CQI Report: Systems, Spring 2023

Submitted by:

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1 Subcommittee Information

The following courses are part of this subcommittee. A course may have several sections and instructors. Christoph Lauter also teaches CS3432 and CS4375, and Deepak Tosh also teaches CS4375, but they did not teach those courses in Spring 2023.

Subcommittee CS Courses	CRN number	Instructor name
CS 3432	23381	Shirley Moore
CS 3432	13947 (Fall 2023)	Eric Freudenthal
CS 4375	24410	Nigel Ward
CS 4375	24866	Eric Freudenthal
CS 4175	25984	Shirley Moore

Report date: 04/02/2025

Faculty meeting presentation date: 04/04/2025

2 Summary

The three required systems courses for undergraduate computer science majors are the following:
- CS 3432: Computer Organization
- CS 4375: Operating Systems Concepts
- CS 4175: Parallel Computing

CS3432 and CS4375 have been required courses for decades. CS4175 is a fairly new course that was added as a required course starting in Fall 2021 to address parallelism outcomes that were not previously covered. CS3432 is 4 credits and meets as a 3 contact hour lecture section and an associated 3 contact hour lab section, with the lab section focusing on hands-on learning and programming exercises. CS4375 and CS4175 do not have lab sections, but programming assignments are generally given as homework assignments. CS3432 lab assignments use both C and assembly language (e.g., MIPS, RISC-V, MSP-430). CS4375 has been taught using either C or Python, and programming exercises have varied from using OS facilities, e.g., system calls, to modifying or writing kernel code. CS4175 has been taught using a variety of Python, C, C++, Pthreads, OpenMP, and MPI, and programming exercises have carried out either on the students' laptops or on an educational supercomputer allocation. Although the courses are taught in various ways, all instructors for a course use and evaluate the same set of learning outcomes, although they may add additional advanced outcomes as time and student progress permit.

Evidence collection for this assessment too place during the Spring and Fall of 2023, with individual course reports finalized in the Summer and Fall of 2024. The committee met on September 23 and 30, 2024, to discuss options for how to proceed with recommendations and to review the reports and a rough

draft of changes to the course outcomes.

Links to the individual course reports are provided at the end of this document. We summarize the findings as follows:

- CS3432: There were two sections assessed with final enrollments of 45 (Moore, Spring 2023) and 49 (Freudenthal, Fall 2023). 43 students passed the Spring 2023 section, and 40 students passed the Fall 2023 section (a grade of C or better is required to pass). Almost all outcomes that were assessed were met in both sections on at least one assessment instrument, although in the Spring 2023 section, some outcomes that were met on quizzes and programming assignments were not met on the final exam. The outcomes that were not met in one or both sections were NR1, NR3, NR4, and NR6. NR3 and NR4 are clerical in nature and students are prone to make mistakes. NR1 is important and lack of achievement of this outcome should be addressed.
- CS4375: Based on the course report for the section taught by Ward, of the 30 course outcomes, 22 were met, 3 were not fully assessed (15, 16, 7 - one aspect) , and 6 were not met (4, 6, 8, 14, 18, 7 - one aspect). However, the performance was always at least 50%. Of the 46 students who remained enrolled in this section, 45 passed (A grade of D or better is required to pass), and 37 earned a grade of C or better. Based on the course report for the section taught by Freudenthal, of the 29 course outcomes, 9 were not assessed (1, 6, 8, 9, 12, 19, 27, 28, and 29), and the other 20 were all met by at least 89% of the students, and most by 95% or better. Of the 41 students who completed the course, 96% passed, with 80% earning a grade of A. Of the outcomes not met in Ward's section, two (6 and 8) were not assessed in Freudenthal's section, and the others (4, 14, 18, 7) all had 95% success rate in Freudenthal's section.
- CS4175: All 48 students who remained enrolled in the single section of the course passed the course (A grade of D or better is required to pass), with 45 earning a grade of C or better. Outcomes 1d, 1f, 1g, and 2d were not taught nor assessed due to lack of time in the 1-credit course. Two Level 1 outcomes (1k and 1m) were taught but only informally assessed during class discussion. All outcomes that were formally assessed were met except for 1b (62%) and 2k (67%).

3 Recommendations and follow up

3.1 Reflection on previous report recommendations and actions taken

For CS3432:

1. Rename CS3432 from Computer Architecture to Computer Organization

   Action taken: Course was renamed starting in Fall 2022.

