Using E-Homework to Provide Disaggregate Problem Solving Assessment in a Senior-Level Traffic Engineering Course

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Abstract – As with most senior level engineering courses, traditional homework problems in traffic engineering are multi-step problems which require lengthy solution times, leading to difficulty in both in the development homework assignments which balance time required with breadth of coverage and in the assessment of student work, especially when mistakes occur early in the solution process. As with exams, disaggregate assessment (or stepwise assessment) helps to minimize issues which arise from early errors in assessment. This paper first presents basic motivations for using and the process of developing disaggregate e-homework in a senior level transportation class. The paper begins with the motivations for use, continues with an example of breaking a problem down into disaggregate parts, demonstrates the process of coding these parts into e-homework questions, and then concludes with a discussion of the relative costs and benefits of using disaggregate e-homework assignments.

Keywords: homework, online, assessment, disaggregate, traffic engineering.

INTRODUCTION

One of the most basic challenges associated with any engineering course is the determination of a reasonable means of student assessment during the course. By far, the two most common assessment tools are exams and homework. However, as students progress through an engineering program, the problems they are presented continually increase in both complexity and solution time. Once students have reached senior level courses, most problems presented to them involve a multi-step solution process, and working a single problem often takes more than an hour.

With these increases in complexity and solution time come additional challenges in assessment. No longer can an in-class exam, even a two- or three-hour final exam, provide students with sufficient time to demonstrate their understanding of all the methods and topics covered during the course. Take-home exams provide additional time for students to work lengthy problems, but provide the potential for students to work together in groups, reducing its effectiveness as an assessment tool.

The increased time and complexity also affect the use of homework assignments as an assessment tool. Assigning sufficient homework problems to allow students to explore all aspects and nuances of a solution method, especially with repetition of key concepts, can result in an unmanageable assignment, both for student and faculty.

While no longer a "new" tool, the potential for e-homework to provide student assessment in senior-level engineering courses is still largely untapped, especially in multi-step problems. The purpose of this paper is to review the motivations for, the use of, and the benefits and costs of using e-homework in a senior-level transportation engineering class, CEE 4630 – Traffic Engineering at Tennessee Tech University.
This paper first presents basic motivations for using and the process of developing disaggregate e-homework in a senior level transportation class. The paper begins with the motivations for use, continues with an example of

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breaking a problem down into disaggregate parts, demonstrates the process of coding these parts into e-homework questions, and then concludes with a discussion of the relative costs and benefits of using disaggregate e-homework assignments.

MOTIVATIONS

Consider first the motivations for disaggregate assignments in general. My first exposure to this concept came at a short course by Porter & Felder [1]. They presented a comparison between a traditional exam question and a disaggregate exam question for an introductory engineering course. The two are presented in Exhibit 1.

Note that both exam questions cover the same material, but the disaggregate question provides new starting points for students who are unsure of their work.

Next, consider my personal motivations for both disaggregate and e-homework. The first time I taught CEE 4630 Traffic Engineering, I began the semester with a traditional homework assignment. The course had 10 students, and the homework included 4 questions. While developing the assignment and initial grading key was reasonably simple (I used problems from the course text and had a copy of the solution manual), it still took over seven hours to grade. Invariably, students made errors early in the solution process, leaving two basic options: simply count the rest of the problem wrong and base a student's assessment on how many steps they could complete before their first mistake, or re-work later steps of the problem using incorrect early answers from each student's paper to base assessment on how many steps a student could complete correctly. In the end, reduced grading time became a motivation for both disaggregate homework and e-homework.

Later into that first semester, I found that the problems available in the text did not cover all the concepts which were taught in class, so it was necessary to develop additional problems for students. At this point, I was still using aggregate homework with full problems, so the development of new problems which targeted specific concepts and combinations of concepts was a time consuming, iterative process. So, reducing the time needed to develop homework assignments was also a motivation for disaggregate homework.

