MEMO

To: VaNTH ERC members
From: Sean Brophy
Date: September 11, 2001
Subject: Addendum to August 9th Assessment and Evaluation Primer

The August 9th Assessment and Evaluation Primer (download document at http://www.vanth.org/vanth/thrustFiles/250.doc) provides an outline for how to design additional assessment methods to evaluate students knowledge and evaluation methods for researching student learning and a module's effectiveness. In addition, the Primer contains a set of milestones for defining and reviewing new assessment items that will eventually form the foundation for our evaluation plan. Our goal listed in the Primer is to have an initial set of assessment items to begin reviewing on September 17. The challenge statement below provides a quick summary of the assessment goals. The "generate ideas" section provides some guidelines to help craft these assessment items. Please take some time to generate several assessment items that fit the criteria detailed in the A&E Primer. The easiest starting point could be to review existing items from prior courses and rework them to fit the criteria outlined in the primer and below. Send your assessment items to Sean Brophy at (mailto://sean.brophy@vanderbilt.edu). We will arrange a working group with A&E and LS representatives to review these items with the authors to fine-tune them to the desired criteria.

The challenge: Our goal is to identify assessment items that require students to generate more than only the necessary computations related to problems in a specific domain. Assessments can fall along a continuum as shown in Figure 1. Many traditional assessment items target facts and computational procedures because they can objectively target specific learning outcomes, they depend less on prior knowledge, and they are easy to administer and grade. These can be very beneficial for achieving certain learning outcomes, such as, familiarization with terms, fluency in application of specific fundamental principles and computational skills. Worded correctly they can even get at process level ability of students. However, often these types of assessments are highly structured problem statements that identify a specific solution to a problem. Therefore, students can be limited in their opportunities to demonstrate their abilities for the initial phases of problem solving (e.g problem formulation, problem representation, project planning, etc). On the other end of the continuum, course projects are used to develop students' abilities to formulate problems, manage the complexity of a problem, identify potential solutions, create action plans, work in teams, and communicate ideas to name a few engineering skills. Projects encourage students to take a high degree of action to generate a solution. However, the time duration, size and complexity of these projects can make it difficult to provide formative feedback to students to make a difference in the existing course. Smaller assessments are needed that fall closer to the middle of this continuum (see the gray area of Figure 1). These assessment items can be given to

students throughout a course to help them evaluate their progress toward a wider range of engineering skills.

VaNTH's challenge based instruction is designed to develop skills like problem formulation skills, constraining the problem space, defining additional questions and knowing where and how to search for additional information. Assessing these skills will require more than just computational skills. Therefore, the results of this activity to articulate a different set of assessment items will be invaluable in our assessment of the HPL approach to instruction and to understanding how students develop understanding of bioengineering content.

Generate Ideas for assessment items. The A&E and LS group recommends starting this activity with past assessment items used in a course. Here are several guidelines to help redefine these prior assessment items to meet additional learning objectives.

1. Select several challenging assessment items used in previous course. Criteria for selecting these items could include –
    - weak performance by students
    - requires application of several fundamental principles
    - requires a representation (eg FBD) to manage the complexity of the problem
2. Briefly describe the objectives of the assessment. That is, describe what students need to be able to demonstrate in their response to the assessment item.
3. Review each assessment item and determine how much of the problem solving process is structured for the students and how much are students required to generate a solution to the problem.
4. Rewrite the assessment items to require students to formulate problems and manage their complexity (or to other core objectives not previously targeted). Here are several guidelines to stimulate some ideas on how to pose problems, or scenarios, for students to respond to:
    - Pose a problem using a "real" context (i.e. situation, scenario). Put students into a role such as a designer, project manager, physician, review board panel member.
    - Provide more information than is actually need to solve the problem.
    - Ask students to
        - identify the central focus for the problem.
        - identify what are the underlying principles of the problem.
        - justify why these are the underlying principles.
        - identify what information is relevant.
        - find a representation that helps manage the complex interplay of information in a problem.
        - generate questions about what more they need to know and what they would do to find this information.