2. Revise CS3432 learning outcomes to say what students are expected to be able to do so that they can be better assessed.

   Action taken: The CS3432 learning outcomes were revised, and the new learning outcomes were taught and assessed starting in Fall 2022. The revised learning outcomes facilitated more direct assessment, but assessment of some new outcomes still needs to be formalized.

3. Potential conversion of 3432 to a 2xxx course to be generally attended concurrently with 2302 and likely also taught by EPCC.

   Action taken: This change was discussed in CS faculty meetings but was determined to be Impractical.

4. Now that we have multiple instructors for this course using multiple instructional approaches, whether/how we might collaborate in identifying and sharing best practices.

    Action taken: The three instructors for CS3432 have held numerous productive discussions on this topic.

5. Focus on examining the PC's central role in the identification of the next instruction to fetch/execute, and why/how it is updated during execution. many students who failed to understand advanced concepts such as interrupts and function calls also failed to comprehend the fundamental concepts underlying the fetch-execute cycle and the program counter's (PC's) central function and role in a single-issue processor, even during sequential execution.

    Action taken: During subsequent SU21 semester taught by Eric Freudenthal with David Pruitt (TA),
    the central role of the PC (and eventually SP & SR) in the context of sequential instruction and later branching, function calls, and interrupts was stressed heavily and described throughout lectures and coaching session as the course's primary learning outcome. In that semester, the fraction of students who earned a passing grade who were observed to demonstrate mastery of topics related to subroutine linkage was dramatically higher. Moore also heavily stressed the central role of the PC (and SP for stack frames) through use of the Venus simulator to visualize execution and the Logisim tool to implement a single-core RISC-V processor design.

For CS4375:

1. Rename CS4375 from Theory of Operating Systems to Operating Systems Concepts. Update the course description to include networking.

    Action taken: The course was renamed and the catalog description updated starting in Fall 2022.

2. Revise the CS4375 course outcomes to reduce the number and to make them directly assessable, and understandable by students.

    Action taken: The CS4375 course outcomes were revised, and the new outcomes were taught and assessed starting in Fall 2022. The revised outcomes made it possible to formally assess almost all of the outcomes.

3. Cap CS4375 enrollment at 40 to allow the instructor and TA to work with every student and provide timely and individualized feedback.

    Action taken: The CS4375 enrollment could not be capped at 40 due to growing undergraduate enrollment and the lack of availability of additional instructors.

4. Give better readings on networking and security.

    Action taken: Ward used the free online Peterson and Davie *Computer Networks* book and also assigned videos. However, students seem to still not do the reading on these topics, so Ward recommends continuing to search for good reading material on these topics.

5. Give the students worksheets on delay, latency, and powers of two computations, to help them develop better understanding of these concepts.

   Action taken: while, very regrettably, no discussion has yet occurred, the instructor who noted these weaknesses has been finding better ways to teach and reinforce these concepts and spending more time presenting and reviewing them when he teaches the class.

3.2 Recommendations for this cycle – for instructors of these classes.

- Assess all required outcomes formally and quantitatively. Especially in CS3432, some outcomes were either not assessed or were assessed only informally during class discussion, making it difficult to know how well these outcomes were achieved.
- Cap enrollment in CS4375 at 40 or add more TA support and adapt teaching strategy to larger sections. With only a single instructor and a single TA and no lab session, it is difficult to provide the individual attention that students need.
- Focus on improved teaching for outcomes that were not met. Strategies could include calling on students individually during class, relying less on multiple-choice questions, and conducting individual coaching sessions.
- For CS4375, continue looking for better readings on networking and security.
- For CS4175, go into sufficient depth in teaching concurrency topics since students find these to be difficult.
- For CS4375, investigate why reported achievement of learning outcomes and grade distributions vary across the different sections.

3.3 Recommendations for this cycle that require departmental approval (e.g., changes in outcomes)

The Systems CQI Committee consists of eight CS faculty members who teach the required systems courses or are impacted by them (e.g., by teaching a course for which a   required systems course is a prerequisite).

