AC 2012-5435: WORK-IN-PROGRESS: CHALLENGES TO DEVELOPING ONLINE HOMEWORK FOR UPPER-LEVEL ENGINEERING COURSES

Cindy Stowell Ph.D., Sapling Learning

Cindy Stowell is the Director of Content at Sapling Learning. She obtained her B.S. in chemical engineering at Virginia Tech and her Ph.D. in chemical engineering at University of Texas, Austin. She began working for the online learning company Sapling Learning in 2006.

Work in Progress: Challenges to Developing Online Homework for Upper-Level Engineering Courses

While Online homework for college courses has been available commercially for over a decade, the offerings in the engineering disciplines are rather minimal. Several online homework providers offer upper-level courses in the natural sciences, such as organic chemistry, analytical chemistry, biochemistry, and advanced mathematics. The majority of providers however, stop at statics and dynamics when it comes to engineering. There are a few exceptions. Web assign has fluid mechanics and electrical circuit analysis homework, but each is only tied to a specific textbook. McGraw Hill's connect is in a similar situation with thermodynamics and circuit analysis tied to a particular book. Why isn't online homework available for upper-level engineering courses?

This paper examines the need and effectiveness of online homework for upper-level engineering courses as well as the difficulties in creating such a product. The experiences and outcomes of an e-learning company, Sapling Learning, that developed commercial online homework for the second year chemical engineering course, Material and Energy Balances are presented.

Because online homework in the engineering fields is a rarity, some background is required to understand how Sapling Learning began developing online chemical engineering homework. In 2008, Sapling Learning began developing textbook-independent homework and sold the product directly to instructors and universities to be paired with any textbook. "Technology T.A.'s" at Sapling Learning have graduate degrees in science and interact directly with instructors, set up instructor's courses, and write additional homework questions if requested.

Originally the company started writing homework for two disciplines: general chemistry and organic chemistry. Despite the larger potential market for general chemistry, the company initially won more student adoptions for organic chemistry. For the fall 2009 semester, 7379 students used Sapling Learning in organic chemistry compared to 1982 students in general chemistry.

It was hypothesized that because so many homework systems are available for general chemistry, the competition was greater than for organic chemistry, leading to more initial adoptions. There was no competition in chemical engineering. So, in 2009 Sapling Learning began to develop online homework for chemical engineering's material and energy balances course to sell in 2010. In addition to the lack of competition, the decision to develop a material and energy balances course was made for a few reasons. First, online, randomized homework would be useful for a course where the largest market share textbook hasn't been revised since 2005[1] and contains many of the same homework questions as the previous edition from the 1980's. As textbooks remain on the market, the number of students having worked each problems increases, which also leads to an increase in the availability of solutions, both in print and in the internet. Second, materials and energy balance questions are time consuming to complete, and also to grade. When students do get their graded pencil and paper homework back, it may be a week later, when that topic is not fresh in the students' mind. Being graded and presented with a solution immediately reinforces the material, and allows the student to correct their misconception quickly.

An example of a typical material and energy balance question developed by Sapling Learning is shown in Fig. 1a below. As most questions in material and energy balances are rather complicated, each online homework question is broken down into smaller parts. Each question contains a hint located in the lower panel, viewable by students before beginning the question. If a student does not complete each part of the question correctly, they will see feedback addressing the particular stage of the question the student is getting wrong, as shown in Fig. 1b. Finally, when a student has either gotten the question right or has given up, they may view the complete solution as shown in Fig. 1c. Tutorial-style questions also are available. In tutorial-style questions, if students get the answer incorrect, new questions are offered to the students that walk them through smaller steps, eventually leading them to the answers for the main question.