In addition to demands on faculty time, there is also a consideration of student time. As most students take more than one class in any given semester, there is an understood expectation that while each class will have its own share of work each week, faculty will not overload student to the point that one class overwhelms a student and prevents them from being able to meet expectations in other courses. As problem complexity grows, presenting students with comprehensive homework assignments with reasonable solution times becomes a challenge. Disaggregate homework techniques, with the partial problem approach, allow for a more robust homework assignment with reduced solution times by focusing

Exhibit 1. Sample Aggregate and Disaggregate Exam Questions (from [1])

Aggregate:

CHE 203 Spring 1987

EXAM #1. 50 minutes—closed book.

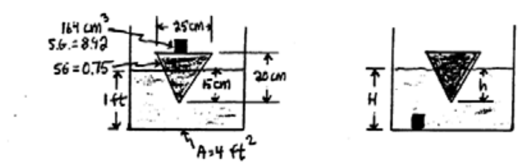
A solid inverted cone floating in an 8 ft^3 cubical tank filled to a depth of 1 ft with a height of 20 cm and a diameter of 25 cm has a 10 in^3 copper block on it. The cone is 15 cm deep. At a certain time the block which has a specific gravity of 8.92 is carefully removed and dropped in the tank. What does the cone, which has a specific gravity of 0.75, do? Note that 1 in. = 2.54 cm.

Disaggregate:

CHE 203 Spring 1987

EXAM #1. 50 minutes—open book.

A solid cone of base diameter 25 cm, height 20 cm, and specific gravity 0.75, floats point downward in a liquid. A copper block with a volume of 164 cm^3 and a specific gravity of 8.92 rests on the base of the cone. The cone is immersed to a depth of 15 cm. The tank is a cube 2 ft on each side. The liquid level is half the height of the tank. At a certain time the copper block is removed and dropped in the tank.



(a) (20) Calculate the masses of the cone and of the copper block. Recall that $V_{cone} = \pi r^2 h/3$, where r and h are the base radius and height, respectively.

(b) (30) Use Archimedes' Principle to determine the density of the liquid (g/cm^3). (Hint: Similar triangles may play a useful role in this calculation.)

(c) (30) Calculate the vertical distance (cm) from the liquid surface to the base of the cone after the block is removed. *Note:* If you could not do Part (b), assume a liquid specific gravity of 2.9.

(d) (20) Calculate the vertical distance (cm) from the bottom of the tank to the base of the cone after the block is removed, assuming that you have solved Part (c). *Note:* If you could not do Part (c), assume a solution to that part . 7 cm. If you have no time to work out numbers, outline a solution procedure.

student attention on the portion of the problem where different methods are required. Thus, consideration of student time demands is also a motivation for disaggregate homework.

While disaggregate homework could certainly be presented as traditional homework, its application as e-homework provides additional benefits. As noted above, time required for grading is a motivation for both disaggregate and e-homework. Personally, my primary motivation (after grading time) for moving to e-homework as the delivery method was the ability to serve each student with the same problem type, but different numerical inputs. This allows students to work together on problems, but reduces the likelihood that one student will simply copy the answer from another student – if each student has slightly different inputs, they need to make their own calculations.

The next section presents an example breakdown from full problem to problem parts.

AN EXAMPLE FROM CEE 4630 – TRAFFIC ENGINEERING

CEE 4630 – Traffic Engineering is a course ideally suited to disaggregate e-homework. The course focuses on analysis of current and expected operational conditions of highway facilities, with the *Highway Capacity Manual 2000* [2] (HCM) as the course text. The procedures outlined in the HCM are based on empirical models developed from field investigation of conditions at facilities across the US. Like other disciplines, software has been developed which can perform the calculations, but the course requires students to perform manual solutions, putting into practice the theoretical concepts presented and discussed in class. These manual solutions are developed using worksheets which have been presented in the manual, to provide consistency in both methodological approach and in presentation of results.

