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Concept Warehouse Remote: Making Student Thinking Visible

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ABSTRACT

The shift to remote teaching with the COVID-19 pandemic has made delivery of concept-based active learning more challenging, especially in large-enrollment engineering classes. I report here a modification in the Concept Warehouse to support delivery of concept questions. The new feature allows instructors to make students' reasoning visible to other students by showing selected written explanations to conceptually challenging multiple-choice questions. Data were collected for two large-enrollment engineering classes where examples are shown to illustrate how displaying written explanations can provide a resource for students to develop multi-variate reasoning skills.

Key words: Formative assessment, conceptual learning, learning technology

INTRODUCTION

Some have argued that deep conceptual understanding forms the foundation for adaptable knowledge needed in engineering practice (Streveler, 2008; Redish & Smith, 2008). C*oncept-based active learning* consists of the implementation of activity-based pedagogies that encourages students to value deep conceptual understanding rather than only factual or procedural knowledge, and then promote students' development of that understanding. We have reported previously in this journal on the Concept Warehouse, a web-based instructional tool that provides faculty a tool to enable concept-based active learning (Koretsky et al., 2014).

Using this tool, we have shown that when students provide written justifications to short multiple-choice concept questions, their thinking becomes more explicit and they are better able to participate in group discussions (Koretsky, Brooks, & Higgins, 2016; Koretsky, Brooks, White, & Bowen, 2016). Importantly, interacting with other students ideas and reasoning processes develops their own reasoning. In this context, an important role of the instructor is to curate the ideas and help students discover which ones have merit and why. Equally important, these discussions help students understand which answers are not correct by identifying and articulating faulty reasoning (Koretsky & Brooks, 2011). However, the shift to remote teaching with the COVID-19 pandemic has made this type of instruction more challenging, especially in large-enrollment classes. We report here on a modification we implemented in the Concept Warehouse to allow instructors to make students' reasoning visible to other students.

METHODS

The Concept Warehouse was used to deliver active learning in two remote classes, Process Data Analysis and Chemical Engineering Thermodynamics II, during the 2020 COVID-19 pandemic. Process Data Analysis is required for bioengineering, chemical engineering, and environmental engineering BS programs while Thermodynamics II is required for the chemical engineering program. These classes had enrollments of 208 students and 105 students, respectively.

As in a face-to-face environment, the instructor selected questions prior to class and interspersed them with synchronous lecture delivery on Zoom. Students accessed the assigned questions on their computer or mobile devices through a Concept Warehouse login. During lecture, a single multiple-choice question or a set of linked multiple-choice questions was provided to students through the Concept Warehouse. For each question, students were requested to select a multiple-choice response, provide a written explanation, and provide a confidence rating, as shown in Figure 1. The instructor viewed the written explanations as they were submitted and selected a subset of those explanations to display to the class in real-time as shown in Figure 2. Examples from each class were selected, as shown in Figure 3 and 4. The examples were among those analyzed to illustrate the ways this tool provides illustrations of student thinking to students during class and how this information can be used to unpack student reasoning processes. The examples were selected since they both address student difficulty with multivariate reasoning even though they are from courses with dissimilar content.

In order to display written explanations in the Concept Warehouse, the instructor needs to add an additional step in the mechanics of class delivery. As with any concept question, the instructor can either select from a repository of over 3,000 questions or write their own question. Once a question or set of questions is selected it is added to the "Manage Questions" tab

