Principles of Programming Languages @ Scale: The Value of Student Collaboration

Spencer Wilson

Overview

- Problem: Students are dissatisfied with CSCI 3155
- Background: What are the principles of CSCI 3155 and how do they support students?
- Experiment: A Research Study on Student Experience
- Results:
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Student Satisfaction and Performance

Over time, students are reporting less satisfaction with CSCI 3155 Principles of Programming Languages at CU Boulder

Embedded in time are factors such:

- Increased class sizes: 70 -> 300 students
- Changes in motivation: intrinsic -> extrinsic (as industry pays well)
- Gaps in knowledge from CoVid and other factors

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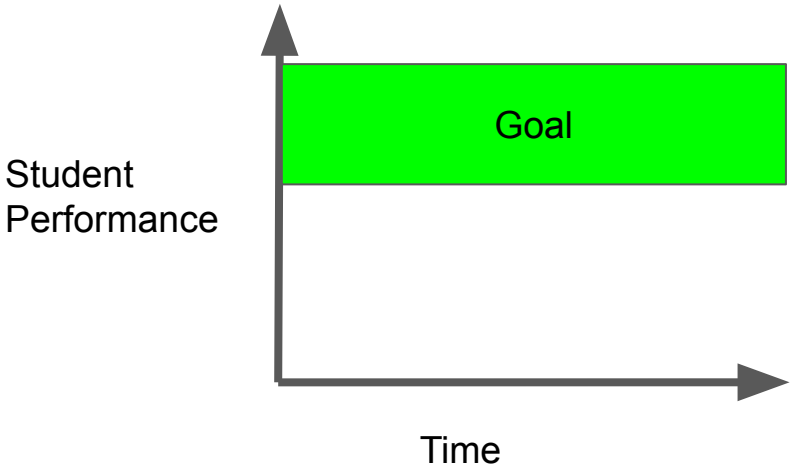

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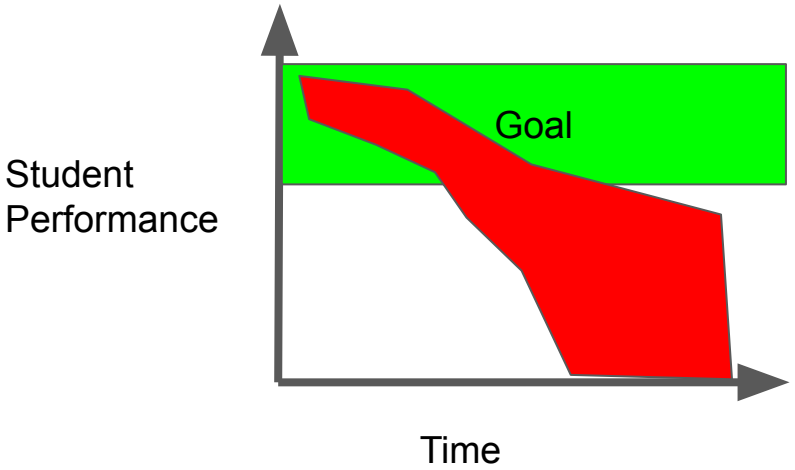

* our best estimate

Lower performance AND
More variance in performance

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Background: The Course Principle

“Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results.” - John Dewey

Students have 6 lab assignments to “do” which serve as the basis of student learning. Students experiment on their own and become questioners of the material.