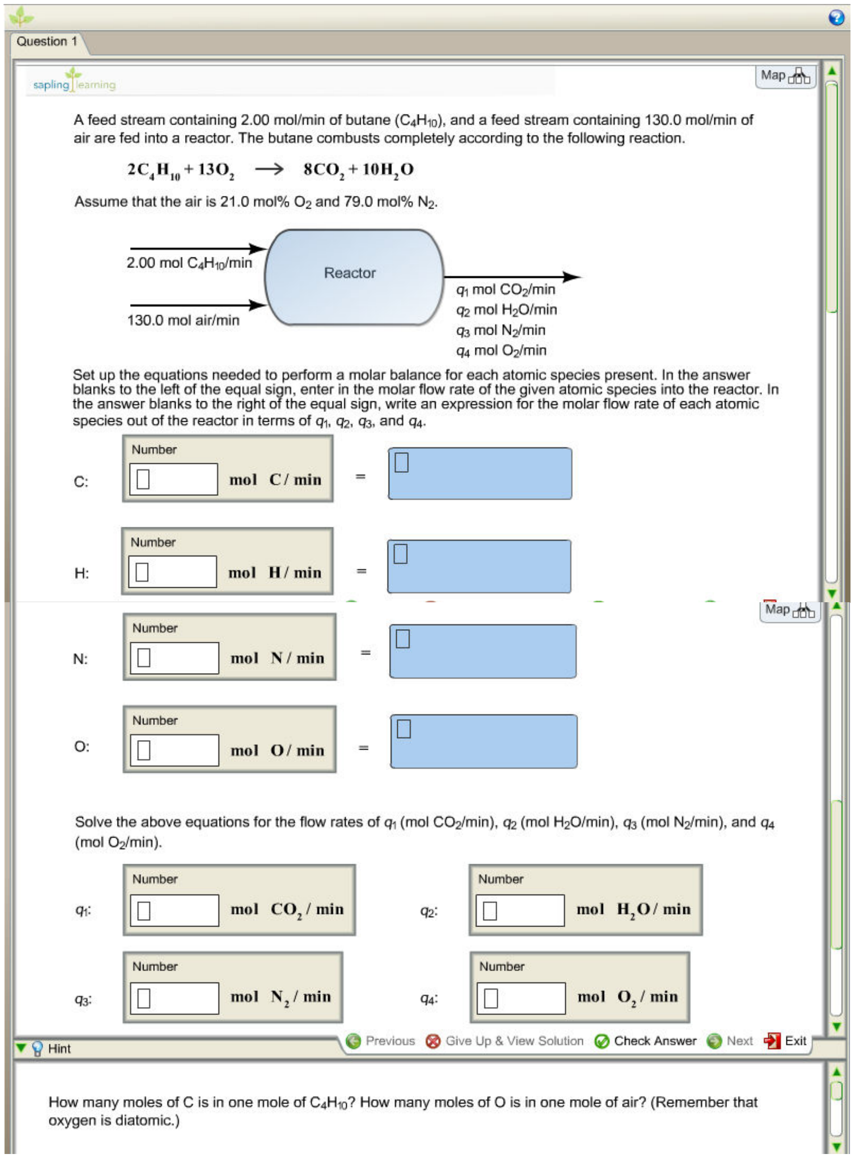


Fig.1a The question stem and hint of a Sapling Learning material and energy balance question. This question uses the atomic balance method, where the number of carbon, hydrogen, nitrogen, and oxygen atoms entering the reactor equals the number of each of those atoms exiting the reactor after combustion.

