The Role of Computer Based Homework for Engineering Design Courses

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Abstract – Evaluation of students in engineering design courses remains a key challenge to educators. While the evaluation techniques presented by computer based homework may not seem applicable to design courses, a basic understanding of the ASCE Body of Knowledge, Bloom's Taxonomy, and the draft Body of Knowledge Outcome Rubric allows for the development of meaningful assignments. Along with a brief introduction to these topics, this paper discussed the relative applicability of different question types typically available for computer based homework, along with example questions from a highway design course. Though not all levels of achievement can be reasonably evaluated, computer based homework, when properly applied, can serve as a useful tool for helping to evaluate student achievement in engineering design courses.

Keywords: homework, online, computer based, design

INTRODUCTION

With the publication of its *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future* (the Body of Knowledge) [1], the American Society of Civil Engineers (ASCE) renewed their commitment to champion the teaching of design within engineering curricula. While this was neither a surprise nor a change from past practice, the challenge for educators remains: how to best evaluate students in engineering design courses. From in-class participation to semester-long group projects, the available tools are nearly limitless, and computer based homework assignments represent a (relatively) new entry into the toolbox. As with any new tool, the key to successful application is a clear understanding of the role to be filled.

To that end, this paper first presents a very brief review of both the Body of Knowledge and its more recent draft Levels of Achievement, which provide insight into methods for evaluation. What follows is an exploration of the applicability of the different question types available in most computer based homework applications. This investigation is supplemented with examples from a highway design class, namely CEE 46040 – Highway Engineering, a senior-level elective offered at Tennessee Tech University.

The paper does not spend time discussing the relative merit of computer based homework in general, as this topic has been frequently addressed in the literature.

A BRIEF BACKGROUND: THE BODY OF KNOWLDEGE [1]

As part of its role in developing requirements for licensure, ASCE began to recognize that the current four-year bachelor's degree was becoming inadequate preparation for practice as a professional civil engineer. This realization led to the adoption in November 2001 of ASCE Policy 465, which supported the concept that a master's degree or equivalent would become a requirement for licensure. ASCE then created the "Task Committee on Academic Prerequisites for Professional Practice" (ACAP[3]) to formulate and execute plans to implement the policy.

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At the heart of the matter, answering three basic questions about engineering education:

What should be taught and learned?
How should it be taught and learned?
Who should teach and learn it?

Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, a report prepared by the Body of Knowledge Committee of ACAP3, focuses on providing the committee's answer to the first of three basic questions, along with introductory answers to the remaining two. That answer is provided in the form of fifteen Learning Outcomes (the Outcomes), presented in Exhibit 1.

Exhibit 1. The Original 15 Outcomes from the Body of Knowledge [1]

1. An ability to apply knowledge of mathematics, science and engineering.
2. An ability to design and conduct experiments, as well as analyze and interpret data.
3. An ability to design a system, component or process to meet desired needs.
4. An ability to function on multi-disciplinary teams.
5. An ability to identify, formulate and solve engineering problems.
6. An understanding of professional and ethical responsibility.
7. An ability to communicate effectively.
8. The broad education necessary to understand the impact of engineering solutions in a global and societal context.
9. Recognition of the need for, and an ability to engage in, life-long learning.
10. Knowledge of contemporary issues.
11. An ability to understand the techniques, skills, and modern engineering tools necessary for engineering practice.
12. An ability to apply knowledge in a specialized area related to civil engineering.
13. An understanding of the elements of project management, construction, and asset management.
14. An understanding of business and public policy and administration fundamentals.
15. An understanding of the role of the leader and leadership principles and attitudes.

The Original Levels of Competence [1] [2]

