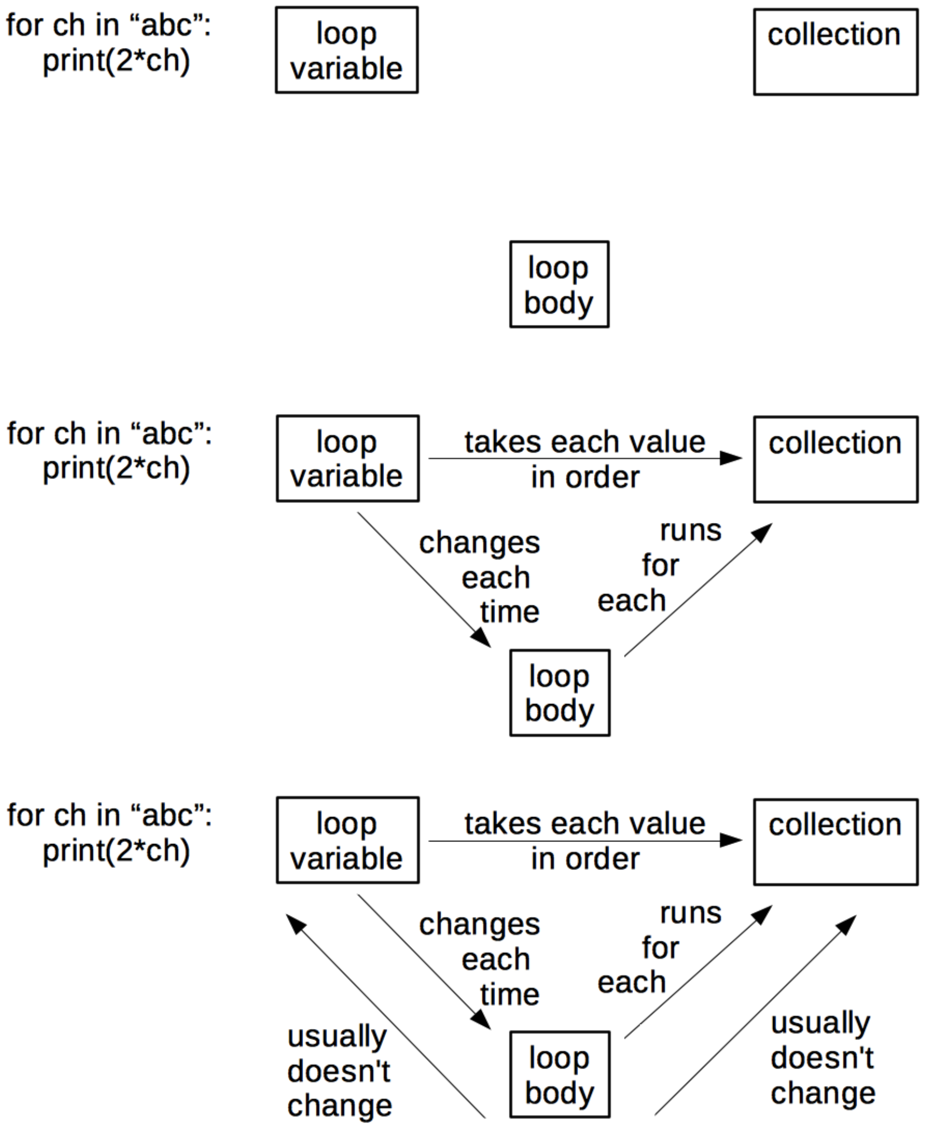
```
*a
*b
*c
```

The three key "things" in this loop are shown in Figure 4.1(a), but they are only half the story—and arguably, the less important half. Figure 4.1(b) shows the *relationships* between those things. We can go further and add two more relationships that are usually (but not always) true as shown in Figure 4.1(c).

Concept maps can be used in many ways:

1. Concept maps aid design of a lesson by helping authors figure out what they're trying to teach. Crucially, a concept map separates content from order: in our experience, people rarely wind up teaching things in the order in which they first drew them.
2. They also aid communication between lesson designers. Instructors with very different ideas of what they're trying to teach are likely to pull their learners in different directions. Drawing and sharing concept maps isn't guaranteed to prevent this, but it certainly helps.

Figure 4.1: Concept Maps



3. Concept maps also aid communication with learners. While it's possible to give learners a pre-drawn map at the start of a lesson for them to annotate, it's better to draw it piece by piece while teaching to reinforce the ties between what's in the map and what the instructor said. (We will return to this idea when we discuss Mayer's work on multimedia learning in Chapter 5.)
4. Concept maps are also a useful for assessment: having learners draw concept maps of what they think they just heard shows the instructor what was missed and what was mis-understood. However, reviewing learners' concept maps is too time-consuming for use in class, but very useful in weekly lectures *once learners are familiar with the technique*. The qualification is necessary because any new way of doing things initially slows people down—if a student is trying to make sense of basic economics, asking them to figure out how to draw their thoughts at the same time is an unfair load.

> **Callout: Meetings, Meetings, Meetings**
>
> The next time you have a team meeting, give everyone a sheet of paper and have them spend a few minutes drawing a concept map of the project you're all working on—separately. On the count of three, have everyone reveal their concept maps simultaneously. The discussion that follows everyone's realization of how different their mental models of the project's aims and organization are is always interesting...

4.2 Seven Plus or Minus Two

The graph model of knowledge is wrong but useful, but another simple model has a sound physical basis. As a rough approximation, human memory can be divided into two distinct layers. The first is called *long-term* or *persistent memory*. It is where we store things like our password, our home address, and what the clown did at our eighth birthday party that scared us so much. It is essentially unbounded: barring injury or disease, we will die before it fills up. However, it is also slow to access—too slow to help us handle hungry lions and disgruntled family members.

Evolution has therefore given us a second system called *short-term* or *working memory*. It is much faster, but also much smaller: in 1956, Miller estimated that the average adult's working memory could hold 7±2 items for a few seconds before things started to drop out. This is why phone numbers are typically 7 or 8 digits long: back when phones had dials instead of keypads, that was the longest string of numbers most adults could remember accurately for as long as it took the dial to go around and around. It's also why sports teams tend to have about half a dozen members, or be broken down into smaller groups (such as the forwards and backs in rugby).

Is this a key effect to emphasize?

Callout: Serial Position Effect

When we memorize words in a list and are asked to immediately recall them, the words first presented will have the best chance to be transferred into long-term memory. On the other hand, the items that are presented last might still be in short-term memory. These are referred to as the primacy and recency effects, respectively, and together they form the *serial position effect*.

Callout: Chunking

Our minds can store larger numbers of facts in short-term memory by creating *chunks*. For example, most of us will remember a word we read as a single item, rather than as a sequence of letters. Similarly, the pattern made by five spots on cards or dice is remembered as a whole rather than as five separate pieces of information. Chunks allow us to manage larger problems, but can also mislead us if we mis-identify something, i.e., see it as something it isn't.

move to Ch 5 ?

7 ± 2 is probably the most important number in programming. When someone is trying to write the next line of a program, or understand what's already there, she needs to keep a bunch of arbitrary facts straight in her head: what does this variable represent, what value does it currently hold, etc. If the number of facts grows too large, her mental model of the program comes crashing down (something we have all experienced).

7 ± 2 is also the most important number in teaching. An instructor cannot push information directly into a learner's long-term memory. Instead, whatever she presents is first represented in the learner's short-term memory, and is only transferred to long-term memory after it has been held there and rehearsed. If we present too much information too quickly, the new will displace the old before it has a chance to consolidate in long-term memory.

This is why it's very important to use a technique like concept mapping a lesson before teaching it - an instructor needs to identify just how many pieces of separate information will need to be "stored" in memory as part of the lesson.

Callout: Building Concept Maps Together

Concept maps can be used as a classroom discussion exercise. Put learners in small groups (2-4 people each), give each group some sticky notes on which a few key concepts are written, and have them build a concept map on a whiteboard by placing those sticky notes, connecting them with labelled arcs, and adding any other concepts they think they need.

Callout: What Are We Doing Again?

Concept maps can also be used to help build a shared understanding of what a project is trying to accomplish. Everyone independently draws a concept map to show what they think the project's goals and constraints are. Those concept maps are then revealed simultaneously. The ensuing discussion can be... vigorous.

4.3 Challenges

Challenge: The Serial Position Effect

Read the following list and try to memorize the items in it: cat, apple, ball, tree, square, head, house, door, box, car, king, hammer, milk, fish, book, tape, arrow, flower, key, shoe.

Without looking at the list again, write down as many words from the list as you can. Compare to other members of the group. What words are remembered the most?

This website[3] implements an interactive version of this exercise.

Challenge: Concept Mapping

Create a hand drawn concept map for something you would teach in five minutes. (If possible, do it for the same subject that created a multiple choice question for earlier.) Trade with a partner, and critique each other's maps. Do they present concepts or surface detail? Which of the relationships in your partner's map do you consider concepts and vice versa?

Chapter 5

Cognitive Load

Lesson:	**20 minutes**
Challenges:	**20 minutes**

In 2006, Kirschner, Sweller, and Clark published a paper titled "Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching" [KSC06]. Its abstract says:

> Although unguided or minimally guided instructional approaches are very popular and intuitively appealing... these approaches ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance.

The paper set off a minor academic firestorm, because beneath link back to "chunking"? Otherwise it doesn't see much use.

the jargon the authors were claiming that inquiry-based learning[1]—allowing learners to ask their own questions, set their own goals, and find their own path through a subject—is intuitively appealing, but doesn't actually work very well. Kirschner et al argued that this was because it requires learners to simultaneously master both a domain's factual content and its problem-solving strategies.

More specifically, the theory of *cognitive load*[2] posits that people have to deal with three things when they're learning:

- *Intrinsic* load is what people have to keep in mind in order to carry out a learning task. In a programming class, this might be understanding what a variable is, or understanding how assignment in a programming language is different from creating a reference to a cell in a spreadsheet.
- *Germane* load is the (desirable) mental effort required to create linkages between new information and old (which is one of the things that distinguishes learning from memorization). An example might be learning how to loop through a collection in Python.
- *Extraneous* load is everything else that distracts or gets in the way, such as knowing that tabs look like multiple characters but only count as one when indenting Python code.