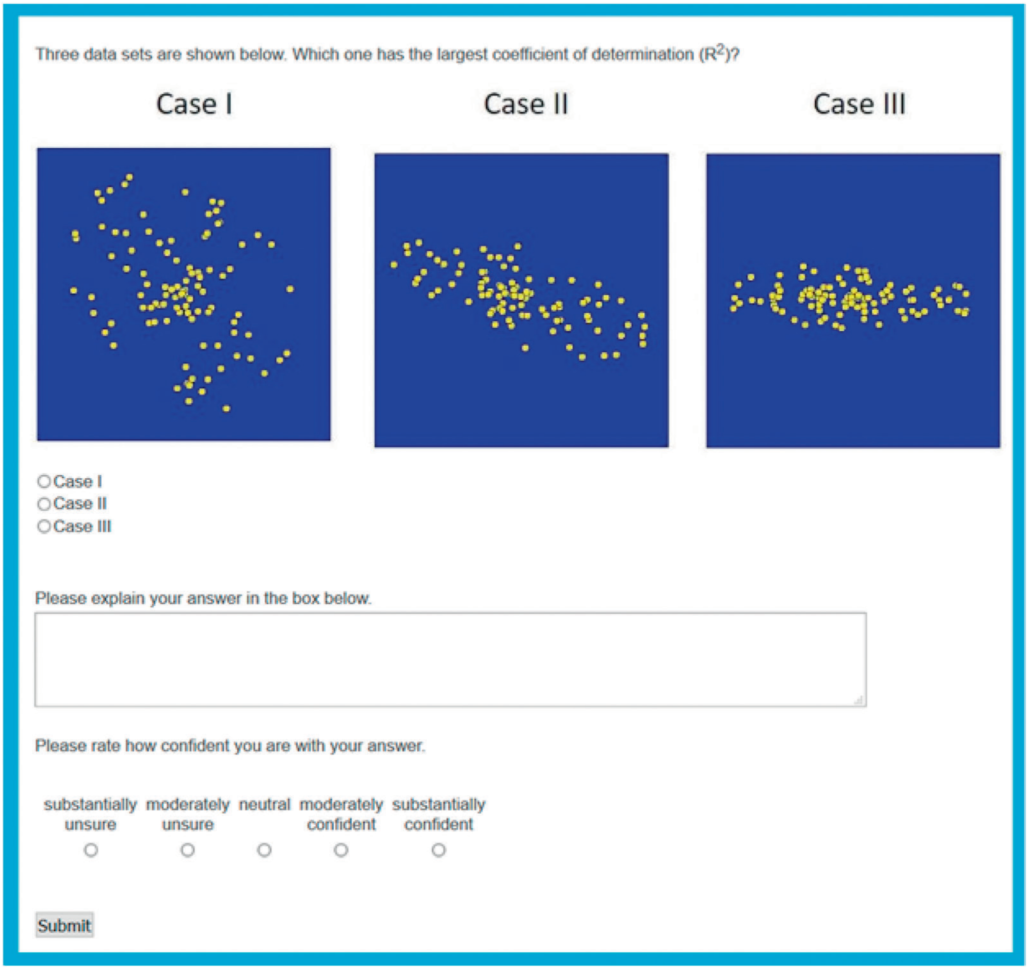


Figure 1. A screenshot of a concept question that students answered in Week 5 during a Zoom lecture in the Process Data Analysis course.

to be assigned during class. In this tab, several questions can be linked together to be answered as a set (e.g., Figure 4 shows the second question of a two question set). Selecting "add short answer follow-up" when assigning adds a box for written explanations (see Figure 1). If the instructor wants to display those explanations, they can view the student explanations as they are submitted in real time on a separate monitor (not visible to the students) and select the ones that they wish to display, as shown with the checked boxes in Figure 2. The "Open Student View" button at the top of the page will allow the instructor to see the set of explanations that they selected and add the explanations check box (see Figures 3 and 4) when the results are displayed for students.