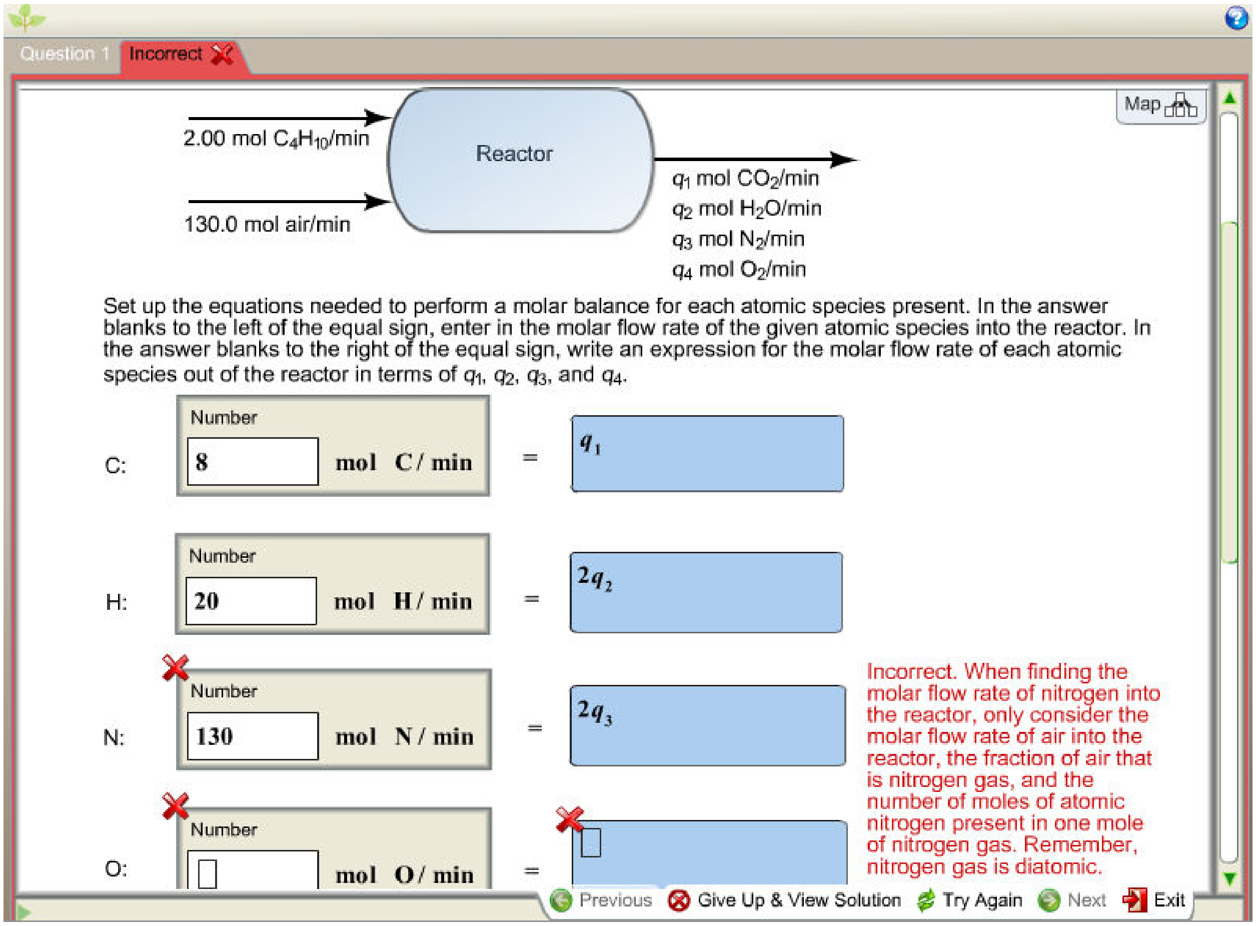
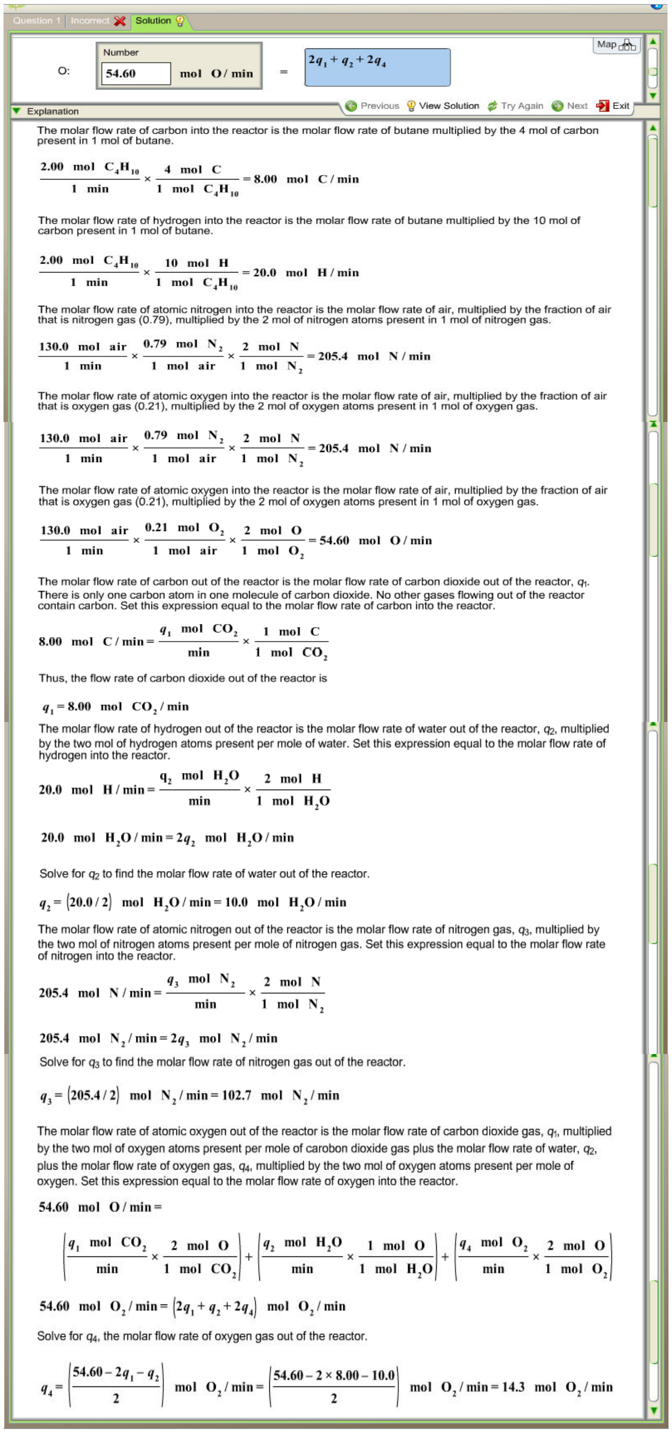