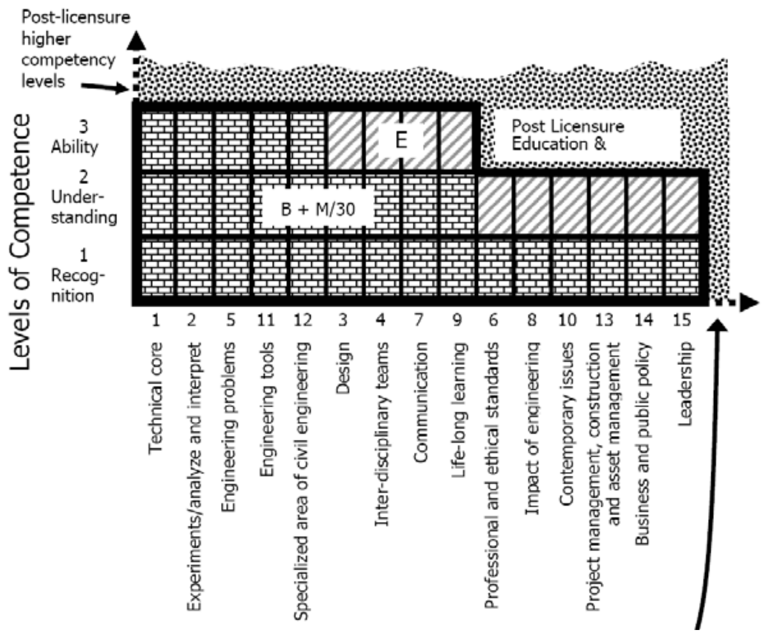
In the original report, three Levels of Competence were identified and defined:

- Level 1 (Recognition) represents a reasonable level of familiarity with a concept. At this level, the engineer is familiar with a concept, but lacks the knowledge to specify and procure solutions without additional expertise. For example, an engineer might recognize that a particular architectural plan poses significant construction difficulties without having the expertise to devise improved construction or design alternatives.
- Level 2 (Understanding) implies a thorough mental grasp and comprehension of a concept or topic. Understanding typically requires more than abstract knowledge. For example, an engineer with an understanding of professional and ethical responsibility should be able to identify and to communicate ethical issues arising from a practical case study.
- Level 3 (Ability) is a capability to perform with competence. An engineer with the ability to design a particular system can take responsibility for the system, identifying all the necessary aspects of the design, and match objectives with appropriate technological solutions. As an engineer develops, the engineer's abilities also develop so that more challenging and difficult problems can be solved.

A mapping was then created to identify what level of competence was required for each of the Outcomes along the path to licensure. This mapping is shown in Exhibit 2.

As various stakeholders reviewed, asked questions, and made suggestions regarding the Outcomes and associated levels of competency, deficiencies became clear. As a result, the Levels of Achievement Subcommittee (the Subcommittee) was formed and charged to address these concerns. The Subcommittee investigated various learning taxonomies in hopes of finding a better way to articulate the desired outcome achievement levels, eventually identifying Bloom's Taxonomy as the best suited to the need.

Exhibit 2. Mapping Levels of Competence to the Original 15 Outcomes, from [1]



B + M/30 = Expected During Bachelor's Degree and Master's Degree (brick pattern)
E = Expected During Pre-Licensure Experience (diagonal hatch pattern)

Bloom's Taxonomy of Educational Objectives [2] [3]

Bloom's Taxonomy was chosen by the Subcommittee to provide a framework to define revised Levels of Achievement within the Body of Knowledge for several reasons, including its wide acceptance within the education community and its emphasis on using action verbs to define measurable Outcomes. Bloom's Taxonomy identifies six levels of the cognitive domain, and is described briefly in Exhibit 3.

The Revised Outcomes and Levels of Achievement [2]

Following the emphasis in Bloom's Taxonomy, the Subcommittee revised each of the original Outcomes using action verbs and developed a revised mapping to identify what level of achievement was required for each outcome along the path to licensure. As part of the revision process, the Subcommittee substituted "Achievement" for "Competence," to differentiate between potential (competence) and performance (achievement). The Subcommittee also took advantage of the revision process to more clearly differentiate the Levels of Achievement expected from formal education and those expected from pre-licensure experience. The revised Outcomes are given in Exhibit 4.

The Body of Knowledge Outcome Rubric [2]

While not specifically part of the Subcommittee's tasks, the process of revising the Levels of Achievement within the Outcomes of the Body of Knowledge, and then identifying the expectations of both formal education and pre-licensure experience within each outcome, provided the Subcommittee with an opportunity to create a Body of Knowledge Outcome Rubric (the Rubric). Essentially a cross-classification table, the Rubric provides concise, action-verb descriptions of each achievement level within each outcome of the Body of Knowledge.

