

## Computer Science Program Learning Outcomes Assessment Project 2005-2006

Although Edsger Dijkstra reportedly said that “Computer science is no more about computers than astronomy is about telescopes” our program, like most Computer Science programs, is largely concerned with the study of problem solving using computers. It is concerned with questions such as “what problems can and cannot be solved by computers”, “how can we verify that a solution to a problem is correct”, “why is one solution better than another”. It stresses applications in areas such as Bioinformatics, Applied Physics and Computer Graphics.

*CSUCI graduates will possess an education of sufficient breadth and depth to appreciate and interpret the natural, social and aesthetic worlds and to address the highly complex issues facing societies. Graduates will be able to:*

- *Identify and describe the modern world and issues facing societies from multiple perspectives including those within and across disciplines, cultures and nations (when appropriate).*
- *Analyze issues, and develop and convey to others solutions to problems using the methodologies, tools and techniques of an academic discipline.*

### Computer Science Program Goals and Student Learning Outcomes

There are five Computer Science program learning outcomes:

1. Demonstrate critical thinking and problem solving skills by identifying, evaluating, analyzing and presenting fundamental software solutions and their applications.
2. Demonstrate the knowledge of current computing practices and broad technology use in industry and society, including a working knowledge of software development techniques.
3. Students will be cognizant of emerging new technologies and industrial practices connected to the computer industry.
4. Demonstrate communication, research and cooperation skills by working effectively with others in interdisciplinary group settings - both inside and outside the classroom.
5. Demonstrate a sense of exploration that enables them to pursue rewarding careers in high-tech and bio-tech industries with life-learning.

For the 2005-2006AY, the program selected a core learning goal to assess:

Demonstrate critical thinking and problem solving skills by identifying, evaluating, analyzing and presenting fundamental software solutions and their applications

When people think of what a Computer Scientist does, they often think first of software analysis and design and it is a critical part of the skill set of our graduates. Although there are many other aspects to our program, this core outcome seemed to be the best one to being with.

We measured students in our two 200-level classes (Comp 232 and Comp 262) because

- (a) all students in these classes have passed introductory and intermediate programming courses
- (b) all students in the BS in Computer Science have to take these classes.

The number of students taking the final exams in Comp 232 and Comp 262 were 15 and 6 respectively with some overlap. After discussing various possibilities, we decided to assess the selected outcome by seeding final examinations in these two classes with questions designed selected from the following three external sources:

AP Examination in Computer Science  
 GRE in Computer Science  
 ETS Major Field Test in Computer Science

We drew up a shortlist of 8 questions; these are listed in Appendix A

## Data and Analysis

### Comp 232

The Comp 232 instructor took a direct approach. He selected 5 of the 8 questions, included them unchanged in the final exam and gave students extra credit for answering them. Here are the scores for the questions as reported (correct answer in parentheses after the question number).

| Comp 232 |        |        |        |        |        |       |
|----------|--------|--------|--------|--------|--------|-------|
| Student  | Q1 (b) | Q2 (c) | Q3 (c) | Q4 (a) | Q5 (c) | Score |
| 1        | b      | d      | b      | a      | b      | 2     |
| 2        | b      | b      | a      | a      | d      | 2     |
| 3        | d      | c      | d      | c      | c      | 2     |
| 4        | a      | b      | d      | a      | e      | 1     |
| 5        | c      | c      | c      | a      | c      | 4     |
| 6        | b      | a      | b      | a      | c      | 3     |
| 7        | b      | c      | a      | a      | d      | 3     |
| 8        | a      | e      | a      | a      | a      | 1     |
| 9        | a      | c      | c      | a      | c      | 4     |
| 10       | a      | a      | c      | a      | e      | 2     |
| 11       | b      | c      | c      | a      | c      | 5     |
| 12       | a      | c      | a      | a      | d      | 2     |
| 13       | c      | a      | e      | a      | d      | 1     |
| 14       | c      | c      | c      | a      | a      | 3     |
| 15       | b      | b      | a      | a      | d      | 2     |
| Q Score  | 6/15   | 7/15   | 5/15   | 14/15  | 5/15   |       |

### Comp 262

It is the practice of the Comp 262 instructor to give oral final exams. Rather than go with the question pool, he chose 5 of his own questions which are somewhat less related to the program learning outcome. Students were permitted to skip some questions in the oral exam so he only reported a sample of the student answers. The questions, student answers and instructor's evaluations are shown in Appendix B.

