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Expert Code Review and Mastery Learning in a Software Development Course

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INTRODUCTION

Why Try Mastery Learning?

Motivation

- Some students made it to upper-division courses, but unable to pass those courses on first try
  - Most delay graduation and retake
  - Many upper-division courses offered once a year
- Often have weak but broad level of programming
- Somewhere between start and end of degree, not quite preparing these students for harder classes

Software Development

- Bridges lower division programming courses and upper division programming-heavy courses
- Provides student **project experience**
- Goal is to produce **well-designed** large software project, approximately 2k lines of code
- Promotes **iterative development**
- Undergraduates already have two introduction to programming courses (Python and Java)

Issues Identified

- Possible to gain enough partial credit to pass the course without mastering all of the core concepts
- Easy to test for correctness, difficult to test design
  - Unit tests and scripts for correctness
  - Code review for design
- Assigning partial credit to code design tricky
  - Teacher assistants unfamiliar with code review
  - Unwilling to give low grades for functional code

Issues Identified

- Originally believed iterative projects would lead to iterative development
  - Students loath to refactor "working" code
  - Students not sure of issues and how to fix them
- Only a certain core of projects were really critical for upper division courses
  - Needed multithreading, code design mastery
  - Did not need mastery of web-related topics

Hypothesis

- Use homework and quizzes to address breath, and projects for depth
- Use **mastery learning** to force students to master core concepts necessary for upper division courses
- Use **expert code review** to enforce mastery learning for code design
- Force students to **refactor code** until passes both unit tests and code review