Fig. 1b. Feedback addressing an error in a specific step of the question in Fig. 1a.



Question 1 | Incorrect | Solution

O: Number 54.60 mol O / min = $2q_1 + q_2 + 2q_4$

Map

Previous | View Solution | Try Again | Next | Exit

Explanation

The molar flow rate of carbon into the reactor is the molar flow rate of butane multiplied by the 4 mol of carbon present in 1 mol of butane.

$$\frac{2.00 \text{ mol } C_4H_{10}}{1 \text{ min}} \times \frac{4 \text{ mol C}}{1 \text{ mol } C_4H_{10}} = 8.00 \text{ mol C / min}$$

The molar flow rate of hydrogen into the reactor is the molar flow rate of butane multiplied by the 10 mol of carbon present in 1 mol of butane.

$$\frac{2.00 \text{ mol } C_4H_{10}}{1 \text{ min}} \times \frac{10 \text{ mol H}}{1 \text{ mol } C_4H_{10}} = 20.0 \text{ mol H / min}$$

The molar flow rate of atomic nitrogen into the reactor is the molar flow rate of air, multiplied by the fraction of air that is nitrogen gas (0.79), multiplied by the 2 mol of nitrogen atoms present in 1 mol of nitrogen gas.

$$\frac{130.0 \text{ mol air}}{1 \text{ min}} \times \frac{0.79 \text{ mol } N_2}{1 \text{ mol air}} \times \frac{2 \text{ mol N}}{1 \text{ mol } N_2} = 205.4 \text{ mol N / min}$$

The molar flow rate of atomic oxygen into the reactor is the molar flow rate of air, multiplied by the fraction of air that is oxygen gas (0.21), multiplied by the 2 mol of oxygen atoms present in 1 mol of oxygen gas.