The example which follows in this section was **not** chosen for its complexity, but rather as a simple, conceptual example that can be followed by those without a transportation background. As such, there are no advanced theoretical concepts included in this example, and the solution can easily be determined with paper and pencil – no calculator required. What is important about the example is not its technical challenge (or lack thereof), but the process of disaggregating the problem and later presenting it as a series of e-homework questions.

The selected example is a small part of a traffic signal operational analysis, namely the determination of a lane group saturation flow rate. The complete manual solution to a traffic signal analysis problem includes 10 worksheets, some of which are used with every problem, and some of which apply only in certain conditions. The determination of saturation flow rate is required for all problems, and documentation of its calculations consumes about half of one worksheet. A copy of this portion of the worksheet is shown in Exhibit 2.

Exhibit 2. Saturation Flow Rate Worksheet (from [2])

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)						
Base saturation flow, s_0 (pc/h/ln)						
Number of lanes, N						
Lane width adjustment factor, f_w						
Heavy-vehicle adjustment factor, f_{HV}						
Grade adjustment factor, f_g						
Parking adjustment factor, f_p						
Bus blockage adjustment factor, f_{bb}						
Area type adjustment factor, f_a						
Lane utilization adjustment factor, f_{LU}						
Left-turn adjustment factor, f_{LT}						
Right-turn adjustment factor, f_{RT}						
Left-turn ped/bike adjustment factor, f_{Lpb}						
Right-turn ped/bike adjustment factor, f_{Rpb}						
Adjusted saturation flow, s (veh/h) $s = s_0\, N\, f_w\, f_{HV}\, f_g\, f_p\, f_{bb}\, f_a\, f_{LU}\, f_{LT}\, f_{RT}\, f_{Lpb}\, f_{Rpb}$						

The determination of lane group saturation flow rate depends on a base value, which depends on the type of area the signal is located in, the number of lanes in the group, and on 11 different adjustment factors, each dependent on different conditions at the intersection.

In a traditional (aggregate) homework assignment, the lane group saturation flow rate would be calculated about midway through a simple problem, or early in a more complex problem. The result of this calculation is a fundamental part of most of the remaining calculations, so errors in this step will affect virtually every other answer in the process.

In a disaggregate assignment, it is likely that this portion of the problem would be given to students as a whole. That is, students would be given a problem which asks them to determine the saturation flow rate of one or two lane groups, with the inputs to the adjustment factors specifically selected to cover different conditions. An example of a single disaggregate problem for determining lane group saturation flow rate is given in Exhibit 3.

Exhibit 3. Sample Single Lane Group Saturation Flow Rate Problem

Determine the saturation flow rate for a lane group consisting of a through-left lane and a through-right lane at a traffic signal located in the CBD, given:

Lane Width = 11 ft
Heavy Vehicles = 12%
Grade = +3%
Parking Maneuvers = 20 per hour
Busses Stopping = 4 per hour
Volumes: Left-Through-Right = 75-350-120
No pedestrian or bicycle blockage

However, this basic, disaggregate problem still contains multiple steps in which a student can err, still resulting in the need to assess their performance in each of the individual steps. This is where e-homework delivery can provide significant advantages over traditional delivery, even with disaggregate problems.

Consider Exhibit 4, which provides a sample set of equations for determining the saturation flow rate adjustment factors. Each of these factors is determined using its own equation, so the problem can be broken down even further into disaggregate parts. Each individual adjustment factor can be served to students as an individual e-homework question.

Exhibit 4. Sample Equations for Determining Saturation Flow Rate Adjustment Factors (from B)

Factor	Formula	Definition of Variables
Lane width	$f_w = 1 + \frac{(W-12)}{30}$	W = lane width (ft)
Heavy vehicles	$f_{HV} = \frac{100}{100 + \%HV(E_T - 1)}$	% HV = % heavy vehicles for lane group volume
Grade	$f_g = 1 - \frac{\%G}{200}$	% G = % grade on a lane group approach
Parking	$f_p = \frac{N - 0.1 - \frac{18N_m}{3600}}{N}$	N = number of lanes in lane group N_m = number of parking maneuvers/h
Bus blockage	$f_{bb} = \frac{N - \frac{14.4N_B}{3600}}{N}$	N = number of lanes in lane group N_B = number of buses stopping/h

The key, then, is to break down the problem into component parts: large enough to be meaningful, but small enough to eliminate the cascading of errors to later parts of the problem.