✓	Case II	Case 1 has a really large SST and a really small SSR, so the R squared coefficient would be the smallest. Case 2's SSR to SST ratio is bigger than that of case 3, so case 2 would have the larger R squared	☑	2
✓	Case II	In case 2 we see the largest ration in the size of the green arrow to the size of the red arrow.	☐	4
x	Case III	The R^2 value will be largest for case 3 because the sum of distance from the mean is the lowest. It will have SSR and SST that are close together meaning that when you divide SSR by SST you would get a value closer to 1.	☐	4
x	Case III	case 3 has the smallest sum of square error therefore will have the largest coefficient of determination	☐	4
x	Case III	R^2 equals ssr/sst and case three has the smallest sum of squares total thus the largest r^2 value	☐	4
x	Case III	Case 3 has smallest SSt, therefore largest R^2	☐	4
x	Case III	There will be the least variation between data points and regression is how close the trend line is to the data sets. The closer the points to the line the higher the coefficient of determination.	☑	3

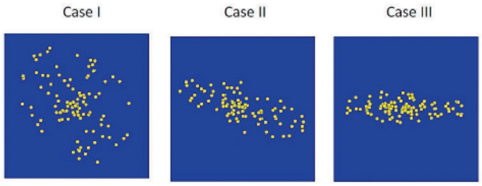
Figure 2. A partial screenshot of the instructor selecting written explanations to display of the question shown in Figure 1 by checking the corresponding boxes in the column that is second from the right. The student confidence rating (1 = substantially unsure; 5 = substantially confident) is shown in the column on the right.

PRELIMINARY RESULTS

Figure 3 presents results from students' responses to a concept question about the coefficient of determination (R^2) in Process Data Analysis. 43.1% of the class correctly chose the data set shown in Case II. This question assesses students' understanding of R^2 as the amount of the total variation that can be explained by the model. 37.6% of the students selected Case III, many thinking as in the first explanation shown that higher R^2 means simply a tighter cluster around the regression line. Case I shows the other extreme where the regression slope is greater but there is more scatter around the data. The six explanations shown enabled a discussion of how there are two competing aspects that need to be considered: how much scatter the data show about the regression line and the steepness of the line (how much of the variation the model explains). Students who only considered one of these effects selected an incorrect answer, either Case III for the former or Case I for the latter. Thus, the student explanations form the basis for considering multivariate reasoning of the magnitude of R^2.

Figure 4 presents responses to a concept question asking students to determine the change in extensive Gibbs energy for a vaporization process in Thermodynamics II. 52.5% of the class correctly chose the response that the Gibbs energy in state 2 was equal to the Gibbs energy in state 1. In the third and fifth responses shown, explanations only consider entropy while the sixth response

Three data sets are shown below. Which one has the largest coefficient of determination (R^2)?