Exhibit 3. Bloom's Taxonomy of Educational Objectives, from [2], modified

Level	Simplified Definition	Illustrative Verbs
6. Evaluation	Judge the value of material	Appraise; compare and contrast; conclude; criticize; critique; decide; defend; evaluate; judge; justify.
5. Synthesis	Put parts together and form a new whole	Adapt; anticipate; collaborate; combine; compile; compose; create; design; develop; devise; facilitate; generate; incorporate; integrate; modify; plan; reconstruct; reorganize; revise; structure.
4. Analysis	Break material into component parts to understand organizational structure	Analyze; break down; correlate; differentiate; discriminate; distinguish; formulate; illustrate; infer; organize, outline; prioritize; separate; subdivide
3. Application	Use learned material in new situations	Administer; apply; articulate; calculate; chart; compute; contribute; determine; demonstrate; establish; implement; prepare; provide; relate; report; show; solve; use.
2. Comprehension	Understand the meaning	Classify; cite; convert; describe; discuss; estimate; explain; generalize; give examples; paraphrase; restate (in own words); summarize.
1. Knowledge	Recalling information	Define; describe; enumerate; identify; label; list; match; name; reproduce; select; state.

Exhibit 4. Revised Outcomes from the Body of Knowledge, from [2]

Outcome		Formal Education	Formal Education and Pre-Licensure Experience
		To satisfy the academic prerequisites for the professional practice of civil engineering, an individual must be able to:	**To enter into the professional practice of civil engineering, an individual must be able to:**
1	**Technical core**	**solve** problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science	**solve** problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science
2	**Experiment**	**design** a civil engineering experiment to meet a need; **conduct** the experiment, and **analyze** and **interpret** the resulting data	**evaluate** the effectiveness of a designed experiment in meeting an ill-defined real world need
3	**Design**	**design** a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**evaluate** the design of a complex system, component, or process to ensure that it meets a client's needs and accounts for all relevant constraints.
4	**Multi-disciplinary**	**function** effectively as a member of a multi-disciplinary team	**organize** an existing multi-disciplinary team to accomplish a complex task
5	**Engineering problems**	**solve** well-defined engineering problems in four technical areas appropriate to civil engineering	**identify**, **formulate**, and **solve** an engineering problem involving integration of several different technical areas appropriate to civil engineering; and **evaluate** the effectiveness of the solution
6	**Prof./ethical**	**analyze** a complex situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action	**self-assess** their long-term professional and ethical development and can **evaluate** both in light of competing and complex real-world alternatives
7	**Communication**	**organize** and **deliver** effective verbal, written, and graphical communications	**plan, compose,** and **integrate** the verbal, written, and graphical communication of a complex project to technical and non-technical audiences
8	**Engineering impact**	**determine** the global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution	**develop** a complex engineering solution that appropriately accounts for the global, economic, environmental, and societal impacts of that solution
9	**Life-long learning**	**demonstrate** the ability to learn on their own, without the aid of formal instruction	**develop** a plan to acquire the expertise necessary to solve a complex problem
10	**Contemporary issues**	**incorporate** specific contemporary issues into the identification, formulation, and solution of a specific engineering problem	**synthesize** the influences of all relevant contemporary issues into the identification, formulation, and solution of an engineering problem
11	**Engineering tools**	**apply** relevant techniques, skills, and modern engineering tools to solve a simple problem	**select** and **organize** the relevant techniques, skills, and modern engineering tools to solve a complex problem
12	**Specialized area**	**evaluate** the design of a complex system or process, or **evaluate** the validity of newly created knowledge within a specialized area of civil engineering	**evaluate** the design of a complex system or process, or **evaluate** the validity of newly created knowledge within a specialized area of civil engineering
13	**Proj. mgmt., const., and asset mgmt.**	**explain** key concepts and problem-solving processes used in management	**develop** management plans for a complex real-world engineering project
14	**Business and public admin.**	**explain** key concepts and problem-solving processes used in business, public policy, and public administration	**analyze** complex real-world problems involving business, public policy, and public administration
15	**Leadership**	**explain** the role of the leader, leadership principles, and attitudes conducive to effective professional practice of civil engineering	**apply** leadership principles to direct the efforts of a small, homogenous group to accomplish a simple task; and **demonstrate** attitudes conducive to effective professional practice of civil engineering

USING THE RUBRIC WITH A DESIGN CLASS: CEE 4640 – HIGHWAY ENGINEERING

CEE 4640 – Highway Engineering is a senior-level elective at Tennessee Tech University in the Transportation Concentration. Its primary focus is the design of highways, using *A Policy on Geometric Design of Highways and Streets* as the course text. Similar to most engineering design processes, the highway design process combines the use of theoretically based values which can be calculated for prevailing conditions; empirically based values which require approximation and/or lookup; and values which are frequently left to the preference of the designer or design authority.