You may already have assessment items that meet the criteria listed above. Please share these items along with a description of your desired objectives for each assessment item. The results of this activity will be very helpful to the A&E and LS group to have a wide

assortment of these assessment items to better understand the range of possible ways to pose bioengineering related problems and the focus on specific learning objectives.

These assessment items should be used in addition to the assessment items currently found along the assessment continuum (Figure 1). These new assessments can be used at several points during a course to trace the trajectory of students on these skills and which will provide feedback on how well the course is developing these skills.

Students may find these assessment items very difficult early in the course, because they may never have been asked to solve these kinds of problem in the past, or are weak in these skills. This lack of prior knowledge can cause anxiety toward how the questions will be graded. Minimizing its worth toward students' over all grade could reduce this anxiety, but students may tend not to put in the effort we desire. Alternatively, the problem solving abilities listed above can be explicitly stated as a course objective. These skills are clearly developmental and require practice (such as in Test Your Mettle or Go Public in the Legacy Cycle). Therefore, students need to value these assessment activities as feedback on their progress toward this course goal. Early in the semester the items can be scored on a low scale, but the assessment items used near the end of the course will be scored on a higher scale. Students should be inspired to work hard on the early assessments as a method to prepare for the higher stakes events at the end of the semester. In future Learning Forums and technical reports we can discuss methods for how to embed these assessments into instruction. Also, we will discuss methods for scoring these assessment items both as formative and summative assessment measures.

Finally, please find attached several alternative assessment items others have created along with a brief description for how the authors use these assessment items. These items target the specific objectives of the authors. However, many of these could be reworked to focus on a different set of learning objectives similar to the ones listed above, in the primer and the core competencies working document.

Thank you for your time and consideration.

