# Using standards-based grading in all classes

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- With AI tools, 40% homework was too much.
- But I didn't want too large of a percentage of grades based on three exams.

# New breakdown

- 55% standards
- 20% final exam
- 10% homework
- 15% other stuff

# Workflow

- Week $n$: class as usual
- End of Week $n$: homework due
- End of Week $n+1$: standards quiz on Week $n$ material (about 15 minutes)
- Weeks $n+2, n+3$, etc.: retakes (in office hours or after new quiz)

# Retakes

- Each week I make up a new set of retakes for all the past standards
- Questions similar in content and difficulty to previous ones, but each week is different
- Students get one retry per week at each standard

# Classes I've used this for

- Intro Computer Science
- Computer Security
- Operating Systems
- Theory of Computation
- Database Management Systems
- Algebraic Structures
- Real Analysis

# Standards

- Depending on the class, I ended up with 15 to 30 standards
- 1 to 4 new ones per week, up until about 2 weeks before semester's end

# Standards for Algebraic Structures

1. Modular Arithmetic
2. Group properties
3. Direct Product Groups
4. Basic Algebraic Manipulations
5. Order
6. Elementary Proofs
7. Subgroups
8. Isomorphisms 1
9. Isomorphisms 2
10. Homomorphisms
11. Cyclic Groups 1
12. Cyclic Groups 2
13. Symmetric Groups 1
14. Symmetric Groups 2
15. Cosets
16. Lagrange's Theorem and Consequences
17. Normal Subgroups
18. Quotient Groups 1
19. Quotient Groups 2
20. Rings 1
21. Rings 2

# Standards for Operating Systems

1. OS History
2. Kernel and Systems Calls
3. Process Concepts
4. Scheduling Algorithms 1
5. Scheduling Algorithms Concepts
6. MLFQ and CFS
7. Stride Scheduling
8. C concepts
9. Pointers
10. Memory Allocation in C
11. Bitwise Operations in C
12. Memory allocation
13. Base and Bounds
14. Virtual Memory I
15. Virtual Memory II
16. Page Table Calculations
17. Page Replacement Algorithms
18. Aging Algorithm
19. Clock and WS Clock Algorithm
20. Threads
21. Locks
22. Race Conditions 1
23. Race Conditions 2
24. Condition Variables
25. Semaphores 1
26. Semaphores 2
27. Deadlocks 1
28. Deadlocks 2
29. Devices
30. Disk Scheduling Algorithms

**Standard 3: Direct Product Groups**

1. List all the elements of $D_3 \times \mathbb{Z}_2$.
2. Perform the group operation of $D_3 \times \mathbb{Z}_2$ on $(r_1, 1)$ and $(r_2, 1)$.

## Standard 5: Order

1. Find the orders of the following elements in the indicated groups.
   (a) 2 in $\mathbb{Z}_{20}$
   (b) 3 in $U_{14}$
   (c) $s_1$ in $D_4$.

2. Suppose $g^5 = e$. Which of the following is true? Choose all that apply (which might mean none, one, or more than one apply.)
   (a) $g^k$ will not be $e$ for any $0 < k < 5$.
   (b) The order of $g$ could be less than 5.
   (c) The order of $g$ must be 5.
   (c) $g^{30} = e$

3. Suppose $g$ has order 8. Which of the following is true? Choose all that apply (which might mean none, one, or more than one apply.)
   (a) $g^k$ will not be $e$ for any $0 < k < 8$.
   (b) $g^9 \neq e$
   (c) $g^{20} = e$

**Standard 19: Quotient Groups 2**

1. Consider $\mathbb{R}/\mathbb{Z}$. Prove that every coset of the form $x + \mathbb{Z}$ with $x \in \mathbb{Q}$ has finite order.

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- Questions are just like questions from my exams, just spread across many smaller assessments.
- Students' grades on the standards portion of the class is what percent of the standards they eventually passed.

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- Some standards are short proofs
- In Algorithms, I'm doing "coding" standards based on coding questions on homework (on the homework they wrote a full program, on the standard I take a solution, leave out a few parts, and ask them to fill them in)

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- On short weeks (like Thanksgiving), I just do retakes instead of new standards.
- Two retries per week at the end of the semester, with new standards ending a few weeks before the end.