According to this theory, searching for a solution strategy is an extra burden on top of applying that strategy. We can therefore accelerate learning by giving learners worked examples that show them a problem and a detailed step-by-step solution, followed by a series of *faded examples*. The first of these presents a nearly-complete use of the same problem-solving strategy just demonstrated, but with a small number of blanks for the learner to fill in. The next problem is also of the same type, but has more blanks, and so on until the learner is asked to solve the entire problem.

[1]https://en.wikipedia.org/wiki/Inquiry-based_learning
[2]https://en.wikipedia.org/wiki/Cognitive_load

the term scaffolding would be appropriate to introduce here.

For example, someone teaching Python might start by explaining this:

```
# total_length(["red", "green", "blue"]) => 12
def total_length(words):
    total = 0
    for word in words:
        total += len(word)
    return total
```

then ask learners to fill in the blanks in:

```
# word_lengths(["red", "green", "blue"]) => [3, 5, 4]
def word_lengths(words):
    lengths = ____
    for word in words:
        lengths ____
    return lengths
```

The next problem might be:

```
# concatenate_all(["red", "green", "blue"]) => "redgreenblue"
def concatenate_all(words):
    result = ____
    for ____ in ____:
        ____
    return result
```

and learners would finally be asked to tackle:

```
# acronymize(["red", "green", "blue"]) => "RGB"
def acronymize(words):
    ____
```

Faded examples work because they introduce the problem-solving strategy piece by piece. At each step, learners have one new problem to tackle. This is less intimidating than a blank screen or a blank sheet of paper. It also encourages learners to think about the similarities and differences between various approaches, which helps create the linkages in the mental model that instructors want them to form.

The key to constructing a good faded example is to think about the problem-solving strategy or solution pattern that it is meant to teach. For example, the series of problems are all examples of the *accumulator pattern*, in which the results of processing items from a collection are repeatedly added to a single variable in some way to create the final result.

Cognitive load theory has been criticized as being unfalsifiable[3]: since there's no way to tell in advance of an experiment whether something is germane or not, any result can be justified after the fact by labelling things that hurt performance as "extraneous" and things that don't "germane". However, there is no doubt that faded examples are effective.

Callout: Split Attention

Research by Mayer and colleagues on the *split-attention effect*[4] is closely related to cognitive load theory [MM03]. Linguistic and visual input are processed by different parts of the human brain, and linguistic and visual memories are stored separately as well. This means that correlating linguistic, auditory, and visual streams of information takes cognitive effort: when someone reads something while hearing it spoken aloud, their brain can't help but check that it's getting the same information on both channels.

Learning is therefore more effective when redundant information is *not* being presented simultaneously in two different channels. For example, people find it harder to learn from a video that has both narration and on-screen captions than from one that has either the narration or the captions but not both.

[3]https://edtechdev.wordpress.com/2009/11/16/cognitive-load-theory-failure/

This is also why it's more effective to draw a diagram piece by piece while teaching rather than presenting the whole thing at once. If parts of the diagram appear at the same time as things are being said, the two will be correlated in the learner's memory, so that pointing at part of the diagram will trigger recall of what was being said.

Another way to use cognitive load theory to construct exercises is called a *Parson's Problem*. If you are teaching someone to speak a new language, you could ask them a question, and then give them the words they need to answer the question, but in jumbled order. Their task is to put the words in the right order to answer the question grammatically, which frees them from having to think simultaneously about what to say *and* how to say it.

Similarly, when teaching people to program, you can give them the lines of code they need to sovle a problem, and ask them to put them in the right order. This allows them to concentrate on control flow and data dependencies, i.e., on what has to happen before what, without being distracted by variable naming or trying to remember what functions to call.

Challenge: Create a Faded Example

It's very common for programs to count how many things fall into different categories: for example, how many times different colors appear in an image, or how many times different words appear in a paragraph of text.

1. Create a short example (no more than 10 lines of code) that shows people how to do this, and then create a second example that solves a similar problem in a similar way, but has a couple of blanks for learners to fill in. How did you decide what to fade out? What would the next example in the series be?

2. Define the audience for your examples. For example, are these beginners who only know some basics programming concepts? Or are these learners with some experience in programming but not in Python?
3. Show your example to a partner, but do *not* tell them what level it is intended for. Once they have filled in the blanks, ask them what level they think it is for.

If there are people among the trainees who don't program at all, make sure that they are in separate groups and ask to the groups to work with that person as a learner to help identify different loads.

Challenge: Create a Parson's Problem

1. Write five or six lines of code that does something useful, jumble them, and ask your partner to put them in order. If you are using an indentation-based language like Python, do not indent any of the lines; if you are using a curly-brace language like Java, do not include any of the curly braces.
2. Create a second example similar to the first, but include one line of code that isn't needed to solve the problem. How much harder is it for your partner to put things in order when there's unneeded material getting in the way?

Chapter 6

Lessons

Lesson:	**15 minutes**
Challenges:	**20 minutes**

Most people design lessons as follows:

1. Someone tells you that you have to teach something you haven't thought about in ten years.
2. You start writing slides to explain what you know about the subject.
3. After two or three weeks, you make up an assignment based more or less on what you've taught so far.
4. You repeat step 3 several times.
5. You stay awake into the wee hours of the morning to create a final exam.

There's a better way, but to explain it, we first need to explain how *test-driven development*[1] (TDD) is used in software development. Programmers who are using TDD don't write software and then (possibly) write tests. Instead, they write the tests first, then write just enough new software to make those tests pass, and then clean up a bit.

[1]https://en.wikipedia.org/wiki/Test-driven_development

Dee Fink's guide to integrated design is available free (as in beer)

TDD works because writing tests forces programmers to specify exactly what they're trying to accomplish and what "done" looks like. It's easy to be vague when using a human language like English or Korean; it's much harder to be vague in Python or R.

TDD also reduces the risk of endless polishing, and also the risk of confirmation bias: someone who hasn't written a program is much more likely to be objective when testing it than its original author, and someone who hasn't written a program *yet* is more likely to test it objectively than someone who has just put in several hours of hard work and really, really wants to be done.

A similar "backward" method works very well for lesson design. This method is something called *reverse instructional design* or *understanding by design* (after a book by Wiggins and McTighe with that name [WM05]). There are several variations, but the one we recommend has the following steps:

1. Create learner profiles (discussed in the next section) to figure out who you are trying to teach and what will appeal to them.
2. Draw concept maps to describe the mental model you want them to construct.
3. Create a summative assessment, such as a final exam or performance, that will show you whether learning has actually taken place.
4. Create formative assessments that will give the learners a chance to practice the things they'll be asked to demonstrate in the summative assessment, and tell you and them whether they're making progress and where they need to focus their work.
5. Put the formative assessments in order based on their complexity and dependencies.
6. Write just enough to get learners from one formative assessment to the next. An actual classroom lesson will typically then consist of three or four such episodes, each building toward a short check that learners are keeping up.

This method helps to keep teaching focused on its objectives. It also ensures that learners don't face anything on the final exam that the course hasn't prepared them for.

Callout: How and Why to Fake It

One of the most influential papers in the history of software engineering was Parnas and Clements' "A Rational Design Process: How and Why to Fake It". In it, the authors pointed out that in real life we move back and forth between gathering requirements, interface design, programming, and testing, but when we write up our work it's important to describe it as if we did these steps one after another so that other people can retrace our steps. The same is true of lesson design: while we may change our mind about what we want to teach based on something that occurs to us while we're writing an MCQ, we want the notes we leave behind to present things in the order described above.

Callout: Teaching to the Test

Reverse instructional design is *not* the same thing as "teaching to the test". When using RID, teachers set goals to aid in lesson design, and may never actually give the final exam that they wrote. In many school systems, on the other hand, an external authority defines assessment criteria for all learners, regardless of their individual situations, and the outcomes of those summative assessments directly affect the teachers' pay and promotion. Green's *Building a Better Teacher* argues that this focus on measurement is appealing to those with the power to set the tests, but is unlikely to improve outcomes unless it is coupled with support for teachers to make improvements based on test outcomes [Gre14]. This is often missing, because as Scott pointed out in [Sco99], large organizations usually value uniformity over productivity.

6.1 Learner Profiles

The first piece of the process above is figuring out who your audience is. One way to do this is to write two or three *learner profiles*. This technique is borrowed from user interface design, where short profiles of typical users are created to help designers think about their audience's needs, and to give them a shorthand for talking about specific cases.

Learner profiles have five parts: the person's general background, what they already know, what *they* think they want to do, how the course will help them, and any special needs they might have. A learner profile for a weekend workshop aimed at new college students might be:

1. Jorge has just moved from Costa Rica to Canada to study agricultural engineering. He has joined the college soccer team, and is looking forward to learning how to play ice hockey.
2. Other than using Excel, Word, and the Internet, Jorge's most significant previous experience with computers is helping his sister build a WordPress site for the family business back home in Costa Rica.
3. Jorge needs to measure properties of soil from nearby farms using a handheld device that sends logs in a text format to his computer. Right now, Jorge has to open each file in Excel, crop the first and last points, and calculate an average.
4. This workshop will show Jorge how to write a little Python program to read the data, select the right values from each file, and calculate the required statistics.
5. Jorge can read English proficiently, but still struggles sometimes to keep up with spoken conversation (especially if it involves a lot of new jargon).

A single learner profile is sometimes enough, but two or three that cover the whole range of potential learners is better. One of the ways they help is by serving as a shorthand for design issues: when speaking with each other, lesson authors can say, "Would Jorge understand why we're doing this?" or, "What installation problems would Jorge face?"

also called "Learning goals".

6.2 Learning Objectives

Summative and formative assessments help instructors figure out what they're going to teach, but in order to communicate that to learners and other instructors, a course description should also have *learning objectives*. A learning objective is a single sentence describing what a learner will be able to do once they have sat through the lesson in order to demonstrate what they have learned.

Learning objectives are meant to ensure that everyone has the same understanding of what a lesson is supposed to accomplish. For example, a statement like "understand Git" could mean any of the following, each of this would be backed by a very different lesson:

- Learners can describe three scenarios in which version control systems like Git are better than file-sharing tools like Dropbox, and two in which they are worse.
- Learners can commit a changed file to a Git repository using a desktop GUI tool.
- Learners can explain what a detached HEAD is and recover from it using command-line operations.