The first step in developing computer based homework for any class actually begins with the course syllabus. The course needs to be defined in terms of which Outcomes it will address. As noted above, the primary focus of CEE 4640 is the design of highways, and so the primary Outcome this course addresses is 3 – Design. Because the design process includes problem-solving, a secondary Outcome addressed is 5 – Engineering Problems, and because students are expected to use both industry-standard software packages and references during the course, another secondary outcome addressed is 11 – Engineering Tools. Due to the instructor's preferences, 7 – Communication is also listed as a secondary outcome for this course.

Having determined the outcomes that will be addressed by the course, the next step is to identify the Levels of Achievement that students should reach for each of the included Outcomes. Consider Exhibit 6, which shows the full text of the Rubric for the three outcomes noted above. The cells shaded in blue (and with a "B" at the bottom) are those which the Subcommittee expects to be provided during the bachelor's degree process. This does not prevent the inclusion of more advanced sections in undergraduate courses, nor does it require every class to address all Levels of Achievement for any of its associated Outcomes.

Consider Outcome 7 – Communications as an example. CEE 4640 does not attempt to asses student skills at the Knowledge or Comprehension levels, as students have taken composition classes specifically aimed at allowing students to acquire these abilities. The course does, however, does require students to perform Application and Analysis levels through evaluation of group reports and presentations. Even then, within the Application level, evaluations focus on determining if students can "… apply appropriate graphical standards in preparing engineering drawings" and only rarely considers if students can "…apply the rules of grammar…" [2]

Exhibit 5 shows the typical Levels of Achievement addressed for each Outcome associated with CEE 4640.

Exhibit 5. Outcome Levels of Achievement Addressed in CEE 4640

Outcome	Knowledge	Comprehension	Application	Analysis
3 – Design	X	X	X	X
5 – Engineering Problems	X	X	X	
7 – Communications			X	X
11 – Engineering Tools			X	

Like most senior electives at Tennessee Tech University, CEE 4640 is co-taught with CEE 5640, an introductory level graduate course. The graduate level students are expected to have additional responsibilities beyond those of the undergraduates, so additional Outcomes and Levels of achievement can be defined to help distinguish between the graduate and undergraduate course requirements. In this particular case, CEE 5640 includes the following in addition to the CEE 4640 requirements:

- Outcome 7 – Communication at the Synthesis level
- Outcome 9 – Life-long Learning at the Application level, and
- Outcome 12 – Specialized Area at the Knowledge, Comprehension, Application, and Analysis levels.

Having now clearly defined the content of the course, what remains is to determine how to match available computer based homework question types to evaluate student performance at the included Levels of Achievement.

Exhibit 6. Partial Body of Knowledge Rubric Associated with CEE 4640, from [2]