The next section will present an introduction to the development of e-homework questions.

DEVELOPMENT OF E-HOMEWORK QUESTIONS

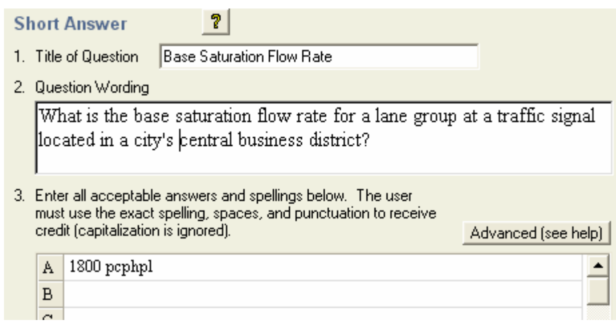
Once a problem has been disaggregated to the desired level, the next step is to code e-homework questions. Here, the capabilities of different course management systems can result in different forms for a problem, though most have similar functions and can be used to serve the same purposes. This paper covers coding of questions in Respondus [3], a test and quiz management software package which can export directly to many course management systems. My original experience used Respondus to export e-homework to the WebCT [4] course management system. Tennessee Tech University now uses Desire2Learn [5] as its course management system. For simplicity, this paper will present development using Respondus.

While more comprehensive descriptions exist, a brief introduction to the typical types of e-homework questions which are available is given in Exhibit 5, from Click [6].

Exhibit 5. Common E-Homework Question Types with Definitions and Simple Examples (from Click [6])

- **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 in 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?

Exhibit 6. Sample Short Answer Question (snapshot from [3])



For most engineering courses, especially upper division courses, the Calculated question is by far the most frequently used. However, this is not the only question which can be used with disaggregate homework. Other question types can serve to assess student understanding, especially to determine if students know what formula, process, or constant is needed next. For example, the first line of the Saturation Flow Worksheet asks for the base saturation flow rate, which is based on what type of area the traffic signal is located in. A sample Short Answer question for this entry is given in Exhibit 6.

Coding of Calculated questions is still fairly basic, and highly dependent on the functions which are available in the course management system. All systems have basic mathematical operations (+, -, *, /, ^) and basic trigonometry functions (sin, cos, tan). Most have some of the more advanced functions (log, ln, exp, abs, factorial) along with support for some important constants (pi, e), but rarely does any system have absolutely everything. All the systems I have encountered use a basic ascii text method for formula entry, which can be challenging to code correctly.

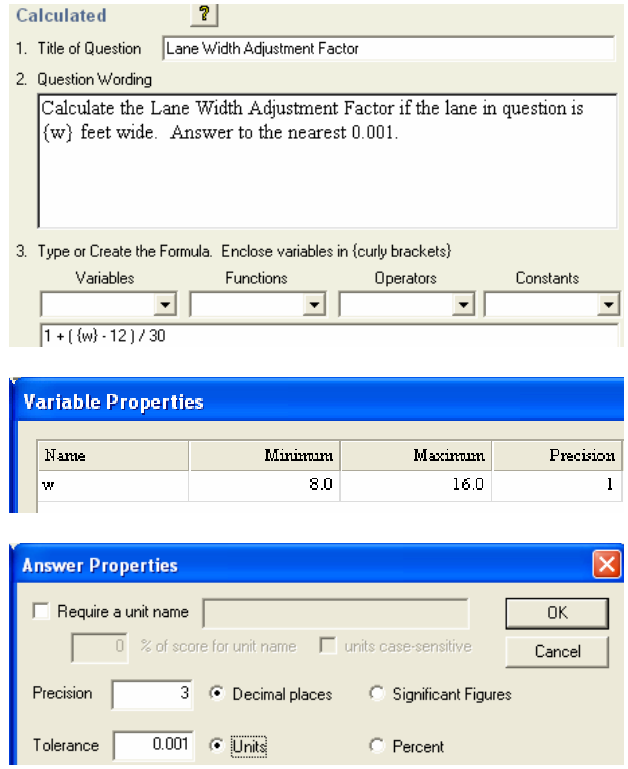
Exhibit 7 shows an example of coding a calculated question using the formula for Lane Width Adjustment Factor, including the question text, the formula, and both variable and answer properties.