Background: Course Breakdown

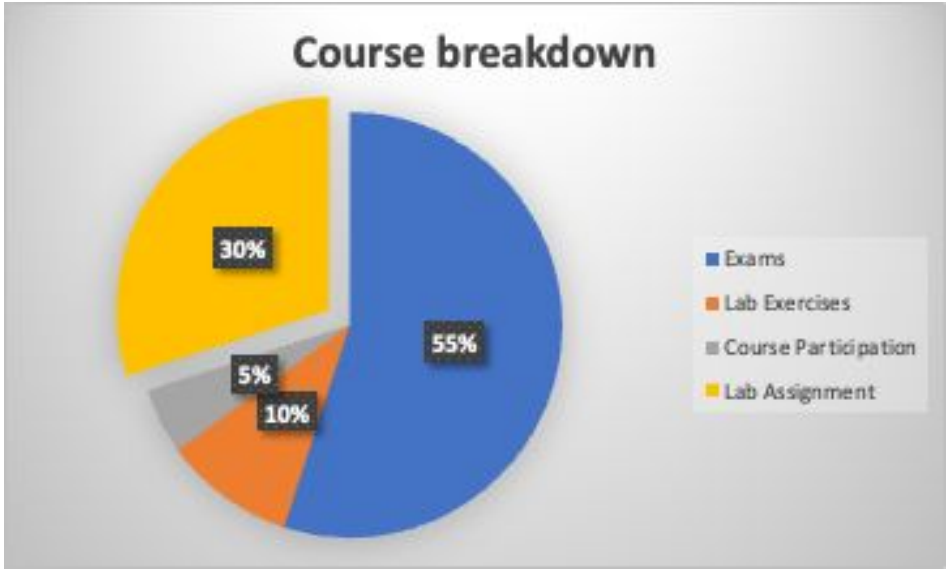
Exams are Summative

What remains is Formative::

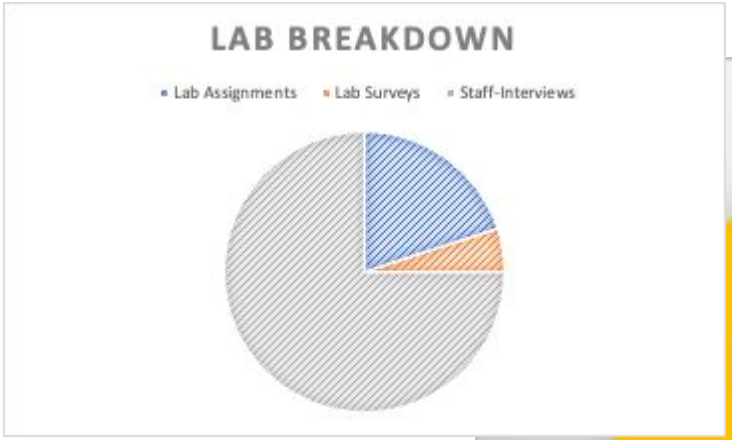
Participation is tracked

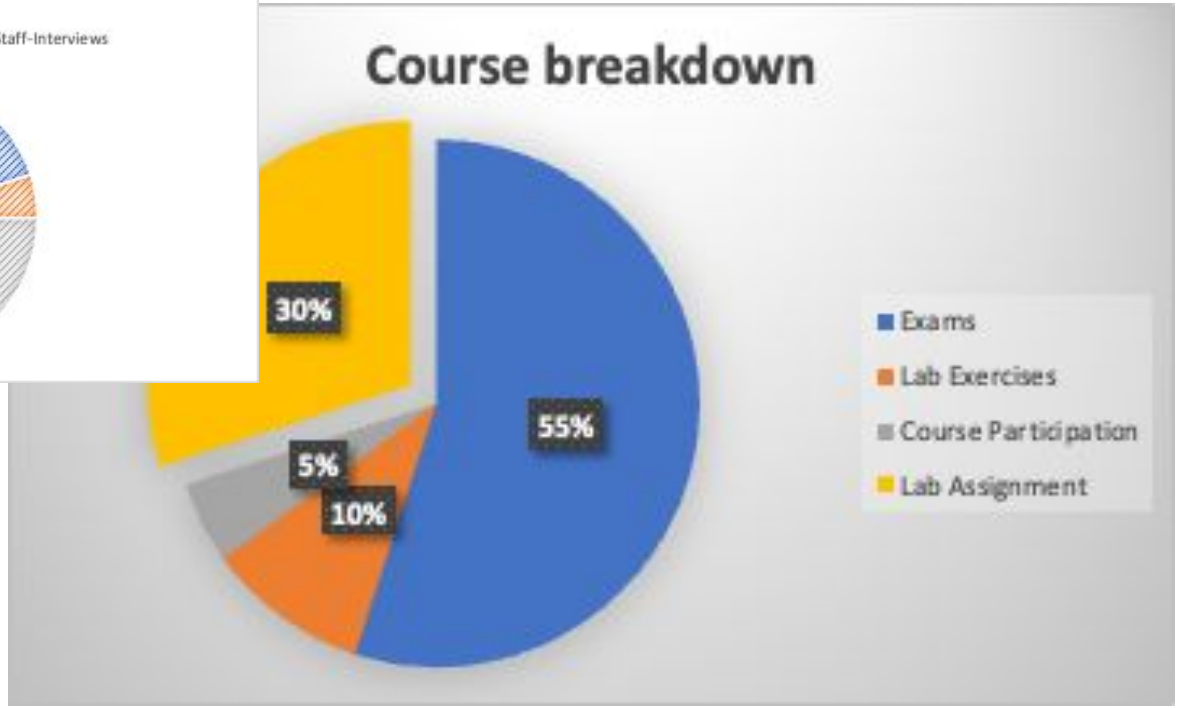
Exercises reinforce each lab's learning objectives