A summary of the recommendations made by faculty teaching the courses that require departmental approval is as follows:

1. Revise the CS3432 course description to reflect revised learning outcomes.
2. CS3432: Remove outcomes involving manual clerical computations.
3. Allow a choice of Level 3 outcomes for CS3432 and CS4375 to allow customization of the course depending on instructor teaching style and student interests.
4. Add new CS3432 outcomes related to modern computer architecture and organization, such as pipelining, caches, and heterogeneous architectures.
5. CS4375: Revise outcomes by grouping according to topic area, removing redundancy and unnecessary outcomes, rephrasing for clarity, and adding missing core OS outcomes.
6. CS4175: Reduce the number of outcomes to a number that can be reasonably taught and assessed in a 1-credit course.
7. Eliminate redundancy between CS4375 and CS4175 by merging the courses or making them co-requisites.

The committee met on Monday, September 23, 2024, to decide on one of three ways to proceed:

Option 1: Make minor changes to the learning outcomes as suggested in the course CQI reports.
Option 2: Per-course overhauls that would involve more substantial changes to the courses' learning outcomes. The rationale for considering this option includes the following: 1) different instructors teach the courses in different ways and the outcomes need to be flexible enough to accommodate different teaching preferences, 2) eliminating some outcomes that are clerical or mechanical (e.g., by-hand encoding of instructions) would make room to add outcomes that better represent the subject areas (e.g., as specified in the ACM/IEEE 2023 CS Curricula) and adapt to new and emerging topics (e.g., heterogenous architectures, support for machine learning), 3) reducing the number of networks outcomes in CS4375 would make room for adequate coverage of core Operating Systems topics and reduce overlap with the Computer Networks course, 4) the number of outcomes for CS4175 are too numerous to be taught and assessed during a 1-credit course.
Option 3: A major overhaul that would merge CS4375 and CS4175 into a single 4-credit course in addition to the outcomes for Option 2. The rationale for considering this option is that these two courses have considerable overlap of their learning outcomes, in particular the concurrency-related outcomes, but since neither is a pre-requisite for the other and the courses are not co-requisites, the outcomes have to be taught redundantly in both courses.

Although a definite decision was not made on September 23 as to which option to pursue, there was general consensus that Options 2 and 3 were worth considering, and the committee chairperson was given the go-ahead to draft a strawman proposal for these options, taking into consideration the committee discussion about specific outcomes that took place during the September 23 meeting.

The committee met again on September 30, 2024, to consider a draft proposal for substantial revision of course outcomes of all three courses and merging the CS4375 and CS4175 courses, with a fallback option of revising the course outcomes for CS4375 and CS4175 and duplicating the concurrency outcomes if merging the courses is not possible. The committee recommended proposing Option 3 to the faculty. The committee approved the general direction of the course outcome revisions but recommended further study and discussion in the next one to two months to converge on the new sets of outcomes and on revised course descriptions. The committee met again on October 21 and November 4 to finalize the proposed new systems learning outcomes. The CQI report and the new systems learning outcomes were presented to the CS faculty on Friday, December 6, 2024. Feedback from the faculty was to revise the Level 3 outcomes so as to not give a choice of different outcomes and to have a sufficient number of Level 3 outcomes. The faculty teaching the systems courses discussed revised Level 3 outcomes that addressed these concerns and arrived at consensus on a new set of proposed outcomes to be presented to the CS faculty on Friday, February 28, 2025.

The CS faculty approved the proposed new outcomes for CS3432 during the February 28, 2025, CS faculty meeting. The CS faculty requested that the following information be added to the proposal for the new CS4475 course: 1) how the 4 credit hours would be scheduled, and 2) what previous CS4375 outcomes were removed. The CS faculty also requested that the CS3432 and CS4475 learning outcomes be renumbered according to the ABET style template. The Systems Committee proposes that the 4 credit hours for CS4475 be scheduled as 4 hours of lecture. The outcomes have been renumbered in the attached Systems Proposed Outcomes 2Apr2025.pdf document. This final CQI report, the new CS4475 course, and the new learning outcomes for CS4475 were approved by the CS faculty on April 4, 2025.

4 Individual CS Course Outcomes Reports

CS3432 CQI Course Report FA23 Freudenthal.pdf

CS3432 CQI Course Report SP23 Moore.pdf

CS4375 CQI Course Report SP23 Freudenthal.pdf

CS4375 CQI Course Report SP23 Ward.pdf

CS4175 CQI Course Report SP23 Moore.pdf