> **Callout: Objectives vs. Outcomes**
>
> A learning *objective* is what a lesson strives to achieve. A learning *outcome* is what it actually achieves, i.e., what learners actually take away. The role of summative assessment is therefore to compare outcomes with objectives.

More specifically, a good learning objective has a *measurable or verifiable verb* that states what the learner will do, and specifies the

Table 6.1: Bloom's Taxonomy

Knowledge	recalling learned information	name, define, recall
Comprehension	explaining the meaning of information	restate, locate, explain, recognize
Application	applying what one knows to novel, concrete situations	apply, demonstrate, use
Analysis	breaking down a whole into its component parts and explaining how each part contributes to the whole	differentiate, criticize, compare
Synthesis	assembling components to form a new and integrated whole	design, construct, organize
Evaluation	using evidence to make judgments about the relative merits of ideas and materials	choose, rate, select

and your fellow + future instructors

criteria for acceptable performance. Writing these kinds of learning objectives may initially seem restrictive or limiting, but will make both you and your learners happier in the long run. You will end up with clear guidelines for both your teaching and assessment, and your learners will appreciate the clear expectations.

☆

One tool that can help when writing learning objectives is Bloom's taxonomy[2], which was first published in 1956. It attempts to define levels of understanding in a way that is hierarchical, measurable, stable, and cross-cultural. Table 6.1 shows some of the verbs typically used in learning objectives written for each of Bloom's levels.

Another way to understand what makes for a good learning objective is to see how a poor one can be improved:

[2]https://en.wikipedia.org/wiki/Bloom's_taxonomy

cwsei.ubc.ca has subsection on this which includes a bunch of CS examples (mainly from Beth Simon's time at UBC)

Spaces on lines.

Learner will be given opportunities to learn good programming practices.	Describes the lesson's content, not the attributes of successful students.
Learner will have a better appreciation for good programming practices.	Doesn't start with an active verb or define the level of learning, and the subject of learning has no context and is not specific.
Learner will understand how to program in R.	Starts with an active verb, but doesn't define the level of learning, and the subject of learning is still too vague for assessment.
Learner will write one-page read-filter-summarize-print data analysis scripts for tabular data using R and R Studio.	Starts with an active verb, defines the level of learning, and provides context to ensure that outcomes can be assessed.

Baume's guide to writing and using good learning outcomes [Bau09] is a good longer discussion of these issues.

Challenge: Learner Profiles

Working in pairs or small groups, create a five-point profile that describes one of your typical learners.

Challenge: Write Learning Objectives

Write one more learning objectives for something you currently teach or plan to teach. Working with a partner, critique and improve the objectives.

Chapter 7

Motivation and Demotivation

Lesson: **20 minutes**
Challenges: **30 minutes**

In order for learners to step out into new and unfamiliar terrain, they need encouragement. This chapter discusses typical ways that learners can be motivated, and more importantly, ways that we can demotivate them.

People learn best when they care about the topic and believe they can master it. This presents us with a problem because most people don't actually want to program: they want to make music or compare changes to zoning laws with family incomes, and rightly regard~~ing~~ programming as a tax they have to pay in order to do so. In addition, their early experiences with programming are often demoralizing, and believing that something will be hard to learn is a self-fulfilling prophecy.

Imagine a grid whose axes are labelled "mean time to master" and "usefulness once mastered". Everything that's quick to master, and immediately useful should be taught first; things in the opposite corner that are hard to learn and have little near-term application don't belong in this course.

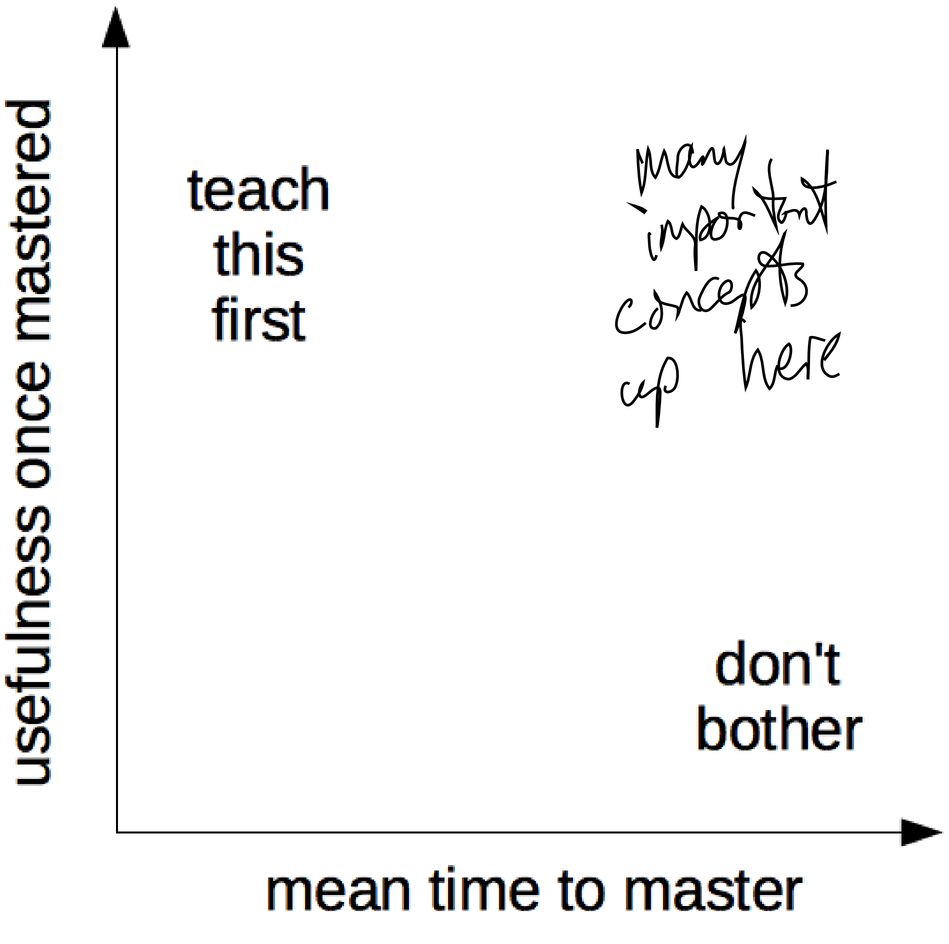
> **Callout: Actual Time**
>
> Any useful estimate of how long something takes to master must take into account how frequent failures are and how much time is lost to them. For example, editing a text file seems like a simple task, but most graphical editors save things to the user's desktop or home directory. If people need to run shell commands on the files they've edited, a substantial fraction won't be able to navigate to the right directory without help. If this seems like a small problem to you, please revisit the discussion of expert blind spot in Section 4.

Many of the foundational concepts of computer science, such as computability, inhabit the "useful but hard to learn" corner of the grid described above. This doesn't mean that they aren't worth learning, but if our aim is to convince people that they *can* learn this stuff, and that doing so will help them do more science faster, they are less compelling than things like automating repetitive tasks.

We therefore recommend a "teach most immediately useful first" approach. Have learners do something that *they* think is useful in their daily work within a few minutes of starting each lesson. This not only motivates them, it also helps build their confidence in us, so that if it takes longer to get to the payoff of a later topic, they'll stick with us.

The best-studied use of this idea is the media computation approach developed by Guzdial and Ericson at Georgia Tech [Guz13]. Instead of printing "hello world" or summing the first ten integers, their students' first program opens an image, resizes it to create ~~a~~ thumbnail, and saves the result. This is an *authentic task*, i.e., something that learners believe they would actually do in real life. It is also *tangible*: if the image comes out the wrong size, learners have a concrete starting point for debugging.

Figure 7.1: What to Teach



Callout: Strategies for Motivating Learners

How Learning Works [ABD+10] contains a list of evidence-based methods to motivate learners. None of them are surprising—it's hard to imagine someone saying that we *shouldn't* identify and reward what we value—but it's useful to check lessons against these points to make sure they're doing at least a few of these things.

What's missing from this list is strategies to motivate the *instructor*. Learners respond to an instructor's enthusiasm, and instructors need to care about a topic in order to keep teaching it, particularly when they are volunteers.

7.1 Demotivation

If you are teaching free-range learners, they are probably already motivated—if they weren't, they wouldn't be in your classroom. The challenge is therefore not to demotivate them. Unfortunately, we can do this by accident much more easily than you might think.

The ~~A~~ most powerful demotivators are *indifference* and *unfairness*. If learners believe that the instructor or the educational system doesn't care about them or the lesson, they won't care either. And if people believe the class is unfair, they will also be demotivated, even if it is unfair in their favor (because consciously or unconsciously they will worry that they will some day find themselves in the group on the losing end). Finally, a "holier-than-thou" or contemptuous attitude from an instructor is a quick way to alienate a classroom and cause learners to tune out.

Here are some quick ways to ~~demotivate~~ (emphasize) your learners:

- Tell learners they are rubbish because they use Excel and/or Word, don't modularize their code, etc.
- Repeatedly make digs about Windows and praise Linux, e.g., say that the former is for amateurs.

- Criticize GUI applications (and by implication their users) and describe command-line tools as the One True Way.
- Dive into complex or detailed technical discussion with the one or two people in the audience who clearly don't actually need to be there.
- Pretend to know more than you do. People will actually trust you more if you are frank about the limitations of your knowledge, and will be more likely to ask questions and seek help.
- Use the J word ("just"). As discussed in Section 4, this signals to the learner that the instructor thinks their problem is trivial and by extension that they therefore must be stupid for not being able to figure it out.
- Feign surprise. Saying things like "I can't believe you don't know X" or "you've never heard of Y?" signals to the learner that they do not have some required pre-knowledge of the material you are teaching, that they are in the wrong place, and it may prevent them from asking questions in the future. (This idea comes from the Recurse Center's Social Rules[1]).

It is not always feigned :-

Callout: Code of Conduct Revisited

As noted in Chapter 1, we believe very strongly that classes should have a Code of Conduct. Its details are important, but the most important thing about it is that it exists: knowing that we have rules tells people a great deal about our values and about what kind of learning experience they can expect.