Sincerely,

Sean P. Brophy

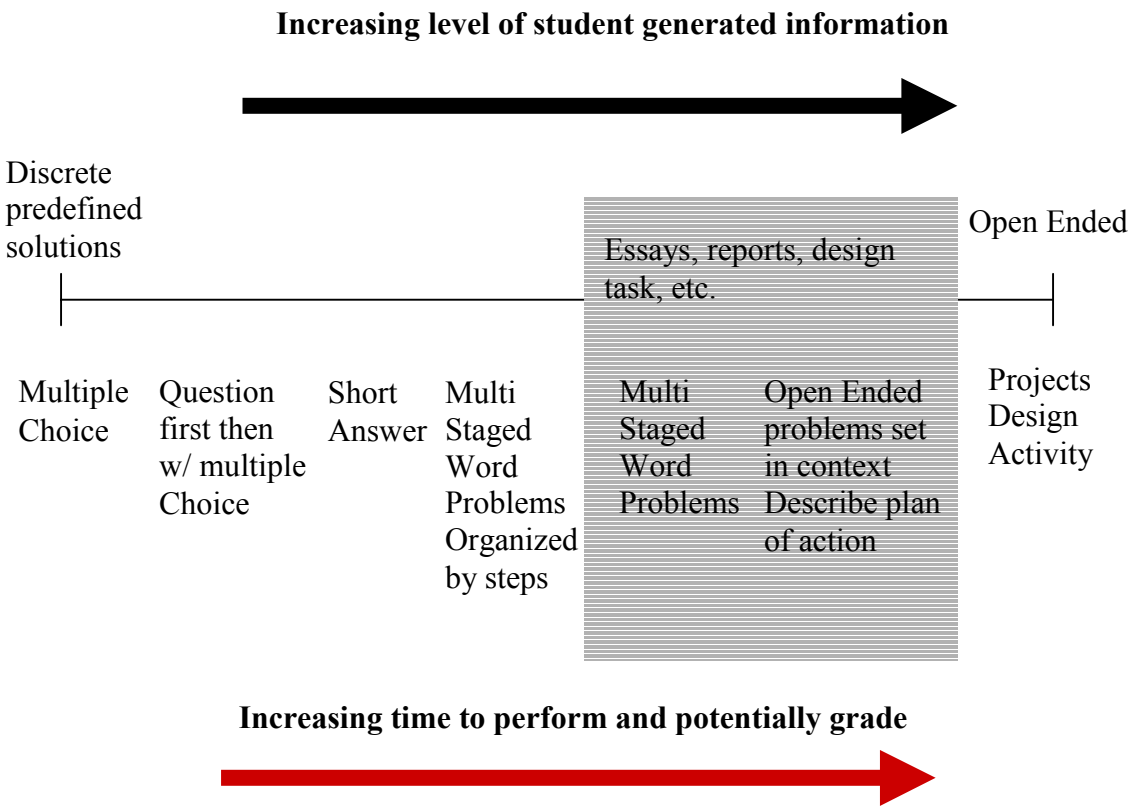


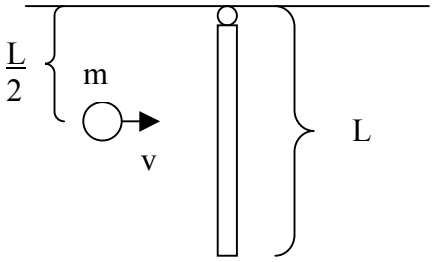
Figure 1 - Continuum of Assessments

Example 1. Applying a strategy of Identification, explanation and application of physics principles

Objectives: Leonard, Dufresene and Mestre (1996) wanted students to develop a strategy for identifying the physical principles related to specific problems. Their strategy means "a qualitative description containing three major components for solving a problem: (1) the major principle(s) and concept(s) that can be applied to solve the problem; (2) a justification for why the principle(s) or concept(s) can be applied; and (3) a procedure by which the principle(s) or concept(s) can be applied to arrive at a solutions." In short the strategy is a discussion of the "what, why and how" of a problem's solution. Therefore, students need to be able to use this strategy when they solve problems. The instructors continually model this strategy in every problem they approach during lecture and review sessions.

Here is a sample homework problem with its posted strategy (taken directly from Leonard et al, 1996)

Problem 1: A stick of mass M and length L is hanging from a ceiling as shown to the right. A piece of putty of mass m is traveling horizontally when it strikes and adheres to the stick at its midpoint. What must have been the speed of the putty, v, if the stick (with putty attached) swings and comes momentarily to rest in a horizontal position before starting to swing down again?



Posted Strategy:

This problem consists of two parts. First, the mass and stick undergo a totally inelastic collision. Angular momentum is conserved about the pivot during the collision since there is no net external torque (about the pivot point). Even though there are two external forces present during the collision, these do not provide net external torque: The force at the pivot has no moment arm (i.e., r=0) and so it does not provide a torque about the pivot. The gravitational force acting on the center of mass of the stick points vertically down and initially is parallel to r (i.e., angle between r and Fg is 0°). Assuming the collision is instantaneous, the gravitational force delivers no angular impulse to the system during the collision. So, assuming there is no friction between the pivot and the rod, there are no angular impulses delivered to the putty-stick system. Thus, for the collusion portion of the problem, equate the initial and the final angular momenta, of the putty-stick system. Note that only the putty contributes to the initial angular momentum since the stick is at rest prior to the collision.

The second part of the problem consists of the putty-stick system rotating to a horizontal position before momentarily stopping. During this portion of the problem, mechanical energy is conserved. Only two forces act on the system during this "swinging" portion: The gravitational force and the force at the pivot. The force at the pivot does no work since the pivot point does not move and we have assumed that there

is no friction between the pivot and the stick. Only the gravitational force (a conservative force) does work, resulting in mechanical energy being conserved. Thus, for the second portion of the problem, equate the initial and final mechanical energies of the system. Assuming the collision was instantaneous, the initial orientation of the putty-stick system is vertical. The center of mass of the system is at the midpoint of the stick. (We need this to evaluate the potential energy of the system.) Applying the two concepts of angular momentum and energy conservation will result in two equations that will allow you to solve for v in terms of the "givens" in the problem.