Labs have sub-components that we explore next

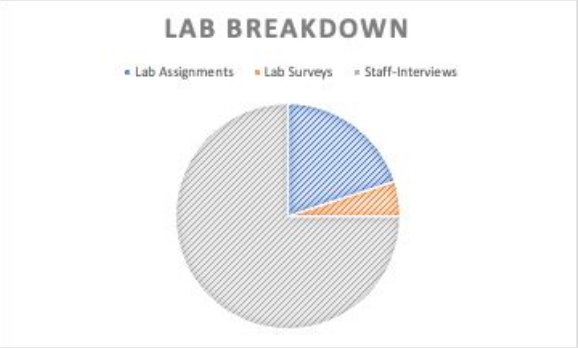


Background: Lab Breakdown



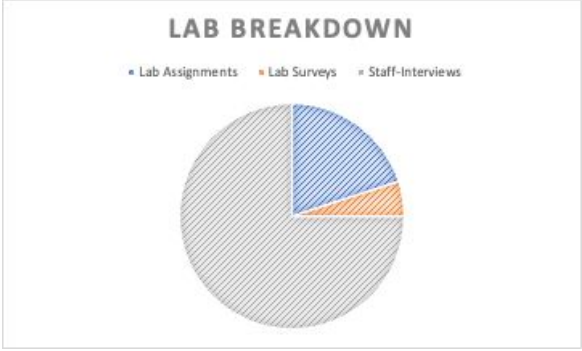


Background: Lab structure



- Collaboration: students work in teams of 2 - 3 people
- Lecture Preparation:
  - Students attempt the lab until they get stuck.
  - Students read and watch videos to support getting unstuck.
- Lecture: Students ask questions about what they got stuck on
  - Supported also by: Recitation, Office Hours, Piazza, Discord
- Students complete the lab in two weeks
- Students submit a survey on their experience
- Students complete a staff-interview 1-on-1 with a member of the course staff

Background: Staff-Interviews



- Staff interviews are in-person
- 1-on-1: 1 student and 1 member of the course staff
- ~ 12 minutes per student
- **Graded for correctness and succinctness**
- Provides qualitative live feedback to students on their performance
- Questions are “secret” and not shared in advance
- Questions include:
  - 1-2 easy questions
  - 1 medium
  - 1 hard
- Works well at scale for Lower Division courses even with 1,000+ students [1]
- Works well when facilitated by the instructor in Upper Division courses [2][3]

[1] Grunwald, D., Boese, E., Hoenigman, R., Sayler, A., Stafford, J. (2015)
[2] East, J.P., Schafer, J.B. (2005) [3] Ruehr, F., Orr, G. (2002)

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Experiment: Design

- Recruit students from Fall 2022
- Consent Process
- Three Interviews:
  1. Student experience in CSCI 3155 in Fall 22.
  2. Students preference in course design, topics, and class size.
  3. Students individual perception of the focus group, debrief the study and closing thoughts
- Focus Group: in sets of two participants to simulate a peer interview on a technical topic from CSCI 3155

Experiment: Consent

We clarify the nature of mandatory reporting

We agree to protect the anonymity of the participants, take actions to ensure this, and allow participants full right to review data demand changes

We agree to not pursue academic integrity issues (this was vital to ensure students safety in honestly reporting their experience in the course)

Experiment: Focus Group: Design

- Brief the students on this process
- Consent including a discussion of anonymity in a focus group
- Lecture on a technical topic of the course “BNF grammars”
- Peer-Interview with Peer-Grading
- Reflection on the students learning from the experience

Experiment: Focus Group: Interview Structure

Each student participates as an interviewee on one question
AND interviewer on another questions

Each Interviewer:

- Has access to a solutions document
- The solutions highlight common mistakes of interviewees
- The solutions highlight nuances of the question and the ideal solution
- The solutions recommend some hints for the interviewee to guide the discussion if they are not able to answer the question as posed

Experiment: Focus Group: Grading structure

- Focus less on exact grade and more on, is this “good enough”

Novice

Approaching

Not Good Enough

Proficient

Advanced Understanding

Ideal State

Experime

- Focus le

Don’t worry about an 87% vs 85%
Instead, state it’s “proficient”

Novice

Approaching

Not Good Enough

Proficient

Advanced Understanding

Ideal State

Experiment: Focus Group: Survey

Quantitative

- Prior to the interview, what was your level of understanding of the topic?
- After to the interview, what was your level of understanding of the topic?