Callout: Never Learn Alone

One way to support at-risk learners of all kinds is to have people sign up for workshops in small teams rather than as individuals. If an entire lab group comes, or if attendees are drawn from the same

[1]https://www.recurse.com/manual#sec-environment

> (or closely-related) disciplines, everyone in the room will know in advance that they will be with at least a few people they trust, which increases the chances of them actually coming. It also helps after the workshop: if people come with their labmates, they can work together to implement what they've learned.

7.2 Impostor Syndrome

Impostor syndrome[2] is the belief that one is not good enough for a job or position, that one's achievements are lucky flukes, and an accompanying fear of being "found out". Impostor syndrome seems to be particularly common among high achievers who undertake publicly visible work[3].

Academic work is frequently undertaken alone or in small groups but the results are shared and criticized publicly. In addition, we rarely see the struggles of others, only their finished work, which can feed the belief that everyone else finds it easy. Women and minority groups, who already feel additional pressure to prove themselves in some settings, may be particularly affected[4].

Two ways of dealing with your own impostor syndrome are:

1. Ask for feedback from someone you respect and trust. Ask them for their honest thoughts on your strengths and achievements, and commit to believing them.
2. Look for role models. Who do you know who presents as confident and capable? Think about how they conduct themselves. What lessons can you learn from them? What habits can you borrow? (Remember, they quite possibly also feel as if they are making it up as they go.)

[2]https://en.wikipedia.org/wiki/Impostor_syndrome

[3]https://www.usenix.org/blog/impostor-syndrome-proof-yourself-and-your-community

[4]http://www.paulineroseclance.com/pdf/ip_high_achieving_women.pdf

As an instructor, you can help people with their impostor syndrome by sharing stories of mistakes that you have made or things you struggled to learn. This reassures the class that it's OK to find topics hard. Being open with the group makes it easier to build trust and make students confident to ask questions. (Live coding is great for this: typos let the class see you're not superhuman.)

You can also emphasize that you want questions: you are not succeeding as a teacher if no one can follow your class, so you're asking students for their help to help you learn and improve. Remember, it's much more important to *be* smart than to *look* smart.

The Ada Initiative has some excellent resources[5] for teaching about and dealing with imposter syndrome.

7.3 Stereotype Threat

Reminding people of negative stereotypes, even in subtle ways, makes them anxious about the risk of confirming those stereotypes, which in turn reduces their performance. This is called *stereotype threat*[6], and the clearest examples in computing are gender-related. Depending on whose numbers you trust, only 12-18% of programmers are women, and those figures have actually been getting worse over the last 20 years. There are many reasons for this (see [MF03] and [MEG$^+$10]), and [Ste11] summarizes what we know about stereotype threat in general and presents some strategies for mitigating it in the classroom.

However, while there's lots of evidence that unwelcoming climates demotivate members of under-represented groups, it's not clear that stereotype threat is the underlying mechanism. Part of the problem is that the term has been used in many ways[7]; another is questions about

[5]http://adainitiative.org/continue-our-work/impostor-syndrome-training/

[6]https://en.wikipedia.org/wiki/Stereotype_threat

[7]http://www.europhd.net/html/_onda02/07/PDF/20th_lab_materials/jane/shapiro_neuberg_2007.pdf

the replicability of key studies[8]. What *is* clear is that we need to avoid thinking in terms of a deficit model (i.e., we need to change the members of under-represented groups because they have some deficit, such as lack of prior experience) and instead use a systems approach (i.e., we need to change the system because it produces these disparities).

A great example of how stereotypes work in general was presented in Patitsas et al's "Evidence That Computer Science Grades Are Not Bimodal" [PBCE16]. This thought-provoking paper showed that people see evidence for a "geek gene" where none exists. As the paper's abstract says:

> Although it has never been rigourously demonstrated, there is a common belief that CS grades are bimodal. We statistically analyzed 778 distributions of final course grades from a large research university, and found only 5.8% of the distributions passed tests of multimodality. We then devised a psychology experiment to understand why CS educators believe their grades to be bimodal. We showed 53 CS professors a series of histograms displaying ambiguous distributions and asked them to categorize the distributions. A random half of participants were primed to think about the fact that CS grades are commonly thought to be bimodal; these participants were more likely to label ambiguous distributions as "bimodal". Participants were also more likely to label distributions as bimodal if they believed that some students are innately predisposed to do better at CS. These results suggest that bimodal grades are instructional folklore in CS, caused by confirmation bias and instructor beliefs about their students.

It's easy to use language that suggests that some people are natural

[8]https://www.psychologytoday.com/blog/rabble-rouser/201512/is-stereotype-threat-overcooked-overstated-and-oversold

programmers and others aren't, but Mark Guzdial has called this belief the biggest myth about teaching computer science[9].

7.4 Mindset

Learners can be demotivated in subtler ways as well. For example, Dweck and others have studied the differences of fixed mindset and growth mindset[10]. If people believe that competence in some area is intrinsic (i.e., that you either "have the gene" for it or you don't), *everyone* does worse, including the supposedly advantaged. The reason is that if they don't get it at first, they figure they just don't have that aptitude, which biases future performance. On the other hand, if people believe that a skill is learned and can be improved, they do better on average.

see below

A person's mindset can be shaped by subtle cues. For example, if a child is told, "You did a good job, you must be very smart," she is likely to develop a fixed mindset. If on the other hand she is told, "You did a good job, you must have worked very hard," she is likely to develop a growth mindset, and subsequently achieve more. Studies have also shown that the simple action of telling learners about the different mindsets before a course can improve learning outcomes for the whole group.

As with stereotype threat, there are concerns[11] that research on grown mindset has been oversold, or will be much more difficult to put into practice than its more enthusiastic advocates have implied. While some people interpret this back and forth of claim and counter-claim as evidence than education research isn't reliable, what it really shows is that anything involving human subjects is both subtle and difficult.

[9]http://cacm.acm.org/blogs/blog-cacm/189498-top-10-myths-about-teaching-computer-science/fulltext

[10]https://en.wikipedia.org/wiki/Mindset#Fixed_mindset_and_growth_mindset

[11]http://www.learningspy.co.uk/psychology/growth-mindset-bollocks/

7.5 Accessibility

Not providing equal access to lessons and exercises is about as demotivating as it gets. If you look at the old Software Carpentry lessons on Python[12], for example, the text beside the slides includes all of the narration—but none of the Python source code. Someone using a screen reader[13] would therefore be able to hear what was being said about the program, but wouldn't know what the program actually was.

While it may not be possible to accommodate everyone's needs, it *is* possible to get a good working structure in place without any specific knowledge of what specific disabilities people might have. Having at least some accommodations prepared in advance also makes it clear that hosts and instructors care enough to have thought about problems in advance, and that any additional concerns are likely to be addressed.

> **Callout: It Helps Everyone**
>
> Curb cuts[14] (the small sloped ramps joining a sidewalk to the street) were originally created to make it easier for the physically disabled to move around, but proved to be equally helpful to people with strollers and grocery carts. Similarly, steps taken to make lessons more accessible to people with various disabilities also help everyone else. Proper captioning of images, for example, doesn't just give screen readers something to say: it also makes the images more findable by exposing their content to search engines.

The first and most important step in making lessons accessible is to *involve people with disabilities in decision-making*: the slogan *nihil de nobis, sine nobis*[15] (literally, "nothing about us, without us") predates accessibility rights, but is always the right place to start. A few other recommendations are:

[12]http://swcarpentry.github.io/v4/python/flow.html
[13]https://en.wikipedia.org/wiki/Screen_reader
[15]https://en.wikipedia.org/wiki/Nothing_About_Us_Without_Us

- *Find out what you need to do.* The W3C Accessibility Initiative's checklist for presentations[16] is a good starting point focused primarily on assisting the visually impaired, while Liz Henry's blog post about accessibility at conferences[17] has a good checklist for people with mobility issues, and this interview[18] with Chad Taylor is a good introduction to issues faced by the hearing impaired.
- *Know how well you're doing.* For example, sites like WebAIM[19] allow you to check how accessible your online materials are to visually impaired users.
- *Don't do everything at once.* We don't ask learners in our workshops to adopt all our best practices or tools in one go, but instead to work things in gradually at whatever rate they can manage. Similarly, try to build in accessibility habits when preparing for workshops by adding something new each time.
- *Do the easy things first.* There are plenty of ways to make workshops more accessible that are both easy and don't create extra cognitive load for anyone: font choices, general text size, checking in advance that your room is accessible via an elevator or ramp, etc.

7.6 Inclusivity

Inclusivity is a policy of including people who might otherwise be excluded or marginalized. In computing, it means making a positive effort to be more welcoming to women, people of color, people with various sexual orientations, the elderly, the physically challenged, the formerly incarcerated, the economically disadvantaged, and everyone else who doesn't fit Silicon Valley's white/Asian male demographic.

[16]http://www.w3.org/WAI/training/accessible

[17]https://modelviewculture.com/pieces/unlocking-the-invisible-elevator-accessibility-at-tech-conferences

[18]https://modelviewculture.com/pieces/qa-making-tech-events-accessible-to-the-deaf-community

[19]http://webaim.org/

Lee's paper "What can I do today to create a more inclusive community in CS?" [Lee17] is a brief, practical guide to doing that with references to the research literature. These help learners who belong to one or more marginalized or excluded groups, but help motivate everyone else as well; while they are phrased in terms of term-long courses, many can be applied in our workshops:

note: gendered pronoun a couple pages ago ...switch to "they"?

- Ask learners to email you before the workshop to explain how they believe the training could help them achieve their goals.
- Review notes to make sure they are free from gendered pronouns, that they include culturally diverse names, etc.
- Emphasize that what matters is the rate at which they are learning, not the advantages or disadvantages they had when they started.
- Encourage pair programming.
- Actively mitigate behavior that some learners may find intimidating, e.g., use of jargon or "questions" that are actually asked to display knowledge.

ref earlier? maybe summarize here or footnote?

7.7 Challenges

Several of these challenges use "think-pair-share". If you have not already covered this, please look at Section 8.10 now.

Challenge: Authentic Tasks

Think about something you did this week that uses one or more of the skills you teach, (e.g., wrote a function, bulk downloaded data, did some stats in R, forked a repo) and explain how you would use it (or a simplified version of it) as an exercise or example in class.