Leonard, W. J., Dufresne, R. J. & Mestre, J. P. (1996). Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems. American Journal of Physics, 64 (12), p 1495-1503.

LS/A&E Comments:

This problem is a constrained situation to determine if students can identify the various physical principles that define the motion of this putty and pendulum, including conservation of energy and momentum. By applying the Leonard's three component strategy, students are asked to formulate an argument for what, why and how these principles relate to this putty hitting the stick problem. Students could have been asked to compute various values for the velocity of the putty/pendulum, or how long it would take to travel to the peek. This would require the students to apply the principles. However, the final answer does not help an instructor know whether the students really understand why the principles apply (Students may just attempt to work with the equation currently being studied in the course). The problem also relates to a communication issue, that is, how well can students concisely articulate the their plan for solving the problem.

This problem could be taken another step to pose it in terms of a bioengineering "context". What are situations where energy and momentum transfer exists? What are the potential difficulties students will have with the step toward combining these physical principles with biological structures?

Example 2. Goal Based Scenario – Manufacturing plan for a new battery

Objectives: McMartin, McKenna, and Youseffi (2000) have worked with industry representatives to create authentic contexts for posing problem to students. The objectives of these problems are listed in the instructions below. These contexts, or scenarios, are complex and require students to generate questions and identify a multiple plans of action, then determine the most optimal design much like what would be done for a course project. However, students are not asked to complete the execution of their plan. Therefore, the time and effort to complete this activity is short. McMartin, McKenna, and Youseffi used these scenarios to research novices abilities to solve these kinds of problems. They have developed criteria to assess these student products in a viable and reliable way.

THE BATTERY – Instructions (taken directly from McMartin, McKenna, and Youseffi 2000)
The scenario appearing below gives you the opportunity to display your skills addressing open ended problems, i.e. those that have no clear, distinct solution, but instead have numerous possible outcomes. The way in which you answer the question is up to you, e.g., outline or essay, with or without diagrams. The key elements of your response that we will be evaluating are listed below.

- That you frame the problem accurately, i.e. identify scope of problem, and clarify the important aspects of the problem.
- That you can articulate any constraints to the problem i.e. social, economic, technical.
- That you are able to determine if the problem is worth solving, i.e. what are the trade-offs, what are the criteria for the making such a decision?
- That you can articulate a process for developing a solution(s), i.e. identify tasks and sub-tasks, organize resources, and develop a realistic schedule for developing and implementing your solution.
- That you understand where and how to get information necessary to help the team members in their respective tasks.

SCENARIO
Modern life seems to revolve around electronic devices, and the trend with these devices has always been towards smaller and smaller products. One component, which is critical, but has so far confounded many engineers and scientists, is the design of a better battery. For this problem assume that some new materials have been developed which have exciting new electro-chemical properties. Your company has decided to manufacture a new battery with them, and has asked you to prepare an outline for the design and manufacture of the new battery. Since the battery is intended for small devices, such as laptop computers, the size of the battery is critical. The output voltage of a battery though, is a function of the number of layers of anode and cathode materials and is therefore fixed.

YOUR TASK

Assume you are the Project Engineer for the team responsible for this assignment and you are preparing a preliminary report for your team to help focus them in the weeks to come. As part of another project, you are about to leave on a business trip. Therefore, the report needs to include enough information for the team to start without you. Please discuss in as much detail as possible, the framework and contents of this report.

McMartin, F., McKenna, A., and Youseffi, K. (2000). Scenario Assignments as Assessment Tools for Undergraduate Engineering Education, *IEEE Transactions on Education*, Vol. 43, No. 2, pp. 111-119. http://www.vanth.org/vanth/thrustFiles/256.pdf .

LS/A&E Comments

This scenario based assessment method provides a way to assess students ability to manage complex situations in order to identify the underlying problem. That is, to define the critical factors in this design and to identify an effective plan of action. Again, the focus is much less on computational ability and more on problem formulation and information gathering and refining.