BACKGROUND

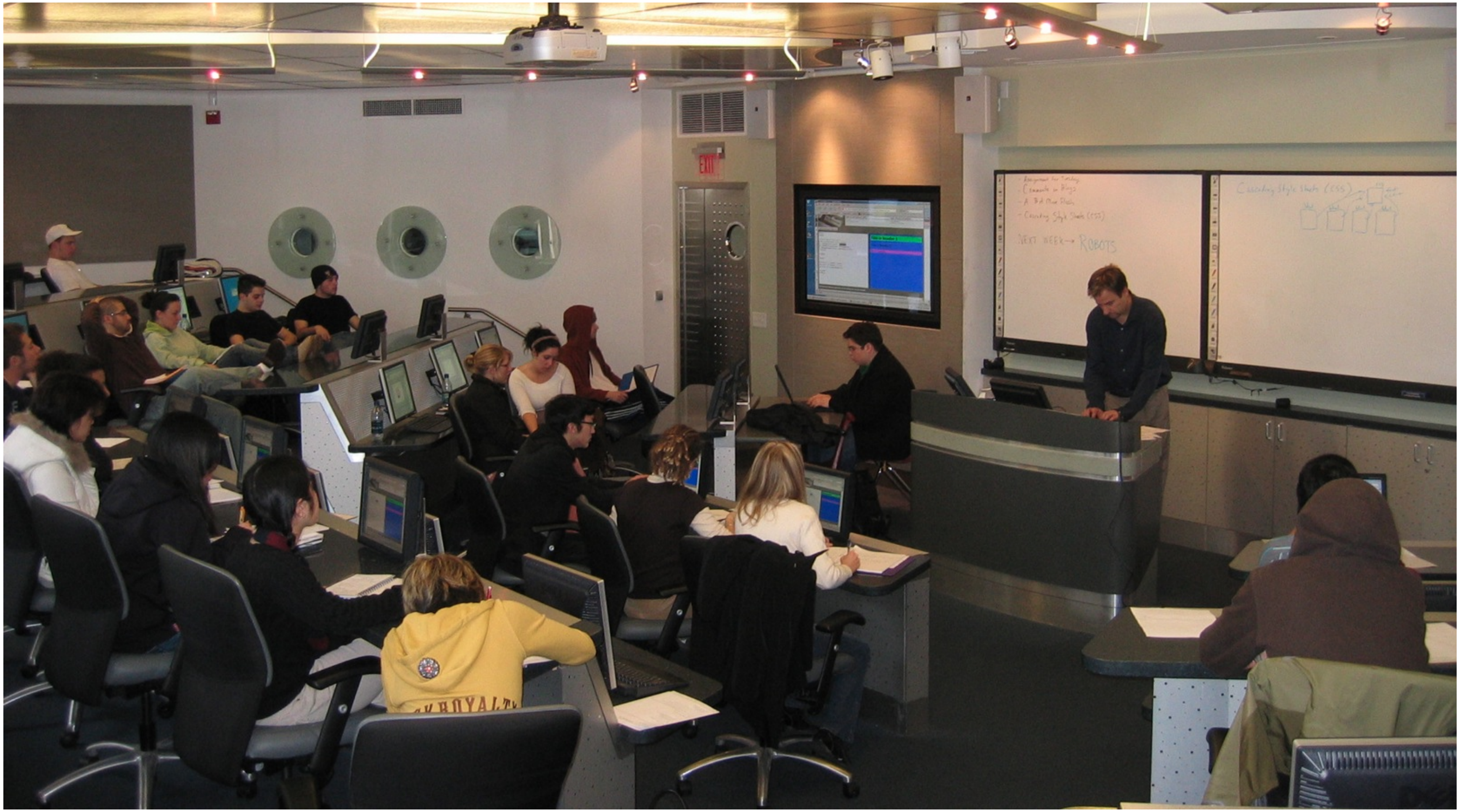
Software Development Course

Course Basics

- Semester-long course
- Hour-long classes meeting three times a week
- Approximately 10 to 30 students per section
- Offered every semester
- Mostly undergraduate majors (part of core)
- Also included minors and new graduate students*

*We revisit this later on in the talk.

Environment



http://cs.usfca.edu/facilities.html

Traditional Approach

- Lecture
  - Hour long twice weekly
  - Slide-based or live code walkthroughs
- Lab
  - Hour long once weekly
  - In-class homework and quizzes*
- Exams
  - One midterm and one final exam
  - Closed-book closed-note except Java API

*These were added in later versions of the course.

Traditional Approach

- Seven large iterative programming projects
  - Word Count
  - Inverted Index
  - Partial Search*
  - Multithreading
  - HTML Parsing
  - Web Crawler
  - **Search Engine**
- Assigned throughout semester

*Used to include a redesign component.

Student Experience

- Very popular among students
  - Helpful in future courses
  - Helpful for finding software development jobs
- Very motivated by search engine project
- Reputation for being fairly easy to pass
  - Kludge together something before deadline
  - Get partial credit and move on to next project

APPROACH

Mastery Learning and Expert Code Review

Approach

- Traditional Approach (Breadth)
  - Lectures
  - Homework
  - Quizzes
  - Exams
- Mastery Learning (Depth)
  - Projects

Projects

- Reduced from 7 to 5 projects
  - Keep inverted index, partial search, multi-threading, web crawler, and search engine
  - Assign word count and HTML parsing projects as homework instead
- Two-stage project submission
  - Teacher assistant runs tests for correctness
  - Instructor performs code review for design
- Must continue to refactor until both stages pass

Projects

- Unable to start next project until current passes
- Provide *suggested deadlines* to try and keep students on track
- Accelerated deadline schedule to promote an agile approach and provide time for resubmission
  - Students instructed to expect to submit twice
  - Students must also master time management
- Cutoff deadlines given to ensure enough time for resubmission and still pass

Project Grading

- Projects are worth majority of grade
- Project grade based on how many projects passed
  - Must pass multithreading project to pass course
  - If perform poorly on exams, must also pass web crawler to pass the course
- Small penalty deducted if students resubmit project too many times*
- Small extra credit added if students submit by suggested deadlines*

*Again, this reflects how it is done currently. It was slightly different in previous semesters.