# Tracking Grades

| | | Standard 1 | Standard 2 | Standard 3 | Standard 4 | Standard 5 | Standard 6 | Standard 7 | Standard 8 | Standard 9 | Standard 10 | Standard 11 | Standard 12 | Standard 13 | Standard 14 | Standard 15 | Standard 16 | Standard 17 | Standard 18 | Standard 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| [redacted] | | | | x | | | x | | x | | | | | | x | x | ✓ | | | |
| | | | | | | | | | | | | | | | x | x | x | | | |
| | | ✓ | x | x | x | | | x | x | ✓ | x | | x | x | x | x | x | | | |
| | | | x | | | | | | | | | ✓ | ✓ | ✓ | | | | | | |
| | | | | x | | x | | | | | | | ✓ | | x | x | x | | | |
| | | | | | | | | ✓ | | | | | ✓ | x | x | x | x | | | |
| | | | ✓ | | | x | | | | x | | ✓ | ✓ | | x | x | x | | | |
| | | | | | | | | | | | | | | | ✓ | ✓ | ✓ | | | |
| Week 7 | | | | | | | | | | | | | | | | | | | | |
| [redacted] | | | | | | | | | | | | | | | | | | x | x | x |
| | | | | | | | | | | | | | | | ✓ | ✓ | x | ✓ | ✓ | ✓ |
| | | | | | | | | | | | | | | | | | | x | ✓ | ✓ |
| | | | | | | | | | | | | | | | | ✓ | x | ✓ | ✓ | ✓ |
| | | | | | | | x | ✓ | | ✓ | | | | | | | | x | ✓ | x |
| | | | | | | | | | | | | | | | | | | ✓ | x | x |

# How students did

**Computer Security**

| | 2018-19 | 2019-20 | 2020-21 | 2021-22 | 2022-23 | 2023-24 |
|---|---|---|---|---|---|---|
| median score | 75.1 | 77.1 | 82.5 | 78.8 | 64.5 | 74.7 |
| number of students | 32 | 17 | 28 | 41 | 41 | 44 |
| take-home? | no | no | yes | yes | no | no |
| standards? | x | x | x | x | x | ✓ |

# Positive student comments

- "I do really like the standards system since it helps me to actually learn the topics and make sure I know them rather than just cram for tests. I know previously in your classes, I relied too much on the notes for my homework, which is fine and I got a lot out of those classes, but I think my mastery of Theory of Computation surpassed that of the classes last year and the standards system played a role in that."

- "Taking you theory of computations class last semester almost rewired my brain in the way of standards instead of test, I appreciate this way of tests a lot more since its not just cram study and then pray, its actually learning , I could probably take the standards again this year and get around the same score as I did last semester."

# More positive student comments

- "I loved the idea of standards and how we could retake them to improve our grade. I liked how much they were weighted so it enforced us to actually learn the material being taught in class and keep it in our heads throughout the semester."
- "I do like the assessments, even if we had to take them over and over again, it helped reinforce the information a bit."
- "I liked how the standards allowed for an oportunity to better learn and grow, by having more than one retake it shows understanding that sometimes you make the smae mistake over again in order to better learn and understand overall!"
- "Dr. Heinold's method of evaluating each week based on pass/fail standards is great. As a student who sometimes does not perform well on traditional exams due to anxiety, having these little moments to evaluate that add up are great."

# Negative student comments

- "Similar to his other classes, failed standards pile up in a way that it seems daunting to retake them especially if you are caught up on one topic"
- "I feel a bit like a fraud because I don't think I understand the content as well as the grade shows."
- "The way to retake standards was a bit scarier than needed. It led to me at the very least leaving alot to be done with more and more building up"
- "The grading system and standards were too difficult in terms of content and keeping up with weekly."
- "The all or nothing method of grading can be really rough when you pretty much know the topic but don't get perfect for one reason or another."

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- *Don't students just blow off the class until the end of the semester and rush to get everything done then?*
  A few, but not as many as I expected. In any given week, about 1/3 of students do some retakes.

# Some numbers

- Last spring 36.2% of first tries were correct.
- Eventual get rate was 88.7%
- Average of 2.3 attempts before getting it right or giving up

# Conclusions

- High-achieving students will do well with any reasonable approach.
- Standards seem to help the mid-range students.
- System is self-adjusting in that the number of attempts a student needs is proportional to how much work they need to put in to learn the material.