Performance of the Comp 232 students was generally weaker than we expected. Each of the questions tests a fundamental area of software analysis and design. We will examine the syllabi of the feeder courses (Comp 150 and Comp 151) to ensure that material is introduced, reinforced and mastered appropriately.

The questions posed by the Comp 262 instructor were not closely aligned with the program learning goal we chose to assess.

## Conclusions and Implications for Program Modification

(1) The assessment tool used in the Spring 2006 semester is unsatisfactory for two reasons. First, it measures students at a relatively early point in the degree program; secondly, there is a significant fraction of the majors who bypass one or both of the assessed classes by virtue of transfer credit.

(2) In the light of the Spring 2006 assessment exercise we propose to change the point at which Learning Outcome (1) is measured. We have begun the process of adding a Capstone Project to the major. Many Computer Science programs and many majors at CSUCI have such a degree requirement. All majors will be required to complete the project at CSUCI and, as a culminating experience, it will help us better assess the whole of the major. We expect to consult with other programs regarding tools for assessing capstone projects.

## References

Educational Testing Service, *The Graduate Record Examination in Computer Science*. Referenced from <http://www.ets.org> (accessed September 21, 2006)

Educational Testing Service, *The Major Field Test in Computer Science*. Referenced from <http://www.ets.org> (accessed September 21, 2006)

The College Board, *Examinations in Computer Science A and AB*. Referenced from <http://www.collegeboard.com> (accessed September 21, 2006)

## Appendix A

Question pool for the Comp 232 class.

Q1&2

If the variables are suitably initialized and if  $i$  remains within appropriate bounds, then the following code implements the stack operations *Push* and *Pop* when the stack is represented as an array  $V[1..N]$  with an index variable  $i$ .

Push: {  $V[i] = x; i = i + 1;$  }

Pop( $x$ ): {  $i = i-1; x = V[i];$  }

Q1. Which of the following gives the correct initialization for this stack implementation?

- (A)  $i = 0;$
- (B)  $i = 1;$
- (C)  $i = N-1;$
- (D)  $i = N;$
- (E)  $i = N/2;$

Q2. If it is assumed that suitable changes in the initialization code were also made, which of the following changes to *Push* and *Pop* would yield a correct implementation of a stack.

- I. Replacing the code for *Push* with that for *Pop* and vice versa
- II. Making *Push* decrement  $i$  and *Pop* increment  $i$
- III. Reversing the order of the statements in both *Push* and *Pop*

- (A) I only
- (B) II only
- (C) III only
- (D) I and II only
- (E) II and III only

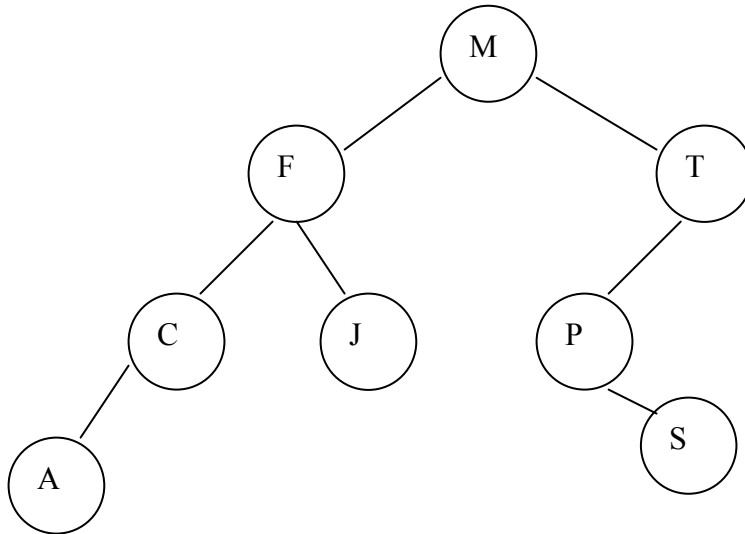
Q3.

Which of the following algorithms has running time  $\Theta(n^2)$  in the worst case but  $\Theta(n \log n)$  on average?

- (A) Bubblesort
- (B) Mergesort
- (C) Heapsort
- (D) Quicksort
- (E) Tournament sort

Q4

If a node in the following binary tree is to be located using a tree search algorithm, what is the expected number of comparisons required to locate one of the items chosen at random?



- (A) 1.75
- (B) 2
- (C) 2.75
- (D) 3
- (E) 3.25

Q5

In systems with support for automatic memory management, a garbage collector typically has the responsibility for reclaiming allocated memory object whose contents cannot affect any future legal computation. Such objects are identified by determining that they cannot be reached from a root set. Which of the following is NOT part of the root set in a typical garbage collector?