Code Review

- Performed by instructor, not teacher assistant
  - Instructor has code review experience
  - Instructor more strict on design and style
- Performed interactively with student*
  - Each session maximum 20 minutes
  - Specific criteria evaluated for each project
  - Comments made directly in students' code and committed to their svn repositories
- Result is either pass, conditional pass, or resubmit

*This is how we are doing it this semester, which has evolved since when we wrote the paper.

Review Criteria

- Assume once criteria passed in one project, will be correct in following projects
  - Not ideal, but necessary due to time constraints
- Inverted index (first project) criteria
  - Proper code style (e.g. comments, names)
  - Proper use of keywords (e.g. static)
  - Proper generalization (e.g. reusable code)
  - Proper encapsulation (e.g. no passing references of private mutable members)

RESULTS

Grades, Submissions, Lessons Learned

Measurements

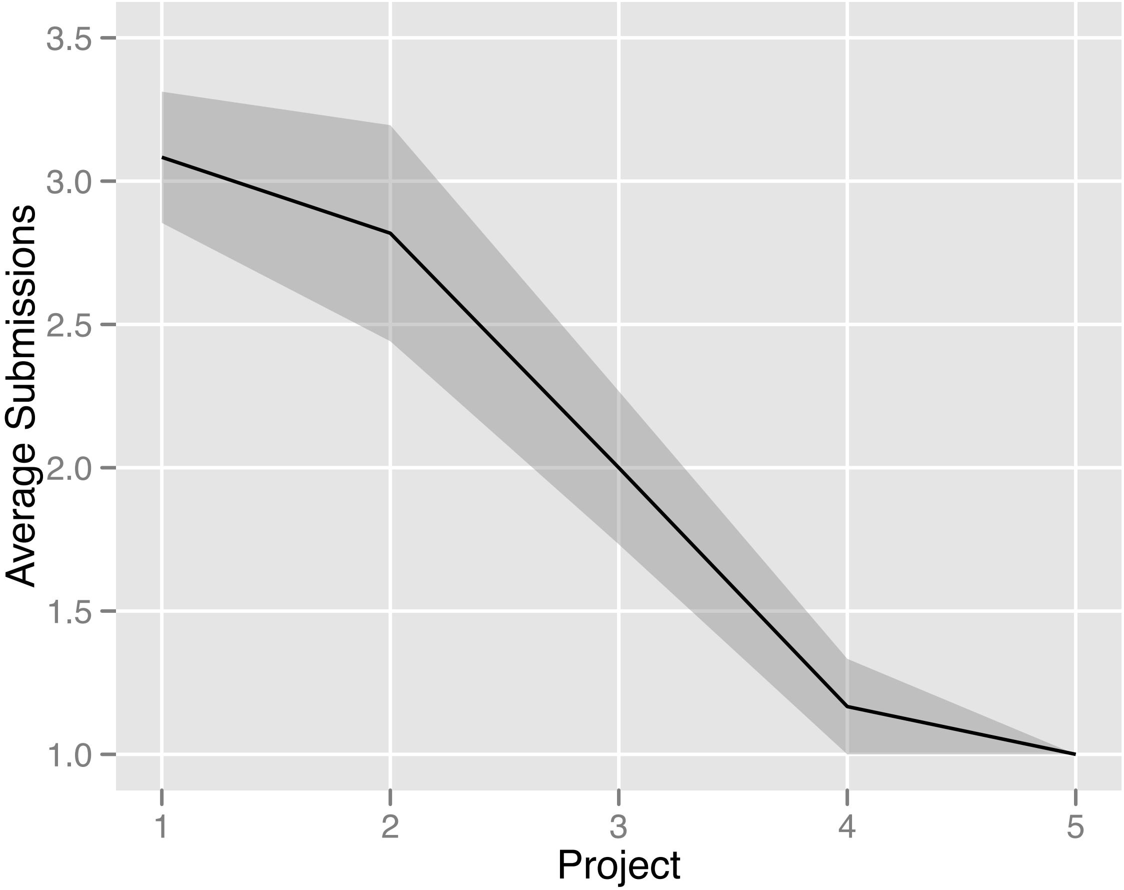
- Compared two semesters
  - Fall 2011 using traditional approach
  - Spring 2012 using expert code review
- Evaluated student performance
  - Number of submissions
  - Average project grades
  - SLOC per project
- Evaluated student experience
  - Conducted survey

