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CLA Report

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Collegiate Learning Assessment (CLA)
Project Report

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April 30, 2009

1. Course information

The CLA performance task was administered in my MATH 412 Advanced Calculus. The majority of students enrolled in this class are math or math education majored seniors.

I chose to conduct a CLA performance task in my MATH 412 because this course emphasizes many skills the Collegiate Learning Assessment measures, such as critical thinking, analytic reasoning, problem solving and written communication. A major goal of the course is to teach students to understand mathematical proofs as well as to be able to formulate and write them.

2. Performance task

The performance task consisted of two parts. The first part was made of a number of independent short questions, which were intended to measure the student's basic mathematical reasoning skills such as *negation* and *deduction*. The second part was the main part of the task, which was intended to measure the student's comprehensive ability in critical thinking, mathematical reasoning and written communication. There were two problems in the second part – *Product Sequence* and *Nonnegative Integral Exponents*.

In Product Sequence, the student's classmate Kenneth claims that the product of two sequences must converge to zero if one of the two sequences converges to zero, and has a proof for his claim. The student is asked to evaluate Kenneth's arguments, explain the reasons for his/her conclusions, and justify those conclusions by referring to specific sources provided in the accompanying documents.

In Nonnegative Integral Exponents, another classmate Kelly claims that she has successfully proved, using mathematical induction, that all nonnegative integral powers of any nonzero real number are one. The student is requested to determine whether Kelly's proof is valid or not and explain the reasons. If the student thinks Kelly's arguments are invalid, he/she needs to argue whether or not all nonnegative integral powers of any nonzero real number are one.

There were six (6) documents (labeled Documents A-F). Document A gives one form of Principle of Mathematical Induction and the steps of proof by mathematical induction. The document was chosen because mathematical induction was used by Kelly in her arguments for Nonnegative Integral Exponents. Document B is a list of laws of exponents, which were cited in Kelly's proof. Document C consists of a formal definition of the limit of a sequence and a theorem that lists some basic properties of limits. The definition was included in the document because a deduction question was based on it. The theorem was chosen because in Product Sequence, Kenneth cited it for his arguments. Document D is a definition of a

limit point (or cluster point or accumulation point) and an explanation of the definition, which was used to in a deduction question. Document E gives a formal definition of the negation of a statement and a couple of examples of negations, which the student could refer to in those negation questions. Document F defines deductive reasoning and illustrates the definition by an example, which served as a reference for the student to answer those deduction questions.

A successful response to Product Sequence required students to understand the theorem about the limit of a product sequence, which had been proven to be true, realize that the main line of Kenneth's arguments was based on the theorem, and then examine the assumptions in Kenneth's claim to see whether all the conditions of the theorem were present. Students were expected to realize that the sequence {bn} in Kenneth's claim was *arbitrary*-it may or may not have a limit, and thus the assumption of the limit of {bn} being b in Kenneth's arguments was improper and groundless. Students were further expected to decide that Kenneth's claim was untrue and justify their conclusion by constructing a counter example.

To respond to Nonnegative Integral Exponents successfully, students were required to understand the principle of mathematical induction, especially the strong form of the method given in Document A, find a flaw in Kelly's arguments, and disprove Kelly's claim by showing a counter example. In analyzing Kelly's arguments, students were expected to realize that when n is a nonnegative integer, n-1 may not be nonnegative (for example, when n=0, which is nonnegative, n-1=-1, which is not nonnegative) and thus, although $n-1 \leq 1$, $a^{n-1} = 1$ was not warranted by the induction hypothesis.

Since the performance task was designed mainly for the students in a proof oriented real analysis course, logic thinking, mathematical reasoning and idea expression were highlighted. A successful response to the performance task required students to integrate information mostly in narrative form although constructing counter examples involved information in quantitative form.

3. Performance Task Administration

The performance task was administered on April 15, 2009.

The student's score on the assessment will be calculated in the final grade. It weighs fifteen percent (15%) in the final grade.

4. Student Performance

Form the performance, students showed some strengths in their basic mathematical reasoning skills. Students were particularly good in forming the negation of a given statement, especially a statement in plain English. Out of the four given statements, every student got at least three correctly. Another strength is that for a given claim, students were most time able to come up with a correct answer when they were asked whether or not you agree with the claim. That is, based on the provided definitions, theorems, and other information, they were able to make a true or false conclusion pretty accurately.

However, students showed some consistent weaknesses in their performance.

First, in basic mathematical reasoning they had problems to form the negation of a slightly more complicated statement, especially a statement involving mathematical terms. For example, for the statement "Every number in the set *A* is less than or equal to the number

b", three out of four students came up with an incorrect negation. One student overstated conclusion as "Every number in the set *A* is greater than the number *b*" while another student wrote "Some number in the set *A* is greater than or equal to the number *b*".

The students were also weak in deductive reasoning. For an example, when the students were asked whether the following statement is true and why, three out of four students were unable to offer a correct explanation.

If a sequence {xn} converges to a number L, then for every positive number ε, there must be a positive integer N such that |xn – L|< ε/3 for all positive integer n > N.

In fact, since {xn} converges to L, according to the definition of convergence (see Document C), for *every positive number* ε, there must be a positive integer N such that |xn – L|< ε for all positive integer n > N. In particular, for the positive number ε/3 (which should be positive since ε is positive), there should be a positive integer N such that |xn – L|< ε/3 for all positive integer n > N.

One big weakness shown in student performance is that they had trouble to spot deception and holes in the arguments of others. Half of the students were unable to figure out what was wrong in the two arguments. One probable reason is they did not draw connections between the given conditions in the claims and the conditions required in the theorem which they apply.

Another weakness found in student performance is that many students did not know how to argue a claim is untrue. They were not aware that using a *counter example* is one of the most effective ways to show an assertion does not hold, which is especially true for mathematical assertions.

From their performance I also found many students had not mastered the principle of mathematical induction. When they were asked to evaluate Kelly's induction proof to see if there was a flaw in it, three out four students failed to point out the logical flaw. Some students questioned $a^n = 1$ by saying that it needs to be proved while others questioned $a^{n-1} = 1$ by stating that it is not assumed by the induction hypothesis.

5. Recommendation and follow up

Knowing that our students' performance on the CLA will be part of our institutional assessment, I will innovate and redesign all the courses I teach to address the skills and competencies assessed by the CLA. When preparing a course, we need consider what skills are appropriate to address in this course based on the nature and contents of the course. For examples, problem solving may be more appropriate for a calculus course to address while analytic reasoning is more appropriate for a geometry course to address. When teaching a course, we should not just show students how to solve a specific problem or prove a specific theorem. We need to comment on what methods or skills we just used and how they fit into the big picture of some commonly used general methods. When evaluating students, we should try to avoid giving them only multiple choice, or short answer problems. Give them some comprehensive, open ended problems to test their critical thinking, analytic reasoning, problem solving and critical writing skills. If possible at all (e.g. when a class is not big), we should hold a one-on-one conference with each individual to discuss his/her strengths and weaknesses after such a test.

I recommend all faculty member to administer the CLA performance task in their classes. My students liked the task even though many of them did not get a good score on it. Through the task, they found their strengths and weaknesses, and learnt some subject specific knowledge as well as some general skills, which has stimulated their interest and effort in their study.