Note that in addition to coding the question text, this example includes the use of a variable for lane width, {w}. This helps to highlight some of the benefits of using e-homework over traditional disaggregated assignments.

- Each student will receive different numerical inputs to the same problem type. In this question, a value for lane width between 8.0 and 16.0 will be selected for each student.
- The correct answer will be calculated to the nearest 0.001 for each student based on their individual value for lane width.
- Answers within +/- 0.001 of the computer-calculated correct answers will be accepted for full credit.
- In addition, units could be required (this particular example is unitless) and can count for some portion of the problem's points.

In addition, if emphasis on particular aspects of the problem is desired, more questions can be entered. For example, emphasis on the difference between lanes narrower than ideal and lanes wider than ideal can be given by creating a second identical question, then changing the variable properties in each question – one allows values from 8.0 to 11.0 feet, and the other allows values from 13.0 to 16.0 feet. Then each student could receive a question from each condition to help provide the desired emphasis.

Exhibit 7. Sample Calculated Question (snapshots from [3])



To complete the process of determining each adjustment factor, ten additional questions would provide full coverage of each, with additional questions for optional emphasis. In addition, a culmination question can be added to help tie up the separate parts. This will be discussed in more detail in the next section, which discusses the relative costs and benefits of using disaggregate e-homework.

Costs and Benefits of Disaggregate E-Homework Assignments

Based on the motivations listed above, one of the key elements in determining the success of disaggregate e-homework is the amount of time required of both faculty and students. In terms of creating assignments, more time is required to develop a disaggregate homework than a traditional homework, but this time is offset by the reduced grading time for disaggregate homework. The creation time is further increased for developing e-homework, but again is offset by reduced grading time. Based only on personal experience, I would estimate that creating (and later editing) a high quality disaggregate e-homework takes less time than creating and twice grading a traditional homework assignment. Thus, if the e-homework can be re-used over several semesters, then the time involved becomes a benefit.

Regarding time spent on assignments by students, my intent was to create disaggregate e-homework which required about the same amount of time as a traditional assignment, but which was able to cover more material with less needless repetition. The result is an assignment with more questions, with each question taking less time.

However, time alone is not the determining factor. More important by far is student learning. As the course in question has a relatively low enrollment (10-12 is typical), and because of the sort time spans involved (once with traditional homework, twice with disaggregate e-homework) there a no reliable statistical analysis to test the relative benefits. It can be seen, however, that grade distributions over the three times the course has been taught are relatively stable, so it is unlikely that the disaggregate e-homework is causing a detriment to student learning.

The most significant concern likely to arise from disaggregate e-homework is that lack of problem solving continuity for students. That is, if students spend their time always focused on individual steps, can they lose track of how all the steps fit together into a whole problem? In CEE 4630, I use two methods to combat this particular problem.

First, each homework assignment includes culmination questions which serve to tie several individual parts back together into one step of the problem solving process. Culmination questions are not a question "type" as discussed in Exhibit 5, above; rather, "culmination" refers to the fact that a major portion of the problem (or an entire problem) has come to a conclusion.