Caveats

- Difficult to get statistically significant results!
  - Small classes sizes to begin with (≤ 30)
  - Did not include graduate students
  - Did not include minors
  - Did not include ghost students*
- Only 9 students for Fall and 12 for Spring semester
- Different types of students in Fall versus Spring
  - Fall had separate section for graduates
  - Spring combined undergrads and grads

*Some students never showed up, or dropped before the first project suggested deadline.

Results



Provided for Spring semester (with mastery learning and expert code review) only.

Results

	#S	SLOC		Grade	
Project	**SP**	**FA**	**SP**	**FA**	**SP**
1: Inverted Index	3.1	186	218	58%	100%
2: Partial Search	2.8	341	418	76%	90%
3: Multithreading	2.0	494	706	93%	76%
4: Web Crawler	1.2	686	914	84%	38%
5: Search Engine	1.0	2360	1781	96%	16%
Average:	2.5	569	590	81%	82%

See discussion in paper.

Comments

- "I had fun with the projects and they made me work hard."
- "Projects were more challenging because there would usually be significant refactoring that had be done after each grading session."
- "The hardest thing was the grading process of the projects, it takes way too long for the resubmission process to take place."*
- "I really understand the idea of object oriented programming after CS212."

*A very common complaint.

Conclusions

- Mastery of code design and refactoring improved
  - Supported by decreasing number of submissions
- Mastery of complex concepts improved
  - Supported by higher grades of first three projects
- Project progression was slower
  - Supported by lower grades of last two projects
- Time required for the code review was reasonable
  - Maximum 30 students, 20 minutes per review
  - Only subset of students need review each week

Drawbacks

- Time Issues
  - Time consuming to setup and get process down
  - Must coordinate verification and code reviews to avoid major delays
  - Students must wait longer for grades
- Attrition
  - Better prepares majors, what about minors?
  - Students still fail due to poor code, but now also poor time management

Drawbacks

- Progression
  - Difficult to reset student expectations
  - Difficult to acclimate students to new process
  - Disbelief that I will force them to resubmit when they already have "working" code
  - Difficult to convince students they are running out of time for submissions
- Evaluation
  - Difficult to calculate student grade mid-semester

CONCLUSION

Summary and Final Thoughts

Summary

- Some students failing upper division courses
- Focus on bridge course between lower and upper division courses
- Keep traditional approach for breadth on lectures, homework, quizzes, and exams
- Use mastery learning enforced via expert code review for projects and code design
- Some initial success of approach

Adaptation

- Requires low faculty to student ratio
- Requires space in schedule for resubmission
  - Difficult on quarter schedules
- Requires incremental projects
  - Otherwise difficult to justify refactoring
- Requires appropriate subset of topics for mastery
- Requires mid-level course
  - Expert code review less necessary for lower levels

Future Directions

- Before Class
  - Watch slide-based lectures
  - Watch short code walkthroughs
- Class Time
  - Lab exercises and quizzes
  - Longer code walkthroughs
- Code Reviews
  - Every other week despite project status (30 students, 20 minutes, 5 hours weekly)

MOOC Comparison

- Low enough faculty/student ratio for more one-on-one interaction than possible with MOOCs
- Better assessment of student status
  - Automatic assessment of homework and quizzes
  - Manual assessment of projects and exams
- Still get benefit of recorded videos
  - Students can easily re-watch videos
  - Frees up class time for other activities

Questions?

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