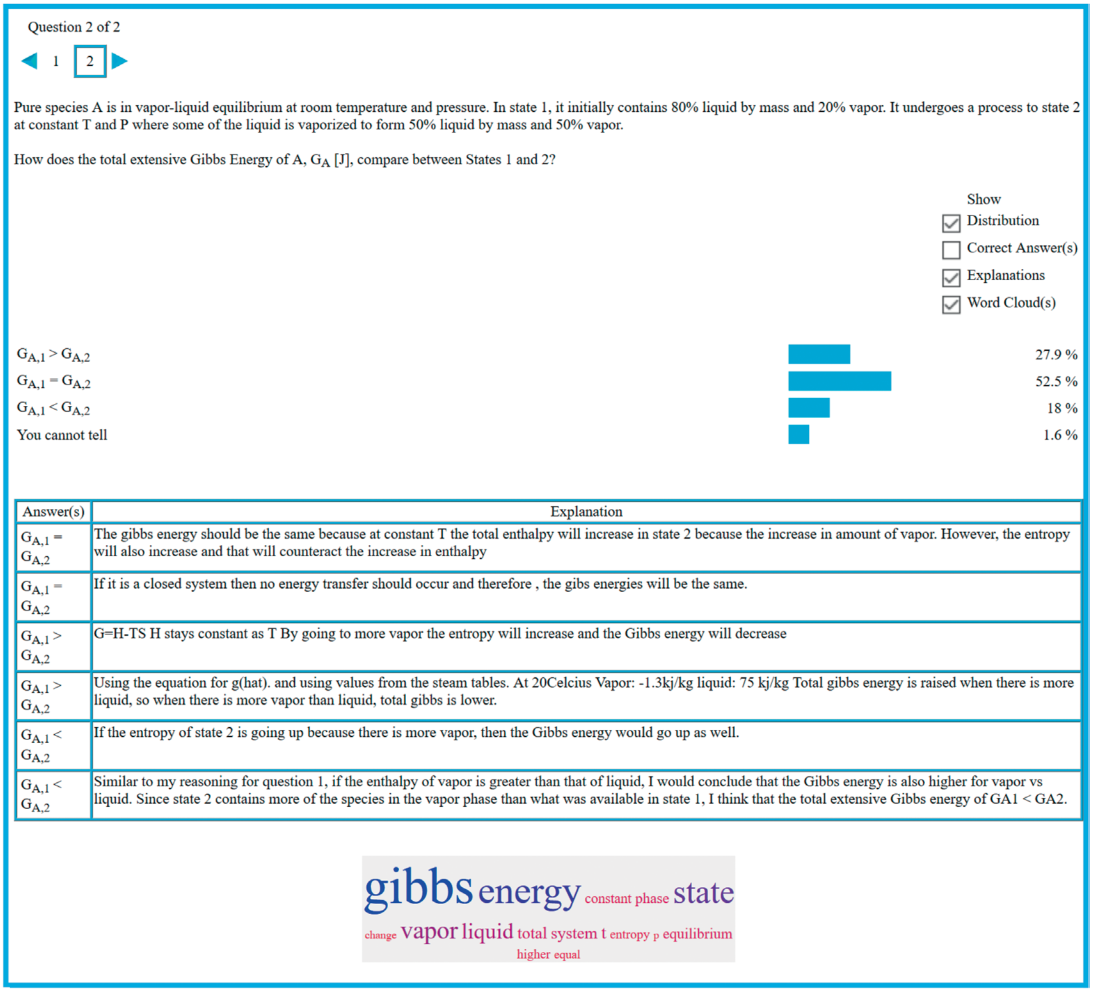
Show
- ☑ Distribution
- ☐ Correct Answer(s)
- ☑ Explanations
- ☐ Word Cloud(s)

Case I	19.3 %
Case II	43.1 %
Case III	37.6 %

Answer(s)	Explanation
Case I	Case 1 would have the largest value for SSr/SSt because of the larger slope if a best fit line were put in place.
Case I	The dots are far apart meaning the coefficient of determination is larger
Case II	Case III has the lowest total and residual variation, but the y-variable is not correlated with the x-variable. Case II has a slightly higher residual variation than Case III, but the y-variable shows a clear variation with the x-variable. Therefore, in Case II, the SST is higher but the SSR is significantly higher than in Case III, so Case II has the highest R^2.
Case II	Case 1 has a really large SST and a really small SSR, so the R squared coefficient would be the smallest. Case 2's SSR to SST ratio is bigger than that of case 3, so case 2 would have the larger R squared
Case III	There will be the least variation between data points and regression is how close the trend line is to the data sets. The closer the points to the line the higher the coefficient of determination.
Case III	The variance in case 3 is more explained by the model and therefore that explained variance over the total variance will be greater.

Figure 3. The response of students' multiple-choice responses and selected explanations for t he question shown in Figure 1 for Process Data Analysis.

only contains enthalpy. The correct response 1 considers the effect of both entropy (disorder) and enthalpy (energy) stating they will "counteract." One of the students who only considered one of these properties wrote in the Zoom chat, "Hey I need to consider both!" The second explanation



Question 2 of 2

1 2

Pure species A is in vapor-liquid equilibrium at room temperature and pressure. In state 1, it initially contains 80% liquid by mass and 20% vapor. It undergoes a process to state 2 at constant T and P where some of the liquid is vaporized to form 50% liquid by mass and 50% vapor.