	OUTCOME	Level 1: KNOWLEDGE	Level 2: COMPREHENSION	Level 3: APPLICATION	Level 4: ANALYSIS	Level 5: SYNTHESIS	Level 6: EVALUATION
3	**Design**	Graduates can **define** engineering design; **list** the major steps in the engineering design process; and **list** constraints that affect the process and products of engineering design. B	Graduates can **describe** the engineering design process; **explain** how real-world constraints affect the process and products of engineering design. B	Graduates can **design** a simple component (e.g., a structural member) to meet a well-defined set of requirements and constraints. B	Graduates can **design** a system or process (e.g., a truss or water treatment process) to meet a well-defined set of requirements and constraints. B	Graduates can **design** a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. B	Graduates can **evaluate** the design of a complex system, component, or process to ensure that it meets a client's needs and accounts for all relevant constraints.
5	**Engineering problems**	Graduates can **list** key factual information related to four technical areas of civil engineering. B	Graduates can **explain** key concepts and problem-solving processes in four technical areas appropriate to civil engineering.	Graduates can **solve** well-defined engineering problems in four technical areas appropriate to civil engineering.	Graduates can **identify**, **formulate**, and **solve** an ill-defined engineering problem in any of four technical areas appropriate to civil engineering.	Graduates can **identify**, **formulate**, and **solve** an ill-defined engineering problem involving integration of several different technical areas appropriate to civil engineering.	Graduates can **identify**, **formulate**, and **solve** an engineering problem involving integration of several different technical areas appropriate to civil engineering; and **evaluate** the effectiveness of the solution.
7	**Communication**	Graduates can **list** the characteristics of effective verbal, written, and graphical communications. B	Graduates can **describe** the characteristics of effective verbal, written, and graphical communications. B	Graduates can correctly **apply** the rules of grammar and composition in verbal and written communications; and **apply** appropriate graphical standards in preparing engineering drawings. B	Graduates can **organize** and **deliver** effective verbal, written, and graphical communications. B	Graduates can **plan, compose,** and **integrate** the verbal, written, and graphical communication of a complex project to technical and non-technical audiences. E	Graduates can **evaluate** the effectiveness of the integrated verbal, written, and graphical communication of a complex project to technical and non-technical audiences.
11	**Engineering tools**	Graduates can **identify** the techniques, skills, and modern engineering tools that are necessary for engineering practice. B	Graduates can **explain** how these techniques, skills, and modern engineering tools are used in engineering practice. B	Graduates can **apply** relevant techniques, skills, and modern engineering tools to solve a simple problem. B	Graduates can **select** and **organize** the relevant techniques, skills, and modern engineering tools to solve a complex problem. E	Graduates can **create** new techniques and tools to solve a complex problem.	Graduates can **evaluate** the effectiveness of techniques and tools that have been developed to solve a complex problem.

Blue Cells = Expected During Bachelor's Degree (B)
Pink Cells = Expected During Pre-Licensure Experience (E)
Grey Cells = Expected During Post-Licensure Experience

MATCHING AVAILABLE QUESTION TYPES WITH LEVEL OF ACHIEVEMENT EVALUATION

Most computer based homework applications provide essentially the same question types, including True-False, Multiple Choice, Multiple Answer, Matching, Short Answer, Paragraph, and Calculated. While many of the question types are readily understood, a brief description of each type, the associated computer grading methods, and an extremely basic example are given below. Though the comparison, evaluation, or selection of a particular application is beyond the scope of this paper, Tennessee Tech University provides RESPONDUS as an application software and WebCT as a delivery medium.

In CEE 4640, student progress in both the Design and the Engineering Problem Outcomes are evaluated using computer based homework. The following sections discuss the relative applicability of different question types to these Outcomes, and provide sample problems which could be used during the class, related to the design of horizontal and vertical curves.

Exhibit 7. Common Question Types with Definitions and Simple Examples

- True-False. The instructor provides a comment. Students are asked to select if the comment is true or false. Credit is given if the student chooses correctly.
  - It is raining. True False
- Multiple Choice. The instructor provides a question and several possible answers. Students are asked to select the one appropriate answer. Credit is given if the student chooses correctly.
  - It is… A)Raining B)Snowing C)Sunny
- Multiple Response. The instructor provides a question and several possible answers. Students are asked to select as many answers as are appropriate. Credit can be given proportionally or absolutely.
  - It is… A)Cool B)Hot C)Windy D)Calm E)Raining F)Sunny
- Matching. The instructor provides two lists. Students are asked to match items from one list to the related item in the other list. Credit can be given proportionally or absolutely
  - Match Conditions with Likely Weather: 1)Cloudy 2)Clear A)Sunny B)Raining
- Short Answer. The instructor provides a question. Students are asked to provide an answer, typically a few words or a number. Credit can be given for an exact match with a pre-determined answer or by searching for key words or phrases in the student answer.
  - (phrase or keywords) What is the forecast for today?
  - (number) What is the % chance of rain today?
- Paragraph. The instructor provides a question. Students are able to provide a free form answer, often called an essay, though the answer is not limited to text only. Unlike the other question types, the Paragraph is not typically computer-graded. Rather, the computer simply collects the student answers and provides them to the instructor for grading. For this reason, many avoid this question type.
  - How has the weather changed over the past 100 years?
- Calculated. The instructor provides a question which includes at least one numeric variable. Students are asked to calculate an answer. Credit is given if the student's answer matches the result calculated by the computer using a formula provided by the instructor.
  - If it rains at a rate of {X} inches per hour for {Y} hours, what will be the total rainfall?