Pair up with your neighbor and decide where this exercise fits on a 2×2 grid of "short/longtime to master" and "low/high usefulness"? In the shared notes, write the task and where it fits on the grid. As a group, discuss how these relate back to the "teach most immediately useful first" approach.

Challenge: Pick One Strategy for Inclusivity

Pick one activity or change in practice from Lee's paper [Lee17] that you would like to work on. Put a reminder in your calendar three months in the future to self-check whether you have done something about it.

Challenge: Brainstorming Motivational Strategies

Think back to a programming course (or any other) that you took in the past, and identify one thing the instructor did that motivated you. Pair up with your neighbor and discuss it, and then share the story in the group notes.

Challenge: Demotivational Experiences

Think back to a time when you demotivated a student (or when you were demotivated as a student). Pair up with your neighbor and discuss what you could have done differently in the situation, and then share the story and what could have been done in the group notes.

Challenge: Walk the Route

Find the nearest public transportation drop-off point to your building and walk from there to your office and then to the nearest washroom, making notes about things you think would be difficult for someone with mobility issues. Now borrow a wheelchair and repeat the journey. How complete was your list of challenges? And did you notice that the first sentence in this challenge assumed you could actually walk?

Challenge: Who Decides?

In Littky and Grabelle's *The Big Picture: Education is Everyone's Business* [LG04], Kenneth Wesson wrote, "If poor inner-city children consistently outscored children from wealthy suburban homes on standardized tests, is anyone naive enough to believe that we would still insist on using these tests as indicators of success?" What are examples in your own experience of "objective" assessments that reinforce the status quo?

Chapter 8

Teaching Practices

Lesson:	**60 minutes**
Challenges:	**90 minutes**

FIXME: introduction

8.1 Have a Code of Conduct

An important part of making a class productive is to treat everyone with respect. We therefore strongly recommend that every group offering classes based on this material adopt a Code of Conduct like the one in Section A, and require people taking part in the class to abide by it.

We believe equally strongly that your actual programming classes should also have and enforce a Code of Conduct. Programming is a scary topic for many novices, and workshops are meant to be a judgment free space to learn and experiment. The behavior of the instructor and other participants may make more of an impression on a novice learner than any "technical" topic you teach.

If you do this, hosts should point people at it during registration, and instructors should remind attendees of it at the start of the work-

Appendix, not Section

shop. The Code of Conduct doesn't just tell everyone what the rules are: it tells them that there *are* rules, and that they can therefore expect a safe and welcoming learning experience.

If you are an instructor, and believe that someone in a workshop has violated the Code of Conduct, you may warn them, ask them to apologize, and/or expel them, depending on the severity of the violation and whether or not you believe it was intentional. Whatever you do:

- Do it in front of witnesses. Most people will tone down their language and hostility in front of an audience, and having someone else present ensures that later discussion doesn't degenerate into conflicting claims about who said what.
- Contact the organizer or host of your class as soon as you can and describe what happened. Remember, a Code of Conduct is meaningless without a procedure for enforcing it.

A Code of Conduct cannot stop people from being offensive, any more than laws against theft stop people from stealing. What it *can* do is make expectations and consequences clear. In our experience, people rarely violate the Code of Conduct in person, though some are more likely to online, where they feel less inhibited. And remember, a Code of Conduct is *not* an infringement on free speech. People have a right to say what they think, but that doesn't mean they have a right to speak wherever and whenever they want. If someone wishes to say something disparaging about someone else, they can go and find a space of their own in which to say it.

8.2 Take Notes Together

Many studies have shown that taking notes while learning improves retention [ATS75, BBTR11]. As we will discuss in Section 4, this happens because taking notes forces you to organize and reflect on material as it's coming in, which in turn increases the likelihood that you will transfer it to long-term memory in a usable way.

Our experience, and some recent research findings, lead us to believe that taking notes *collaboratively* helps learning even more [III15], even though taking notes on a computer is generally less effective than taking notes using pen and paper [MO14]. Taking notes collaboratively:

- It allows people to compare what they think they're hearing with what other people are hearing, which helps them fill in gaps and correct misconceptions right away.
- It gives the more advanced learners in the class something useful to do. Rather than getting bored and checking Twitter during class, they often take the lead in recording what's being said, which keeps them engaged, and allows less advanced learners to focus more of their attention on new material. Keeping the more advanced learners busy also helps the whole class stay engaged because boredom is infectious: if a handful of people start updating their Facebook profiles, the people around them will start checking out too.
- The notes the learners take are usually more helpful *to them* than those the instructor would prepare in advance, since the learners are more likely to write down what they actually found new, rather than what the instructor predicted would be new.
- Glancing at the notes as they're being taken helps the instructor discover that the class didn't hear something important, or misunderstood it.

We usually use Etherpad[1] for collaborative note-taking, though many instructors have shifted to Google Docs[2], both because it scales better and because it allows people to add images to the notes. Whichever is chosen, classes also use it to share snippets of code and small datasets,

[1]http://etherpad.org
[2]https://docs.google.com

and as a way for learners to show instructors their work (by copying and pasting it in).

Shared note-taking is almost always mentioned positively in post-workshop feedback. However, it's also common for participants to report that they find it distracting, as it's one more thing they have to keep an eye on. We believe the positives outweigh the negatives, but think that some careful controlled studies would tell us whether we're right, and how to use it better.

8.3 Assess Learners' Motivation and Prior Knowledge

Most formal educational systems train people to treat all assessment as summative, i.e., to think of every interaction with a teacher as an evaluation, rather than as a chance to shape instruction. For example, we use a short pre-assessment questionnaire to profile learners before workshops to help instructors tune the pace and level of material. We send this questionnaire out after people have registered rather than making it part of the sign-up process because when we did the latter, many people concluded that since they couldn't answer all the questions, they shouldn't enrol. We were therefore scaring off many of the people we most wanted to help.

Instead of asking people how easily they could complete specific tasks, we could just ask them to rate their knowledge of various subjects on a scale from 1 to 5. However, self-assessments of this kind are usually inaccurate because of the Dunning-Kruger effect[3]: the less people know about a subject, the less accurate their estimate of their knowledge is.

That said, there *are* things we can do:

- Before running a workshop, communicate its level clearly to everyone who's thinking of signing up by listing the topics that will be

[3]https://en.wikipedia.org/wiki/Dunning%E2%80%93Kruger_effect

covered and showing a few examples of exercises that people will be asked to complete.

- Provide multiple exercises for each teaching episode so that more advanced learners don't finish early and get bored.
- Ask more advanced learners to help people next to them. They'll learn from answering their peers' questions (since it will force them to think about things in new ways).
- The helpers and the instructor who isn't teaching the particular episode should keep an eye out for learners who are falling behind and intervene early so that they don't become frustrated and give up.

The most important thing is to accept that no class can possibly meet everyone's individual needs. If the instructor slows down to accommodate two people who are struggling, the other 38 are not being well served. Equally, if she spends a few minutes talking about an advanced topic because two learners are bored, the 38 who don't understand it will feel left out. All we can do is tell our learners what we're doing and why, and hope that they'll understand.

It's important to design lessons with a particular audience in mind. It's equally important to find out who's in each specific audience, since this will influence how you introduce yourself, motivate topics, and pace the lessons. Before the start of a Software Carpentry instructor training class, we ask people to fill in a short questionnaire like the one below. It doesn't tell us everything we might want to know, but it does give trainers a pretty clear idea of who they're speaking to.

1. Have you ever participated in a Software Carpentry or Data Carpentry workshop? (Check all that apply.)

   ☐ Yes, as a learner.

   ☐ Yes, as a helper.

   ☐ Yes, as an organizer.

- ☐ Yes, as an instructor.
- ☐ No, but I am familiar with what is taught at a workshop.
- ☐ No, and I am not familiar with what is taught at a workshop.

2. Which of these describes your teaching experience? (Check all that apply.)

    - ☐ I have none.
    - ☐ I have taught a seminar, workshop, or other short or informal course.
    - ☐ I have been a graduate or undergraduate teaching assistant for a college- or university-level course.
    - ☐ I have been the instructor-of-record for a college- or university-level course.
    - ☐ I have taught at the K-12 level.

3. Which of these describes your previous formal training in teaching? (Please choose only one.)

    - ☐ None
    - ☐ A few hours
    - ☐ A workshop
    - ☐ A certification or short course
    - ☐ A full degree

4. How frequently do you work with the tools that Data Carpentry and Software Carpentry teach, such as R, Python, MATLAB, Perl, SQL, Git, OpenRefine, and the Unix Shell?

    - ☐ Every day
    - ☐ A few times a week

☐ A few times a month

☐ A few times a year

☐ Never or almost never

5. How often would you expect to teach on Software or Data Carpentry Workshops after this training?

   ☐ Not at all

   ☐ Once a year

   ☐ Several times a year

6. Why do you want to take this training course?

   ____

8.4 Use Sticky Notes as Status Flags

Give each learner two sticky notes of different colours, e.g., red and green. These can be held up for voting, but their real use is as status flags. If someone has completed an exercise and wants it checked, they put the green sticky note on their laptop; if they run into a problem and need help, the put up the red one. This is better than having people raise their hands because:

- it's more discreet (which means they're more likely to actually do it),
- they can keep working while their flag is raised, and
- the instructor can quickly see from the front of the room what state the class is in.

Sometimes a red sticky involves a technical problem that takes a bit more time to solve. To prevent this issue to slow down the whole class too much, you could use the occasion to take the small break you had planned to take a bit later, giving the helper(s) time to fix the problem.

8.5 Use Sticky Notes to Distribute Attention

FIXME: Sticky notes to distribute attention

8.6 Minute Cards

We frequently use sticky notes as *minute cards*: before each break, learners take a minute to write one positive thing on the green sticky note (e.g., one thing they've learned that they think will be useful), and one thing they found too fast, too slow, confusing, or irrelevant on the red one. They can use the red sticky note for questions that haven't yet been answered. While they are enjoying their coffee or lunch, the instructors review and cluster these to find patterns. It only takes a few minutes to see what learners are enjoying, what they still find confusing, what problems they're having, and what questions are still unanswered.