How does the total extensive Gibbs Energy of A, G_A [J], compare between States 1 and 2?

Show
Distribution
Correct Answer(s)
Explanations
Word Cloud(s)

$G_{A,1} > G_{A,2}$	27.9 %
$G_{A,1} = G_{A,2}$	52.5 %
$G_{A,1} < G_{A,2}$	18 %
You cannot tell	1.6 %

Answer(s)	Explanation
$G_{A,1} = G_{A,2}$	The gibbs energy should be the same because at constant T the total enthalpy will increase in state 2 because the increase in amount of vapor. However, the entropy will also increase and that will counteract the increase in enthalpy
$G_{A,1} = G_{A,2}$	If it is a closed system then no energy transfer should occur and therefore , the gibs energies will be the same.
$G_{A,1} > G_{A,2}$	G=H-TS H stays constant as T By going to more vapor the entropy will increase and the Gibbs energy will decrease
$G_{A,1} > G_{A,2}$	Using the equation for g(hat). and using values from the steam tables. At 20Celcius Vapor: -1.3kj/kg liquid: 75 kj/kg Total gibbs energy is raised when there is more liquid, so when there is more vapor than liquid, total gibbs is lower.
$G_{A,1} < G_{A,2}$	If the entropy of state 2 is going up because there is more vapor, then the Gibbs energy would go up as well.
$G_{A,1} < G_{A,2}$	Similar to my reasoning for question 1, if the enthalpy of vapor is greater than that of liquid, I would conclude that the Gibbs energy is also higher for vapor vs liquid. Since state 2 contains more of the species in the vapor phase than what was available in state 1, I think that the total extensive Gibbs energy of GA1 < GA2.

Figure 4. A concept question and students' multiple-choice answers and selected explanations of a concept question in the Thermodynamics II course. This question is the second one in a linked set.

shows the correct multiple-choice response, but does not provide proper reasoning. In this way, the instructor can reinforce the notion that it is not just about picking the correct multiple-choice answer, but associating that answer with the correct reasons, and better yet, students need to be able to also describe the ways the other reasons are faulty. An inability to recognize multivariable relationships has been reported as a persistent source of student difficulties in thermodynamics classes (Loverude, Kautz, & Heron, 2002; Rozier & Viennot, 1991).

REFLECTIONS AND NEXT STEPS

Examples of a new feature in the Concept Warehouse, instructor-selected display of written explanations, are reported for two classes. In both cases, incorrect student choices corresponded to responses where some of the students show reasoning where students accounted for one variable but failed to consider a second important variable. Being able to see responses of classmates, including those that only considered the second variable and those who considered both, provided a resource to help students reconsider and develop their own reasoning. The feature could be directly used in face-to-face instruction. While multivariate reasoning provides a clear exemplar of this feature, it would be useful to catalog other common ways that seeing other students thinking helps develop their ideas about reasoning. In addition, this tool was used in remote teaching for the first time this spring. Building more effective instructional practices for remote instruction such as its use in Breakout Rooms (for class sizes where that feature is supported) is needed.

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Milo Koretsky is a Professor of Chemical Engineering at Oregon State University. He received his B.S. and M.S. degrees from UC San Diego and his Ph.D. from UC Berkeley, all in Chemical Engineering. He currently has research activity in areas related engineering education. His group works on integrating technology into effective educational practices that promote the use of higher-level cognitive and social skills in engineering problem solving and in promoting change towards motivating faculty to use evidence-based instructional practices. A particular focus is on what prevents students from being able to integrate and extend the knowledge developed in specific courses in the core curriculum to the more complex, authentic problems and projects they face in professional practice. Dr. Koretsky has received recognition through university and international awards and is a Fellow of the American Society of Engineering Education and a Fellow of the Center for Lifelong STEM Education Research at OSU.