Level 1 – Knowledge Questions

The Knowledge Level of Achievement is most frequently defined with the action verbs "define," "list," and "identify." That is, students need only repeat information that has previously been provided to them. For this level, True-False, Multiple Choice, Multiple Answer, Matching, and Short Answer questions are most frequently used. Paragraph questions can also be used, but provide little more than additional work during grading. Calculated questions by their nature imply Application, so are generally not suited for knowledge questions, although there are always special cases. Examples of applicable questions are nonetheless provided in Exhibit 8.

Exhibit 8. Examples of Knowledge Questions

- True-False.
  - When designing Sag Vertical Curves, headlight sight distance must be considered when determining the minimum curve length.
- Multiple Choice / Multiple Response.
  - When designing Sag Vertical Curves, which of the following criteria must be considered when determining minimum curve length? A) Headlight sight distance B) Limits of driver vision C) Presence or absence of roadside lighting D) Local visual "clutter"
- Matching.
  - Identify which condition is most closely associated with each vertical curve calculation:
1) Minimum Crest Curve Length 2) Minimum Sag Curve Length 3) Required Sight Distance
A) Driver Eye Height B) Headlight Sight Distance C) Available Sight Distance
- Short Answer.
  - List the four criteria that together determine the minimum length of a Sag Vertical Curve.
- Paragraph
  - List the steps involved in determining the minimum length of a Sag Vertical Curve.

Level 2 – Comprehension Questions

Unlike Knowledge Questions, Comprehension questions require student to do more the just repeat information they have been given, and are most often defined by the action verbs “describe” and “explain.” As such, there is an (incorrect) instinct to eliminate most of the question types as inappropriate for evaluating Comprehension. The applicability of Paragraph questions is readily accepted, but since these questions require instructor review instead of having automated grading, there seems little advantage to using computer based homework instead of traditional assignments (except perhaps for the elimination of issues related to poor handwriting).

However, evaluation of Comprehension is nothing more than determining if students can express or identify concept meanings without simply repeating rote phrases. While the elimination of these phrases does essentially eliminate Short Answer questions, the remaining question types can still be used provided that the instructor develops new alternate wording to use only in the homework – not as classroom examples, as mentioning these alternates in class would effectively convert these questions back to Knowledge questions. Also, Comprehension can be evaluated using comparative examples; that is, a question can ask if the subject concept is similar to or different from another concept. This requires students to both “Know” a standard definition of the concept and to “Comprehend” it well enough to evaluate the comparison.

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So, despite the fact that Knowledge questions are extremely straightforward, Comprehension questions can use most of the same question types, given a little more creativity on the part of the instructor. Applicable sample questions are given in Exhibit 9.

Exhibit 9. Examples of Comprehension Questions

- True-False.
  - (new phrases) An alternate explanation for the sliding phenomenon that can result as a vehicle traverses a sharp curve is “Cars always wants to go straight, so if the tires do not stick to the road when you turn sharply, the car will slide into the ditch”
  - (analogy) The tipping phenomenon that can result as a vehicle traverses an excessively sharp curve is analogous to leaning back too far and falling out of a chair.
- Multiple Choice / Multiple Response.
  - (new phrases) An alternate explanation for the tipping phenomenon that can result as a vehicle traverses a sharp curve is… A) Cars always wants to go straight, so if the tires do not stick to the road when you turn sharply, the car will slide into the ditch B) …
  - (analogy) The tipping phenomenon that can result as a vehicle traverses and excessively sharp curve is analogous to… A) children being thrown from a playground merry-go-round as it spins B) leaning too far back and falling out of a chair C) a stone being thrown from a sling
- Matching.
  - Match the following horizontal curve related terms with a reasonable alternate definition and / analogous example: 1) tipping phenomenon 2) sliding phenomenon
    A) leaning too far back and falling out of a chair B) Cars always wants to go straight, so if the tires do not stick to the road when you turn sharply, the car will slide into the ditch
- Paragraph.
  - Using your own words, rather than the textbook definition, describe the sliding and tipping phenomena that can result as a vehicle traverses an excessively sharp horizontal curve and/or provide a common example of a different event caused by similar forces (an analogy).