8.7 One Up, One Down

We frequently ask for summary feedback at the end of each day. The instructors ask the learners to alternately give one positive and one negative point about the day, without repeating anything that has already been said. This requirement forces people to say things they otherwise might not: once all the "safe" feedback has been given, participants will start saying what they really think.

Minute cards are anonymous; the alternating up-and-down feedback is not. Each mode has its strengths and weaknesses, and by providing both, we hope to get the best of both worlds.

8.8 Pair Programming

Pair programming is a good practice in real life, and also a good way to teach [PGMS13]. Partners can not only help each other out during the

→ mentioned earlier; maybe even a brief definition for those who are not familiar, not just the citation. e.g. Pair programming means two people work together to code on one machine, one is the "driver" typing code & other is "navigator" (may look things up on second machine) + switch roles at regular intervals (e.g. every 10-20 mins?)

Is this correct? May be in conflict w/ 'own machine' issue

practical, but can also clarify each other's misconceptions when the solution is presented, and discuss common research interests during breaks. To facilitate this, we strongly prefer flat (dinner-style) seating to banked (theater-style) seating; this also makes it easier for helpers to reach learners who need assistance.

When pair programming is used it's important to put *everyone* in pairs, not just the learners who are struggling, so that no one feels singled out. It's also useful to have people sit in new places (and hence pair with different partners) after each coffee or meal break.

and to encourage/support/enforce switching within the pair.

8.9 Setup

Learners tell us that it is important to them to leave the workshop with their own machine set up to do real work. We therefore continue to teach on all three major platforms (Linux, Mac OS X, and Windows), even though it would be simpler to require learners to use just one.

FIXME: Talk about getting learners' machines set up.

Callout: Virtual Machines

We have experimented with virtual machines (VMs) on learners' computers to reduce installation problems, but those introduce problems of their own: older or smaller machines simply aren't fast enough, and learners often struggle to switch back and forth between two different sets of keyboard shortcuts for things like copying and pasting.

Some instructors use VPS over SSH or web browser pages instead. This solve the installation issues, but makes us dependent on host institutions' WiFi (which can be of highly variable quality), and has the issues mentioned above with things like keyboard shortcuts.

8.10 Teaching Online

Many learners find it difficult to get to a workshop, either because there isn't one locally or because it's difficult to schedule time around other commitments, so why don't we create video recordings of the lessons and offer the workshop as a MOOC (Massive Open Online Course)?

The first answer is that we did in 2010-11, but found the maintenance costs unsustainable. Making a small change to this webpage only takes a few minutes. but making *any* change to a video takes an hour or more. In addition, most people are much less comfortable recording themselves than contributing written material.

The second answer is that doing significantly outperforms watching. Specifically, a recent paper by Koedinger et al [KKJ$^+$15] estimated "…the learning benefit from extra doing (1 SD increase) to be more than six times that of extra watching or reading." *Doing*, in this case, refers to completing an interactive or mimetic task with feedback, while *benefit* refers to both *completion rates* and *overall performance*.

And while we do not (yet) have empirical data, we believe very strongly that many novices would give up in despair if required to debug setup and installation lessons on their own, but are more likely to get past these obstacles if someone is present to help them.

An intermediate approach that has proven quite successful is real-time remote instruction, in which the learners are co-located at one (or a few) sites, with helpers present, while the instructor(s) teaching via online video. This model has worked well for this instructor training course, and for a handful of regular workshops, but more work is needed to figure out its pros and cons.

Think-Pair-Share

Think-pair-share is a lightweight technique that helps refine their ideas and compare them with others'. Each person starts by thinking individually about a question or problem and jotting down a few notes. Participants are then paired to explain their ideas to each another, and possibly to merge them or select the more interesting ones. Finally, a few pairs present their ideas to the whole group.

Think-pair-share works because, to paraphrase Oscar Wilde's Lady Windermere, people often can't know what they're thinking until they've heard themselves say it. Pairing gives people new insight into their own thinking, and forces them to think through and resolve any gaps or contradictions *before* exposing their ideas to a larger group.

8.11 Challenges

Challenge: Create a Questionnaire

Using the questionnaire in Section 8.3 as a template, create a short questionnaire you could give learners before teaching a class of your own. What do you most want to know about their background?

Chapter 9

Live Coding

Lesson:	**15 minutes**
Challenges:	**30 minutes**

Teaching is theater not cinema.
— Neal Davis

Teaching is a performance art, just like drama, music, and athletics. And as in those fields, we have a collection of small tips and tricks to make teaching work better.

The first of our recommended teaching practices is so central that it deserves a chapter of its own: live coding. When they are live coding, instructors don't use slides. Instead, they through the lesson material, typing in the code or instructions, with their learners following along. Its advantages are:

- Watching a program being written is more compelling than watching someone page through slides that present bits and pieces of the same code.

- It enables instructors to be more responsive to “what if?” questions. Where a slide deck is like a railway track, live coding allows instructors to go off road and follow their learners’ interests.
- It facilitates lateral knowledge transfer: people learn more than we realized we were teaching by watching *how* instructors do things.
- It slows the instructor down: if she has to type in the program as she goes along, she can only go twice as fast as her learners, rather than ten-fold faster as she could with slides.
- Learners get to see instructors’ mistakes *and how to diagnose and correct them.* Novices are going to spend most of their time doing this, but it’s left out of most textbooks.
- Watching instructors make mistakes shows learners that it’s all right to make mistakes of their. Most people model the behavior of their teachers: if the instructor isn’t embarrassed about making and talking about mistakes, learners will be more comfortable doing so too.

Live coding is an example of the “I/We/You” approach to teaching discussed in Chapter 3. It takes a bit of practice for instructors to get used to thinking aloud while coding in front of an audience, but most report that it is then no more difficult to do than talking off a deck of slides.

> **Callout: Double Devices**
>
> Many instructors now use two devices when teaching: a laptop plugged into the projector for learners to see, and a tablet beside it on which they can view their notes and the shared notes that the learners are taking. This seems to be more reliable than displaying one virtual desktop while flipping back and forth to another.

Here are some tips to make your live coding better:

1. *Be seen and heard.* If you are physically able to stand up for a couple of hours, do it while you are teaching. When you sit down,

you are hiding yourself behind others for those sitting in the back rows. Make sure to notify the workshop organizers of your wish to stand up and ask them to arrange a high table, standing desk, or lectern.

Regardless of whether you are standing or sitting, make sure to move around as much as reasonable. You can for example go to the screen to point something out, or draw something on the white/blackboard (see below). Moving around makes the teaching more lively, less monotonous. It draws the learners' attention away from their screens, to you, which helps get the point you are making across.

Even though you may have a good voice and know how to use it well, it may be a good idea to use a microphone, especially if the workshop room is equipped with one. Your voice will be less tired, and you increase the chance of people with hearing difficulties being able to follow the workshop.

2. *Take it slow.* For every command you type, every word of code you write, every menu item or website button you click, say out loud what you are doing while you do it. Then point to the command and its output on the screen and go through it a second time. This not only slows you down, it allows learners who are following along to copy what you do, or to catch up, even when they are looking at their screen while doing it. If the output of your command or code makes what you just typed disappear from view, scroll back up so learners can see it again - this is especially needed for the Unix shell lesson.

   Other options are to execute the same command a second time, or to copy and paste the last command(s) into the workshop's shared notes.

3. *Mirror your learner's environment as much as possible.* You may have set up your environment to your liking, with a very simple or rather fancy Unix prompt, colour schemes for your development environment, keyboard shortcuts etc. Your learners usually won't

have all of this. Try to create an environment that mirrors what your learners have, and avoid using keyboard shortcuts. Some instructors create a separate 'bare-bone' user (login) account on their laptop, or a separate 'teaching-only' account on the service being taught (e.g., Github).

4. *Use the screen wisely.* Use a big font, and maximize the window. A black font on a white background works better than a light font on a dark background. When the bottom of the projector screen is at the same height, or below, the heads of the learners, people in the back won't be able to see the lower parts. Draw up the bottom of your window(s) to compensate.

   If you can get a second screen, use it! It will usually require its own PC or laptop, so you may need to ask a helper to control it. You could use the second screen to show the Etherpad content, or the lesson material, or illustrations.

   Pay attention to the lighting (not too dark, no lights directly on/above the presenter's screen) and if needed, reposition the tables so all learners can see the screen, and helpers can easily reach all learners.

5. *Use illustrations.* Most lesson material comes with illustrations, and these may help learners to understand the stages of the lesson and to organize the material. What can work really well is when you as instructor generate the illustrations on the white/blackboard as you progress through the material. This allows you to build up diagrams, making them increasingly complex in parallel with the material you are teaching. It helps learners understand the material, makes for a more lively workshop (you'll have to move between your laptop and the blackboard) and gathers the learners' attention to you as well.

6. *Avoid distractions.* Turn off any notifications you may use on your laptop, such as those from social media, email, etc. Seeing notifications flash by on the screen distracts you as well as the learners

- and may even result in awkward situations when a message pops up you'd rather not have others see.

7. *Improvise after you know the material.* The first time you teach a new lesson, you should stick fairly closely to the topics it lays out and the order they're in. It may be tempting to deviate from the material because you would like to show a neat trick, or demonstrate some alternative way of doing something. Don't do this, since there is a fair chance you'll run into something unexpected that you then have to explain.

   Once you are more familiar with the material, though, you can and should start improvising based on the backgrounds of your learners, their questions in class, and what you find most interesting about the lesson. This is like a musician playing a new song: the first few times, you stick to the sheet music, but after you're comfortable with it, you can start to put your own stamp on it.

   If you really want to use something outside of the material, try it out thoroughly before the workshop: run through the lesson as you would during the actual teaching and test the effect of your modification.

   Some instructors use printouts of the lesson material during teaching. Others use a second device (tablet or laptop) when teaching, on which they can view their own notes and the shared notes the learners are taking. This seems to be more reliable than displaying one virtual desktop while flipping back and forth to another.

8. *Embrace mistakes.*

   No matter how well prepared you are, you will be making mistakes. Typo's are hard to avoid, you may overlook something from the lesson instructions, etc. This is OK! It allows learners to see instructors' mistakes and how to diagnose and correct them. Some mistakes are actually an opportunity to point something out, or reflect back on something covered earlier. Novices are going to spend most of their time making the same and other mistakes, but how to deal with them is left out of most textbooks.