Exhibit 8 shows the text from a culmination question for the sample problem of determining lane group saturation flow rate. Note that it provides values for each of the adjustment factors, and asks for the adjusted saturation flow rate. Just as in a traditional homework problem, students have just calculated a value for each of these adjustment factors. Unlike a traditional homework problem, when the time come to combine them to the answer which finishes this step, new values are provided to prevent earlier errors from cascading through this part of the problem.

Exhibit 8. Sample Culmination Question (snapshot from [3])

Calculate the adjusted saturation flow rate given the following:

s_o =1900
N =2
f_w =0.97
f_{HV} =0.885
f_g =0.847
f_p =0.859
f_{bb} =0.935
f_a =0.867
f_{LU} =0.911
f_{LT} =0.963
f_{RT} =0.847

Answer to the nearest vph, no units

Answer:

The second method I use to combat the issue of continuity is to include one or two full length problems as a part of each assignment. This way, students are still required to work an entire problem, in sequence, from start to finish. The fact that these questions are given in conjunction with a disaggregate e-homework eliminates the frustration of trying to cover all possible scenarios in a minimal number of questions, as all conditions of interest can be covered in the disaggregate portion of the assignment.

UNEXPECTED COSTS

A final item of interest is that of unexpected costs. While the eventual cost-benefit analysis shows (at least for me) that disaggregate e-homework has more benefits than costs, there were two unexpected costs that I feel are important to point out.

For one, when a question has an error written into it, some course management systems (WebCT) require you to open each student's individual assignment in order to adjust the grade on each assignment. Not all course management systems have this issue (Desire2Learn allows a correction to all students by question), but there is still a cost to be paid here. The first time a set of e-homework is used, there are likely to be errors (just like on any assignment), so expect to spend time throughout the semester making such corrections. It is best to go ahead and correct both the individual grades and the original question, so that the question is ready to use the next time the course is taught.

For another, changing from one course management system to another can be a very difficult experience. As noted above, Tennessee Tech University has recently changed from WebCT to Desire2Learn as the course management system, and despite assurances that information could be easily exported from one system to the other; the time requirement for this process has been much higher than expected. If you are considering adding e-homework to your courses, check to see if your campus has a change coming and weigh this in your decision-making process.

CONCLUSIONS

While no longer a "new" tool, the potential for e-homework to provide student assessment in senior-level engineering courses is still largely untapped, especially in multi-step problems. This paper presented basic motivations for using and the process of developing disaggregate e-homework in a senior level transportation class. This included motivations for use, examples of breaking a problem down into its component parts, and coding these parts as e-homework.

Some of the benefits of disaggregate homework included an overall reduction in preparation plus grading time for instructors, especially if assignments are used more than once, elimination or reduction of errors which have cascaded from an early mistake into later parts of the problem, and the ability to provide a more comprehensive homework without requiring a disproportionate amount of student time. Some of the costs of disaggregate homework included an increase in initial preparation time and the potential for students to lose track of the overall problem solving process.

While the benefits of e-homework have been detailed in other works, the two mentioned most prominently in this paper are automatic grading and the ability to serve different inputs to each student. Some of the costs include increased time to create homework assignments, difficulty in adjusting incorrect grades in some course management systems, and potential difficulties in porting assignments from one course management system to another.

Overall, disaggregate e-homework has provided significantly more benefit than its cost in CEE 4630 – Traffic Engineering, especially when paired with a reduced number of full (traditional) problems in the assignment.

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Steven received his PhD at NC State University in 2001, under the direction of Dr. Nagui Rouphail, and his dissertation title was *Stopped and Control Delay at Signalized Intersections.* He spent seven years in the public sector working for the North Carolina Department of Transportation. During this time he earned his Professional Engineering license, and he is currently licensed in both Tennessee and North Carolina. In 2006, Steven joined the faculty at Tennessee Tech University as a tenure-track Assistant Professor, his current position. He was recently awarded a Tablet PC as part of TTU's Tablet Initiative in recognition of his continuing efforts to use technology to improve his teaching.

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