Qualitative

- What, if anything, do you believe that you understand well about this topic? Be specific.
- What, if anything, do you believe that you DO NOT understand well about this topic? Be specific.

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Results: Focus Group: Concerns

Grade Inflation: Students express that they are liable to bias each others grades and score each other higher than is deserved

Social pressures:

- **"I don't want to look dumb"** in front of a peer that *might* have more knowledge than themselves (vs a TA that *should* have more knowledge)
- Working with friends may create an environment where students give each other answers, effectively destroying the learning opportunity

Results: Focus Group: Interview Successes

- Collaboration as students learn together and refine each others understanding of the material
- Ability to give advice using common language based on background knowledge of the participants
- Use of the socratic method to coax information from each other
- Friends can actually challenge each other and support each other in ways that strangers in the course cannot

Results: Focus Group: Learning Demonstrated

On a scale of:

- 1: very bad
- 5: very good

Prior to the interview, what was your level of understanding of the topic?

After to the interview, what was your level of understanding of the topic?

Results: Focus Group: Learning Demonstrated

On a scale of:

- 1: very bad
- 5: very good

Prior to the interview, what was your level of understanding of the topic?

After to the interview, what was your level of understanding of the topic?

Participant ID	Prior	After	Change
13	3		
15	2		
58	2		
93	1		
97	2		

Results: Focus Group: Learning Demonstrated

On a scale of:

- 1: very bad
- 5: very good

Prior to the interview, what was your level of understanding of the topic?

After to the interview, what was your level of understanding of the topic?

Participant ID	Prior	After	Change
13	3	4	+1
15	2	4	+2
58	2	3	+1
93	1	4	+3
97	2	4	+2

Data demonstrates some improvement in student understanding of the topics

Results: Focus Group: Finding

Peer-interviewing is not necessarily better, but it may be **at-least-as good as staff-interviewing** and allows for staff time to be reallocated

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Results: Themes: Overview

We identified three themes in the data collected which are relevant to the matter of peer interviews:

- Lab partner variability
- Interviewer variability
- Crowdsourcing

Other themes were observed that did not appear relevant to the current study which we'll detail in the future work section

Results: Themes: Lab partner variability (successes)

Generally positive, students enjoyed:

- Meeting new people (even making friends)
- Collaborating in learning when they could work at the same pace
- Common language used by a peer that was not used by the course staff at lecture, recitation and office hours
- **P13: "I definitely helped people when I could. [I learn a lot by teaching things to my peers.]"**

Results: Themes: Lab partner variability (challenges)

Some students start early AND some students start late which can cause tensions for the team

- Multiple participants describe how one student might finish the lab before their partner begins the lab
- The completed student would then typically be willing to explain the solution to their peer line by line
- But the partner won't understand the full lab and will not push for further help
- **P97: "I would feel bad saying I don't understand it after he went through it line by line."**

Results: Interviewer variability

Successes

- Successful interviews helped to solidify student understanding of the material
- Some students built mentoring relationships with the grader e.g. **P15: "even if I couldn't do it for myself, I just wanted to do it for [my grader]."**

Neutral: some students take whatever interview fits their schedule without regard for the host

Challenges

- Some students maliciously take interviews with the easiest grader to "**get the highest grade possible**"
- Some graders did not support the students learning e.g. **P72: "if you don't know how to answer this, then we'll move on to the next question"**

Results: Themes: Collaboration (challenges)

Students would actively crowdsource questions and solutions for the staff-interviews:

- **P97: "I definitely told other people what was on my interview... We [would share the questions] especially if it felt like a 'wildcard' to students."**
- **P58: "[It's not because I wanted to cheat but rather because I did not understand the content well enough.]"**
- **P15: "Solicitation was never truly helpful."**

While the questions should be “secret” they are in practice known to some students and not known to others causing unfairness.

Results: Themes and Recommendations

Lab partner and interviewer variability: Shifting away from staff-interviews toward peer-interviews does not resolve this challenge. Accordingly we must consider an informed approach to forming student teams.

Crowdsourcing: Complete transparency of the interview questions and possible solutions would violate the integrity of the interview, but would be viable for the peer-interview proposal detailed next.