> The typos are the pedagogy.
> — Emily Jane McTavish

9. *Have fun.* Teaching is performance art and can be rather serious business. On the one hand, don't let this scare you - it is much easier than performing Hamlet. You have an excellent script at your disposal, after all! On the other hand, it is OK to add an element of 'play', i.e. use humor and improvisation to liven up the workshop. How much you are able and willing to do this is really a matter of personality and taste - as well as experience. It becomes easier when you are more familiar with the material, allowing you to relax more. Choose your words and actions wisely, though. Remember that we want the learners to have a welcoming experience and a positive learning environment - a misplaced joke can ruin this in an instant. Start small, even just saying 'that was fun' after something worked well is a good start. Ask your co-instructors and helpers for feedback when you are unsure of the effect you behaviour has on the workshop.

9.1 Challenges

Challenge: The Bad and the Good

Watch this video of live coding done poorly[1] and this video of live coding done right[2] as a group and then summarize your feedback on both using the usual 2×2 grid. These videos assume learners know what a shell variable is, know how to use the `head` command, and are familiar with the contents of the data files being filtered.

Challenge: See Then Do

Teach 3-4 minutes of your chosen lesson episode using live coding to a fellow trainee, then swap and watch while that person live codes for you. Don't bother trying to record the live coding sessions—we have found that it's difficult to capture both the person and the screen with a handheld device—but give feedback the same way you have previously (positive and negative, content and presentation). If you decide to instead teach something from the lesson episode you selected in preparation for this workshop, explain in advance to your fellow trainee what you will be teaching and what the learners you teach it to are expected to be familiar with.

- What felt different about live coding (vs. standing up and lecturing)? What was harder/easier?
- Did you make any mistakes? If so, how did you handle them?
- Did you talk and type at the same time, or alternate?
- How often did you point at the screen? How often did you highlight with the mouse?
- What will you try to do differently next time?

☆ I really like the mini-summaries w/ the citations!

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Appendix A

Code of Conduct

> To make clear what is expected, everyone participating in this class is required to conform to the following Code of Conduct. This code of conduct applies to all spaces managed by our group including, but not limited to, workshops, mailing lists, and online forums (including source code repositories). Workshop hosts are expected to assist with enforcement of the Code of Conduct.
>
> If you believe someone is violating the Code of Conduct we ask that you report it to the course organizer and/or the course's hosts. All reports will be kept confidential.

We are dedicated to providing a welcoming and supportive environment for all people, regardless of background or identity. However, we recognise that some groups in our community are subject to historical and ongoing discrimination, and may be vulnerable or disadvantaged. Membership in such a specific group can be on the basis of characteristics such as such as gender, sexual orientation, disability, physical appearance, body size, race, nationality, sex, colour, ethnic or social origin, pregnancy, citizenship, familial status, veteran status, genetic information, religion or belief, political or any other opinion, membership of a national minority, property, birth, age, or choice of text editor. We do not tolerate harassment of participants on the basis of these categories, or for any other reason.

Harassment is any form of behaviour intended to exclude, intimidate, or cause discomfort. Because we are a diverse community, we may have different ways of communicating and of understanding the intent behind actions. Therefore we have chosen to prohibit certain forms of behaviour in our community, regardless of intent. Prohibited harassing behaviour includes but is not limited to:

- written or verbal comments which have the effect of excluding people on the basis of membership of a specific group listed above;
- causing someone to fear for their safety, such as through stalking, following, or intimidation;
- the display of sexual or violent images;
- unwelcome sexual attention;
- nonconsensual or unwelcome physical contact;
- sustained disruption of talks, events or communications;
- incitement to violence, suicide, or self-harm;
- continuing to initiate interaction (including photography or recording) with someone after being asked to stop; and
- publication of private communication without consent.

Behaviour not explicitly mentioned above may still constitute harassment. The list above should not be taken as exhaustive but rather as a guide to make it easier to enrich all of us and the communities in which we participate. All interactions should be professional regardless of location: harassment is prohibited whether it occurs on or offline, and the same standards apply to both.

Enforcement of the Code of Conduct will be respectful and not include any harassing behaviors.

Thank you for helping make this a welcoming, friendly community for all.

This code of conduct is a modified version of that used by PyCon, which in turn is forked from a template written by the Ada Initiative and hosted on the Geek Feminism Wiki.

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Appendix B

License

to distinguish from App. D which is inst. training

Appendix C

Checklists for Carpentry Workshops

See Atul Gawande's 2007 article "The Checklist[1]" for a look at how using checklists can save lives (and make many other things better too).

C.1 Scheduling the Event

1. Decide if it will be in person, online for one site, or online for several.
2. Talk through expectations with the host(s). If it is in person, make sure the host knows they're covering travel costs for trainers.
3. Determine who is allowed to attend.
4. Arrange trainers.
5. Arrange space. Make sure there are breakout rooms for video recording.
6. Choose dates. If it is in person, book travel.
7. Get names and email addresses of attendees from host(s).
8. Make sure people are added to whatever online registration system is being used.

[1] http://www.newyorker.com/magazine/2007/12/10/the-checklist

C.2 Setting Up

1. Set up a one-page website for the workshop.
2. Add the URL for the workshop website to the tracking system.
3. Check whether any attendees have special needs.
4. If the workshop is online, test the video conference link.
5. Make sure attendees will all have network access.
6. Create an Etherpad or Google Doc for shared notes.
7. Email attendees a welcome message that includes:

    - a link to the workshop home page
    - background readings
    - a description of any pre-requisite tasks

C.3 During the Event

1. Remind everyone of the code of conduct.
2. Collect attendance.
3. Distribute sticky notes.
4. Collect relevant online account IDs (e.g., GitHub IDs).
5. Go through the checkout procedure point by point.
6. Explain how to contribute to lessons.

C.4 After the Event

1. Update online records of who participated in what role.
2. Administer the post-training survey.
3. Email attendees about the checkout process.
4. Debrief with the head of instructor training.
5. Oversee final demonstrations.

C.5 Between Instructor Training Sessions

1. Sign up to lead group lesson discussions.
2. Monitor lessons for contributions and give feedback.

C.6 After Trainees Complete

1. Send new instructors a completion message.
2. Create certificates and send them to learners.

Note that trainers do not examine their own trainees: having them examine each other's helps balance load and maintain consistency of curriculum and standards.

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(ref for inst. trainers vs. ref for instructors.) to clearly distinguish from rest of book

Appendix D Training

Instructor~~'s~~ Guide

or Guide for Inst. Training

This appendix includes material that doesn't naturally fit anywhere else.

D.1 Further Reading

- Ambrose et al's *How Learning Works* [ABD$^+$10] is the best overview of what we know about teaching and learning and why we believe it's true. It's also a great example of secondary literature: every topic gets a few pages, with pointers to the primary literature for those who want to dive in further.
- Brookfield and Preskill's *The Discussion Book* [BP16] is a catalog of ways to get groups (including classes) talking to one another productively.
- Green's *Building a Better Teacher* [Gre14] looks at how attempts to reform public education in the United States (and other English-speaking countries) have foundered over the last forty years because they're focusing on the wrong things.
- Guzdial's *Learner-Centered Design of Computing Education* [Guz15] is an evidence-based argument that we must design computing education for everyone, not just people who think they are going to be-

come full-time professional programmers, and draws material from the author's excellent blog [Guz17].

- Huston's *Teaching What You Don't Know* [Hus09] is a good evidence-based guide to doing exactly that.
- Lang's *Small Teaching* [Lan16] is a short guide to evidence-based teaching practices that can be adopted without requiring large up-front investments of time and money.
- Lemov's *Teaching Like a Champion* [Lem14] is a catalog of good pedagogical practices drawn from observations of hundreds of teachers over thousands of hours.
- Margolis and Fisher's *Unlocking the Clubhouse* [MF03] and Margolis et al's *Stuck in the Shallow End* [MEG$^+$10] look at how women and some racial minorities are systematically pushed out of computing, and what can be done about it.

D.2 Starting Out

To begin your class, the instructors should give a brief introduction that will convey their capacity to teach the material, accessibility and approachability, desire for student success, and enthusiasm. Tailor your introduction to the students' skill level so that you convey competence (without seeming too advanced) and demonstrate that you can relate to the students. Throughout the workshop, continually demonstrate that you are interested in student progress and that you are enthusiastic about the topics.

Students should also introduce themselves (preferably verbally). At the very least, everyone should add their name to the Etherpad, but its also good for everyone at a given site to know who all is in the group. Note: this can be done while setting up before the start of the class.

D.3 You Are Not Your Learners

People learn best when they care about the topic and believe they can master it. Neither fact is particularly surprising, but their practical implications have a lot of impact on what we teach, and the order in which we teach it.

First, as noted in Chapter 7, most people don't actually want to program: they want to build a website or check on zoning regulations, and programming is just a tax they have to pay along the way. They don't care how hash tables work, or even that hash tables exist; they just want to know how to process data faster. We therefore have to make sure that everything we teach is useful right away, and conversely that we don't teach anything just because it's "fundamental".

Second, believing that something will be hard to learn is a self-fulfilling prophecy. This is why it's important not to say that something is easy: if someone who has been told that tries it, and it doesn't work, they are more likely to become discouraged.

It's also why installing and configuring software is a much bigger problem for us than experienced programmers like to acknowledge. It isn't just the time we lose at the start of boot camps as we try to get a Unix shell working on Windows, or set up a version control client on some idiosyncratic Linux distribution.

It isn't even the unfairness of asking students to debug things that depend on precisely the knowledge they have come to learn, but which they don't yet have. The real problem is that every such failure reinforces the belief that computing is hard, and that they'd have a better chance of making next Thursday's deadline at work if they kept doing things the way they always have. For these reasons, we have adopted a "teach most immediately useful first" approach described in Section 7.

Such an important message; maybe shift to Ch 2 (perhaps as Callout?) and reference it in Ch 7

D.4 Overnight Homework

In a two-day class, have learners read the operations checklists as overnight homework and do their demotivational story just before lunch on day 2: it means day 2 starts with *their* questions (which wakes them up), and the demotivational story is a good lead-in to lunchtime discussion.