- (A) Actual parameters of the active procedures
- (B) Dynamically allocated objects on the heap
- (C) Global variables of the program
- (D) Local variables on the call stack
- (E) Values in machine registers

Q6

Hash tables can contribute to an efficient average-case solution for all of the problems described below EXCEPT:

- (A) Counting distinct values: Given a set of  $n$  keys, determine the number of distinct key values.
- (B) Dynamic dictionary: Support the operations of insert, delete, and search in a dictionary.
- (C) Range search: Given values  $a$  and  $b$ , find all the records whose key value is in the range  $[a,b]$ .
- (D) Symbol table lookup: Given a program identifier, find its type and address.
- (E) Finding intersections: Given two sets of keys, find all key values in common to both sets.

Q7

A car dealership needs a program to store information about the cars for sale. For each car, they want to keep track of the following information: number of doors (2, 4, or 5), whether the car has air conditioning, and its average number of miles per gallon. Which of the following is the best design?

- (A) Use one class, Car, which has three data fields: int NumDoors, boolean HasAir and double MilesPerGallon.
- (B) Use four unrelated classes: Car, Doors, AirConditioning and MilesPerGallon
- (C) Use a class Car which has three subclasses: Doors, AirConditioning and MilesPerGallon.
- (D) Use a class Car which has subclass Doors, with a subclass AirConditioning with a subclass MilesPerGallon
- (E) Use three classes: Doors, AirConditioning and MilesPerGallon, each with subclass Car.

Q8

Consider the following code segment:

```
for (int j=1; j <= n; j++)
{
    for (int k=1; k <= n; k=k*2)
    {
        system.out.println(j + " " + k);
    }
}
```

Of the following, which best characterizes the running time of the code segment?

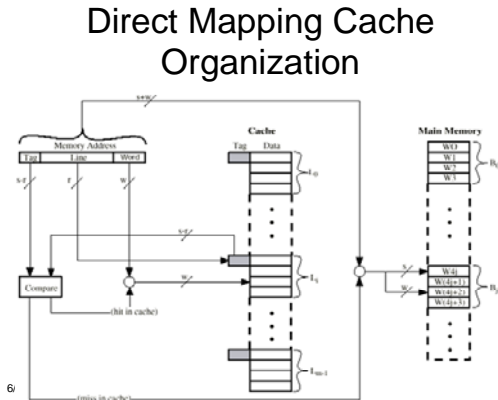
- (A)  $O(\log n)$
- (B)  $O(n)$
- (C)  $O(n \log n)$
- (D)  $O(n^2)$
- (E)  $O(n!)$

## Appendix B

Questions, responses and analyses for the Comp 262 students.

Each item below begins with the question, followed by the slide and the typical “paraphrased” responses of the students. Students were permitted to skip a certain number of questions; after which, they lost credit for being unable to answer a question.

1. Explain the diagram below and compare it to alternate techniques.



Typical responses:

- A. It depicts direct mapping of a cache system. In this scheme, blocks in memory can only be placed in specific locations in the cache memory. Another scheme is associative mapping.

**Instructor’s Assessment:** This is a minimal answer illustrating that the student is vaguely familiar with the concepts and terminology. Grade: C.

- B. The diagram is for direct cache mapping. Only certain memory blocks can be put into each cache memory line. The blocks (tags) which can be placed in these lines begin by assigning the first block to the first cache line and then continues with the next block and the next line until you reach the end of the cache. At that point the next block is assigned to the first line and the process starts all over again in a cyclic manner. Associative mapping permits you to place any memory block into any cache line.

**Instructor’s Assessment:** This is an answer which demonstrates that the student has a good grasp of the concepts and terminology. Grade: B+/A-.

- C. This is a directly mapped cache as compared with an associative cache. Memory groups (blocks) can only be placed in certain cache locations (lines). When you get a memory address, you compare its tag with the tag where this memory would normally be found in the cache. If you get a match or hit, you know the cache contains what you want; otherwise, you have to go out to physical memory and find what you are looking for and put it into the cache.

**Instructor’s Assessment:** This is an answer which demonstrates that the student has a good grasp of the concepts and terminology. Grade: B+/A-.

2. What are two ways of writing information back into memory when you use a cache memory?
- A. Write back and write through are the methods we discussed. Write back happens only when you are about to replace one line in the cache with another block from memory. Then you write the line you are about to replace back into the memory. The other method writes everything each time you change the cache. (Instructor: What are the benefits of write back?). You don't have to write into the main memory each time; only when you are changing the cache.