Level 3 – Application Questions

When engineering faculty think about homework assignments, they are most likely thinking of Application questions, which are typically defined with action verbs “apply,” “solve,” and “design.” Traditional homework assignments provide students with problems to solve, a process that, in advanced classes, can often take an hour or more for each question. While such problems can certainly be delivered directly as computer based homework using Calculated questions, automated grading can create difficulties. The automated grading process eliminates the possibility of partial credit, and formulas for multi-step problems are difficult if not impossible to enter. The use of the Paragraph question would allow students to enter results from a multi-step process, but as noted above, this eliminates the automated grading capabilities. In addition, the frequent use of advanced mathematical formulas during problem solving may be difficult to represent using a text-editor.

There are at least two simple methods for overcoming these difficulties. The first method is question segmenting. Essentially, multi-step problems are broken down into their component parts, so that a student is required to complete each individual step in a problem, and can thus receive partial credit for each step completed successfully. Different question types could be used for each step in the process, though Calculated questions are most likely to apply to computational steps. This method is frequently recommended for use on exams, to help prevent an initial error from resulting in an unsolvable problem.

The second method is to provide one or more answers, and require students to determine if each is acceptable. This method allows more frequent use of True-False, Multiple Choice, and Multiple Answer questions for traditionally computational problems, but without necessarily having to given a strict numeric answer to the student. The two methods can also be combined, that is the question can be segmented and then a series of non-Calculated questions given to evaluate student ability. Applicable sample questions from both methods are provided in Exhibit 10.

Exhibit 10. Examples of Application Questions

- True-False.
  - (full question) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. A 500’ length is enough to satisfy all design minimums.
  - (segmented) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. A 500’ length is enough to provide for driver comfort.
- Multiple Choice / Multiple Response.
  - (full question) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. What length is enough to satisfy all design minimums?
    A) 200’ B) 500’ C) 750’ D) 900’
  - (segmented) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. What length is enough to provide headlight sight distance?
    A) 200’ B) 500’ C) 750’ D) 900’
- Matching.
  - A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. Match the curve length that will most closely meet each minimum design criteria.
    1) Headlight Sight Distance 2) Driver Comfort 3) General Appearance
    A) 350’ B) 500’ C) 700’
- Short Answer.
  - (segmented or full question) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. Determine the minimum lengths required for headlight sight distance, driver comfort, and general appearance. List your answers specifically in that order.
- Calculated.
  - (full question) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. Determine the minimum length of curve based on all applicable criteria.
  - (segmented) A sag vertical curve has been designed to connect a –2% to +4% change in grade on a 35-mph facility. Determine the minimum lengths of curve for headlight sight distance.

Levels 4, 5, and 6 – Analysis, Synthesis, and Evaluation Questions

To this point, neither Synthesis nor Evaluation level work has been introduced in either CEE 4640. The curriculum at Tennessee Tech University includes a multi-disciplinary Senior Design course intended meet the expectations of Synthesis level Design work. As most students take both courses simultaneously, it is unlikely that Synthesis level work be added without significant program restructuring. Evaluation level Design work is identified as not being expected until post-licensure activities, and is unlikely to be found in an undergraduate design course.

While Analysis level work is present in the course, group project work has been and continues to be the method of choice for evaluating student achievement. Analysis level work is typically defined with the action verbs like "formulate," "organize," "select," and "design." As before, Paragraph questions could be used to deliver questions and to collect student responses, without the benefits of automated grading. Given the complex nature of these problems, computer based homework appears less suited than other tools for evaluating student achievement.

CONCLUSIONS

Evaluation of students in engineering design courses remains a key challenge to educators. While the evaluation techniques presented by computer based homework may not seem applicable to design courses, a basic understanding of the ASCE Body of Knowledge, Bloom's Taxonomy, and the draft Body of Knowledge outcome Rubric allows for the development of meaningful assignments. Along with a brief introduction to these topics, this paper discussed the relative applicability of different question types typically available for computer based homework, along with example questions from a highway design course. Though not all levels of achievement can be reasonably evaluated, computer based homework, when properly applied, can serve as a useful tool for helping to evaluate student achievement in engineering design courses.

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