D.5 Video Recorded Lessons

One of the key elements of this training course is recording trainees and having them, and their peers, critique those recordings. We were introduced to this practice by UBC's Warren Code, and it has evolved to the following:

* it comes from the Instruction Skills Workshop (ISW) model.

1. On day 1, show trainees a short clip (3-4 minutes) of someone teaching a lesson and have them give feedback as a group. This feedback is organized on two axes: positive versus negative, and content versus presentation. The first axis is explained as "things to be repeated and emphasized" versus "things to be improved", while the second is explained by contrasting people who have good ideas, but can't communicate them (all content, no presentation) with people who speak well, but don't actually have anything to say.
2. Trainees are then asked to work in groups of three. Each person rotates through the roles of instructor, audience, and videographer. As the instructor, they have two minutes to explain one key idea from their research (or other work) as if they were talking to a class of interested high school students. The person pretending to be the audience is there to be attentive, while the videographer records the session using a cellphone or similar device.
3. After everyone has taught, the trio sits together and watches all three videos in succession, writing out feedback on the same 2x2 grid introduced above. Once all the videos have been reviewed,

the group rejoins the class; each person puts all the feedback on themselves into the shared notes.

In order for this exercise to work well:

- Groups must be physically separated to reduce audio cross-talk between their recordings. In practice, this means 2-3 groups in a normal-sized classroom, with the rest using nearby breakout spaces, coffee lounges, offices, or (on one occasion) a janitor's storage closet.
- Do all three recordings before reviewing any of them, because otherwise the person to go last is short-changed on time.
- People must give feedback on themselves, as well as giving feedback on each other, so that they can calibrate their impressions of their own teaching according to the impressions of other people. (We find that most people are harder on themselves than others are, and it's important for them to realize this.)
- At the end of day 1, ask trainees to review the lesson episode you will use for the live coding demonstration at the start of day 2.
- Try to make at least one mistake during the demonstration of live coding so that trainees can see you talk through diagnosis and recovery, and draw attention afterward to the fact that you did this.

The announcement of this exercise is often greeted with groans and apprehension, since few people enjoy seeing or hearing themselves. However, it is consistently rated as one of the most valuable parts of the class, and also serves as an ice breaker: we want pairs of instructors at actual workshops to give one another feedback, and that's much easier to do once they've had some practice and have a rubric to follow.

Feedback on Live Coding Demo Videos

Part 1[1]: how not to do it

[1]https://youtu.be/bXxBeNkKmJE

- Instructor ignores a red sticky clearly visible on a learner's laptop.
- Instructor is sitting, mostly looking at the laptop screen.
- Instructor is typing commands without saying them out loud.
- Instructor uses fancy bash prompt.
- Instructor uses small font in not full-screen terminal window with black background.
- The terminal window bottom is partially blocked by the learner's heads for those sitting in the back.
- Instructor receives a a pop-up notification in the middle of the session.
- Instructor makes a mistake (a typo) but simply fixes it without pointing it out, and redoes the command.

Part 2[2]: how to do it right

- Instructor checks if the learner with the red sticky on her laptop still needs attention.
- Instructor is standing while instructing, making eye-contact with participants.
- Instructor is saying the commands out loud while typing them.
- Instructor moves to the screen to point out details of commands or results.
- Instructor simply uses '$ ' as bash prompt.
- Instructor uses big font in wide-screen terminal window with white background.
- The terminal window bottom is above the learner's heads for those sitting in the back.
- Instructor makes mistake (a typo) and uses the occasion to illustrate how to interpret error-messages.

[2]https://youtu.be/SkPmwe_WjeY

D.6 Motivation and Demotivation

In the exercise on brainstorming demotivational experiences, review the comments in the shared notes. Rather than read all out loud, highlight a few of the things that could have been done differently. This will give everyone some confidence in how to handle these situations in the future.

Could a sample schedule be included? (or two)

D.7 Logistics

This course has been taught as a multi-week online class, as a two-day in-person class, and as a two-day class in which the learners are in co-located groups and the instructor participates remotely.

Multi-Week Online

This was the first format we used, and ~~we no longer recommend it.~~ Why?

(one sentence?)

- We met every week or every second week for an hour using Google Hangout or BlueJeans. Each meeting is held twice (or even three times) to accommodate learners' time zones and because video conferencing systems can't handle 60+ people at once.
- Each meeting also uses an Etherpad or Google Doc for shared note-taking, and more importantly for asking and answering questions: having several dozen people try to talk on a call hasn't worked, so in most sessions, the instructor does the talking and learners respond through the Etherpad chat.
- Learners post homework online between classes, and comment on each other's work. In practice, it turned out to be hard to get people to comment in detail (or at all).
- We used a WordPress blog for the first ten rounds of training. People found writing and commenting on posts straightforward, but setting up dozens of logins was tedious.

(I guess you did include such details.)

- We tried a GitHub-backed blog in the Winter 2015 class. It didn't work nearly as well: a third of the participants found it extremely frustrating, and post-publication commentary was awkward.
- We tried Piazza in the Fall 2015 class. It was better than GitHub, but still not as good as a simple WordPress blog. In particular, it was hard to find things once there were more than a dozen homework categories.

Two-Day In-Person

This was the second method we tried. The biggest change was the introduction of recorded teaching exercises.

Is this the recommended format?

Or either of these

- Several times during the training, participants are divided into groups of three and asked to teach a short lesson (typically 2-3 minutes long). In turn, one person is the teacher, one the audience, and one the videographer, who records the teacher using a handheld device such as a phone. Group members then rotate roles: the teacher becomes the listener, the listener records, and the videographer teaches. Once all three have finished teaching, the group reviews all three videos, and everyone gives feedback on everyone (including themselves). This feedback then goes into the Etherpad for discussion.
- It's important to record all three videos and then watch all three: if the cycle is teach-review-teach-review, the last person to teach runs out of time. Doing all the reviewing after all the teaching also helps put a bit of distance between the teaching and the reviewing, which makes the exercise slightly less excruciating.
- We use Etherpad or Google Doc for in-person training, both for note-taking and for posting exercise solutions and feedback on recorded lessons. Questions and discussion are done aloud.

Two-Day Online With Groups

In this format, learners are in groups of 4-12, but those groups are geographically distributed.

- We use Google Hangouts and either Etherpad or Google Docs as in the multi-week version. Each group of learners is together in a room using one camera and microphone, rather than each being on the call separately. We have found that having good audio matters more than having good video, and that the better the audio, the more learners can communicate with the instructor and other rooms by voice rather than by using the Etherpad chat.
- We do the video lecture exercise as in the two-day in-person training.

D.8 Effecting Change

This guide is aimed primarily at people working outside mainstream educational institutions, but in order for us to reach and help as many people as possible, we must eventually find ways to work with schools as they are. Henderson et al's "Facilitating Change in Undergraduate STEM Instructional Practices" [HBF11] discusses ways to get educational institutions to actually change what they teach. Their findings are summarized in Table D.1, and the approaches they identify are:

- *Diffusion*: STEM undergraduate instruction will be changed by altering the behavior of a large number of individual instructors. The greatest influences for changing instructor behavior lie in optimizing characteristics of the innovation and exploiting the characteristics of individuals and their networks.
- *Implementation*: STEM undergraduate instruction will be changed by developing research-based instructional "best practices" and training instructors to use them. Instructors must use these practices with fidelity to the established standard.

might fit better after "why we are not a MOOC"; this is a broadening note to end on, while the MOOC discussion is highly related to D.7 (almost belongs there)

- *Scholarly Teaching*: STEM undergraduate instruction will be changed when more individual faculty members treat their teaching as a scholarly activity.
- *Faculty Learning Communities*: STEM undergraduate instruction will be changed by groups of instructors who support and sustain each other's interest, learning, and reflection on their teaching.
- *Quality Assurance*: STEM undergraduate instruction will be changed by requiring institutions (colleges, schools, departments, and degree programs) to collect evidence demonstrating their success in undergraduate instruction. What gets measured is what gets improved.
- *Organizational Development*: STEM undergraduate instruction will be changed by administrators with strong vision who can develop structures and motivate faculty to adopt improved instructional practices.
- *Learning Organizations*: Innovation in higher education STEM instruction will occur through informal communities of practice within formal organizations in which individuals develop new organizational knowledge through sharing implicit knowledge about their teaching. Leaders cultivate conditions for both formal and informal communities to form and thrive.
- *Complexity Leadership*: STEM undergraduate instruction is governed by a complex system. Innovation will occur through the collective action of self-organizing groups within the system. This collective action can be stimulated, but not controlled.

D.9 Why We Are Not a MOOC

If you use robots to teach, you teach people to be robots.
— variously attributed

Table D.1: Strategies for Facilitating Educational Change

Aspect of System to be Changed	**Intended Outcome**	
Individuals	**Prescribed**	**I. Disseminating: Curriculum & Pedagogy** Change Agent Role: tell/teach individuals about new teaching conceptions and/or practices and encourage their use. *Diffusion* *Implementation*
	Emergent	**II. Developing: Reflective Teachers** Change Agent Role: encourage/support individuals to develop new teaching conceptions and/or practices. *Scholarly Teaching* *Faculty Learning Communities*
Environments and Structures	**Prescribed**	**III. Enacting: Policy** Change Agent Role: enact new environmental features that require/encourage new teaching conceptions and/or practices. *Quality Assurance* *Organizational Development*
	Emergent	**IV. Developing: Shared Vision** Change Agent Role: empower/support stakeholders to collectively develop new environmental features that encourage new teaching conceptions and/or practices. *Learning Organizations* *Complexity Leadership*

Massive open online courses (MOOCs) in which students watch videos instead of attending lectures, and then do assignments that are (usually) robo-graded, were a hot topic a few years ago. Now that the hype has worn off, though, it's clear that they aren't as effective as their more enthusiastic proponents claimed they would be [Ube17].

Recorded content is ineffective for most novices learners because it cannot intervene to clear up specific learners' misconceptions. Some people happen to already have the right conceptual categories for a subject, or happen to form them correctly early on; these are the ones who stick with most massive online courses, but many discussions of the effectiveness of such courses ignore this survivor bias.