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Results: Proposal: Design

The proposal for peer-interviewing is detailed in four phases as follows:

1. Training Phase
2. Interview Phase
3. Reflection Phase
4. Action Phase

Results: Proposal: Training Phase

Informed by lessons learned from award winning faculty in online learning [4]

We train students on what to expect in peer-interviewing:

- A collection of videos
- Modeling positive and negative behaviors for the interviewing team
- Modeling different levels of success from the interviewee (N, A, P, AU)
- Questions with automated grading for feedback early in the semester
- Costly upfront, but re-assignable on an as-need basis

[4] Martin, F., Ritzhaupt, A., Kumar, S., Budhrani, K. (2019)

Results: Proposal: Interview Phase

Radical Transparency: the students have full access to the information and solutions.

Time for Studying: if the student team does not understand the questions, they can pause the interview to seek further assistants.

More practice:

- Same number of questions and relative challenge as past courses
- Additional practice questions are optional and can replace studied questions
- This document also supports students as they prepare for their exams in the course

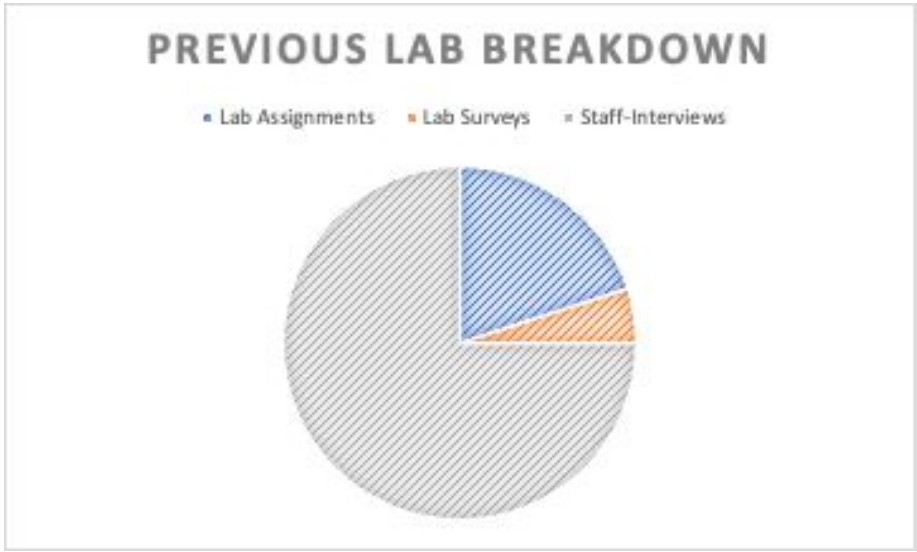
Results: Proposal: Reflection Phase

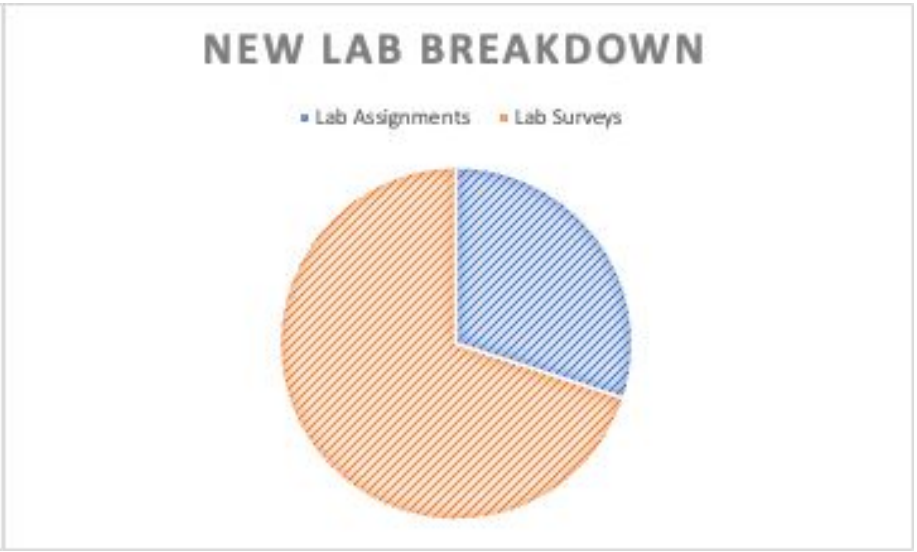
“We do not learn from experience… we learn from reflecting on experience.” - John Dewey

Each students complete a self-reflection on their experience.

This engages students in a critical assessment of their own abilities.

Results: Proposal: Reflection Phase (cont)





We do not grade students on their success in the interview, but instead on their thoughtful completion of this self-reflection.