**Instructor's Assessment:** This is an answer which demonstrates that the student has a good grasp of the concepts and terminology. Grade: A.

- B. (Instructor: I'll help you out...write back and write through, now tell me what each does) One writes information back into memory at the same time it changes the cache and the other waits until you are replacing the information in the cache. (Instructor: which is which?). I think the first is called write through and the other is the write back. (Instructor: what are the benefits of each?)

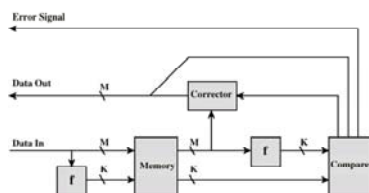
**Instructor's Assessment:** This is an answer which demonstrates that the student is uncertain of the concepts and terminology and not sure which is which. Grade: C-.

- C. Write back and write through. (Instructor: What do they do?) I don't remember exactly.

**Instructor's Assessment:** The student was permitted to skip this question and continue on to the next. Grade: None.

3. Where might the concept of a Hamming code be used in this scheme?

### Error Correcting Code Function



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- A. I think the Hamming code would be computed by the "f" box and the code would be the "k" value stored in the memory along with the data.

**Instructor's Assessment:** This is a minimal answer illustrating that the student is vaguely familiar with the concepts and terminology. Grade: C.

- B. This shows how an error code can be used with data so that you can detect and correct errors in the data. The Hamming code would be determined by "f" and saved as "k". Then, when memory was accessed, a new "k" would be computed and compared to what was

stored to see if they are the same. If not, you have an error and if you use the right Hamming code, you may be able to even correct the error.

**Instructor's Assessment:** This is an answer which demonstrates that the student has a good grasp of the concepts and terminology. Grade: A.

- C. You would feed the data, "M" into a Hamming code thing "F". The code would then be saved and later used when you accessed the memory. A new Hamming code would be computed and compared with the saved value to see if you have to correct the data.

**Instructor's Assessment:** This is an answer which demonstrates that the student has a basic understanding of the concepts and terminology. Grade: C.

4. Which of the following properties does not hold for arithmetic algebra? Also prove your answer by whatever means you wish.

#### Fundamental properties of boolean algebra

|                                   |                                   |              |
|-----------------------------------|-----------------------------------|--------------|
| $x + y = y + x$                   | $x * y = y * x$                   | commutative  |
| $(x + y) + z = x + (y + z)$       | $(x * y) * z = x * (y * z)$       | associative  |
| $x + (y * z) = (x + y) * (x + z)$ | $x * (y + z) = (x * y) + (x * z)$ | distributive |
| $x + 0 = x$                       | $x * 1 = x$                       | identity     |
| $x + (x) = 1$                     | $x * (x) = 0$                     | complement   |

- A. I think it's the distributive one. (The student proceeded to try and prove it algebraically and failed, so the Instructor helped him along proving it by a simple example.).

**Instructor's Assessment:** This is an answer which demonstrates that the student was relying primarily on memory rather than an analysis of each statement. Grade: C.

- B. The distributive rule doesn't work. (The student set up a simple numeric example to prove his correct answer.).

**Instructor's Assessment:** This is an answer which demonstrates that the student was confident about his answer and went about supporting it using a simple, but effective example. Grade: A.

5. Compare a RAID 1 and RAID 5 configuration, citing some of the features and benefits of each.

### RAID 1

- Mirrored Disks
- Data is striped across disks
- 2 copies of each stripe on separate disks
- Read from either
- Write to both
- Recovery is simple
  - Swap faulty disk & re-mirror
  - No down time
- Expensive



(b) RAID 1 (mirrored)  
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### RAID 5

- Like RAID 4
- Parity striped across all disks
- Round robin allocation for parity stripe
- Avoids RAID 4 bottleneck at parity disk
- Commonly used in network servers



6/8/2006 (f) RAID 5 (block-level distributed parity) Final Exam 21

A. The RAID 1 system is a relatively simple configuration, but it uses a lot more disk drives. But it does make the system run faster because you can have parallel reads like you do with a RAID 0 version. The RAID 5 system doesn't use as many disk drives, and it also permits parallel reads. I like the RAID 5 system even though it's more complicated to build.

**Instructor's Assessment:** This is an answer which demonstrates that the student has a general understanding of the concepts and terminology, but it lacked salient details. Grade: B-/B.

B. Both permit parallel reads, but the RAID 5 doesn't use as many disk drives. It looks like the RAID 1 might be easier to build, but I'm not sure.

**Instructor's Assessment:** This is an answer is basic in nature, but the student was unable to develop the answer further. Grade: C.