Results: Proposal: Action Phase

The staff gathers awareness of student challenges and successes reported in the reflection phase.

The staff scaffold future learning with this context awareness, teaching new topics in the context of what students already understand well.

The staff re-addresses any topics which students do not yet understand well so as to construct a strong foundation for future exploration of related topics.

Results: Proposal: Summary

- **Training Phase**: establish the value and process of the interview
- **Interview Phase**: formative assessment of learning
- **Reflection Phase**: graded reflection and development of action plans
- **Action Phase**: execute on the action plans and pivot as needed

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Future Work

Additional themes found in this study to consider interventions:

- The course grading structure was unclear to students (perception of a curve)
- Office hours were overcrowded and at times hosted by staff members that would openly revealing solutions to the assignments (deeply concerning)
- Not knowing how to prepare for lecture (and a lack of awareness of the video lectures on each topic from CSPB 3155)

Implementation and experience report:

- Pilot in Summer 2024 (the current instructor is interested in trying this)
- Larger study with 150+ students in Fall or Spring term (unknown term)

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The current structure of CSCI 3155 has challenges which could be addressed including:

- Variability in staff conducting interviews
- Variability in student team forming
- Students unethically crowdsourcing questions for staff-interviews

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- Variability in student team forming
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In this initial study, peer-interviewing suggests some promise in aiding student learning and removes the challenge of students crowdsourcing question for interviews - creating a more fair environment.

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Questions?
(Could I get a volunteer notetaker for this?)

questions

- Benefit to free up staff time. So what does the staff have to put into these interviews? Monitoring? Understanding how it’s going. Are these goingwell. Are they useful. Can we give feedback and direction to students that aren’t being a good interviewer. We free the graders to do more high level things.
  - Honest conversations.
  - Can re-assign training
- Want to use staff time more effectively. Do we hivre unqualified staff.
- Splitting time? 80-20 to work-train.
  - Depends on the community. The current staff ability.

- The observation of the peer interview is different than a peer interview. I can imagine that the peer-interview observed was better than how it would really happen.
    - Guess 1 hour. Half hour for each student as interviewee. Perhaps similar to the time they currently spend to have the staff-interview and
    - Have staff observe some interviews? Maybe 1/2 of the interview in the term is observed. The staff rotates. Benefits from observing the event.
-

How the instructors track how it’s going. It’s a big ship. You steer the ship. You make more distance and effort into steering the ship. More distance. More indirect influence.

- Don’t want to over-police it will all fail. I’m cautions to put in the guardrail, but I agree it’s valuable
- Coin-flip. Will the students make it happen or not?
- How do we push to make it more likely to work for a given body of students.
- Momentum in the experience. The students are doing their own thing. We can only nudge it once it gets going. What does that nudge look like?

Students in this case learn a whole new skill. How to do an interview. How to work together to teach each other. Shouldn’t student learn this sooner.

- Echos of the course structure itself being poor
- This also is nice in supporting the educational model that we want for our students. We want them to collaborate and the interviews are helping them learn how to do that rather than doing the labs independently and submitting one submission anyway.

Backup slides

Supplemental: Reflective Ungrading

- Emphasis on an X / Check+ system
- Students have flexible assignments
- Students complete their work and grade it themselves
- Students have interim term self reflections of their total course standing
  - Students get 1:1 time with course staff
  - Recommended: instructor only review
  - Question: can a student staff DRI be an intermediary for this at scale while staff is instructor is still the core person responsible for hard discussions?

Supplemental: Contract Grading

- Define what students need to complete “good enough” to get a B
- Define what additional tasks can be completed “good enough” or exceptionally to get an A
  - Extra assignments
  - Extra features on assignments
- Define what happens when the contract is not met, how to fall to C, D or F

Supplemental: Standards Based Grading

- Define standards as topics or bundles of topics
- Grade by standards within each assignments
- Students must demonstrate success on some percentage of all standards
  - E.g. 95% standards is an A
  - E.g. 75% standards is a B
  - E.g. all students must pass the “functional list” standard
- Opportunities to re-attempt standards throughout the semester
  - 4 tries
  - Only need 2 to show mastery of the standard

Supplemental: Zoo vs Anatomy

- Programming Languages courses have two flavors:
  - The zoo of languages and their unique features
  - The shared anatomy of languages which serve as foundations before exploring some of the variance that exist in other languages
- CSCI 3155 at CU Boulder looks at the anatomy of a programming language

Presentation feedback and questions

Questions and feedback

-