$$\frac{130.0 \text{ mol air}}{1 \text{ min}} \times \frac{0.79 \text{ mol } N_2}{1 \text{ mol air}} \times \frac{2 \text{ mol N}}{1 \text{ mol } N_2} = 205.4 \text{ mol N / min}$$

The molar flow rate of atomic oxygen into the reactor is the molar flow rate of air, multiplied by the fraction of air that is oxygen gas (0.21), multiplied by the 2 mol of oxygen atoms present in 1 mol of oxygen gas.

$$\frac{130.0 \text{ mol air}}{1 \text{ min}} \times \frac{0.21 \text{ mol } O_2}{1 \text{ mol air}} \times \frac{2 \text{ mol O}}{1 \text{ mol } O_2} = 54.60 \text{ mol O / min}$$

The molar flow rate of carbon out of the reactor is the molar flow rate of carbon dioxide out of the reactor, q_1. There is only one carbon atom in one molecule of carbon dioxide. No other gases flowing out of the reactor contain carbon. Set this expression equal to the molar flow rate of carbon into the reactor.

$$8.00 \text{ mol C / min} = \frac{q_1 \text{ mol } CO_2}{\text{min}} \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2}$$

Thus, the flow rate of carbon dioxide out of the reactor is

$$q_1 = 8.00 \text{ mol } CO_2 \text{ / min}$$

The molar flow rate of hydrogen out of the reactor is the molar flow rate of water out of the reactor, q_2, multiplied by the two mol of hydrogen atoms present per mole of water. Set this expression equal to the molar flow rate of hydrogen into the reactor.

$$20.0 \text{ mol H / min} = \frac{q_2 \text{ mol } H_2O}{\text{min}} \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O}$$

$$20.0 \text{ mol } H_2O \text{ / min} = 2q_2 \text{ mol } H_2O \text{ / min}$$

Solve for q_2 to find the molar flow rate of water out of the reactor.

$$q_2 = (20.0/2) \text{ mol } H_2O \text{ / min} = 10.0 \text{ mol } H_2O \text{ / min}$$

The molar flow rate of atomic nitrogen out of the reactor is the molar flow rate of nitrogen gas, q_3, multiplied by the two mol of nitrogen atoms present per mole of nitrogen gas. Set this expression equal to the molar flow rate of nitrogen into the reactor.

$$205.4 \text{ mol N / min} = \frac{q_3 \text{ mol } N_2}{\text{min}} \times \frac{2 \text{ mol N}}{1 \text{ mol } N_2}$$

$$205.4 \text{ mol } N_2 \text{ / min} = 2q_3 \text{ mol } N_2 \text{ / min}$$

Solve for q_3 to find the molar flow rate of nitrogen gas out of the reactor.

$$q_3 = (205.4/2) \text{ mol } N_2 \text{ / min} = 102.7 \text{ mol } N_2 \text{ / min}$$

The molar flow rate of atomic oxygen out of the reactor is the molar flow rate of carbon dioxide gas, q_1, multiplied by the two mol of oxygen atoms present per mole of carobon dioxide gas plus the molar flow rate of water, q_2, plus the molar flow rate of oxygen gas, q_4, multiplied by the two mol of oxygen atoms present per mole of oxygen. Set this expression equal to the molar flow rate of oxygen into the reactor.

$$54.60 \text{ mol O / min} =$$

$$\left(\frac{q_1 \text{ mol } CO_2}{\text{min}} \times \frac{2 \text{ mol O}}{1 \text{ mol } CO_2}\right) + \left(\frac{q_2 \text{ mol } H_2O}{\text{min}} \times \frac{1 \text{ mol O}}{1 \text{ mol } H_2O}\right) + \left(\frac{q_4 \text{ mol } O_2}{\text{min}} \times \frac{2 \text{ mol O}}{1 \text{ mol } O_2}\right)$$

$$54.60 \text{ mol } O_2 \text{ / min} = (2q_1 + q_2 + 2q_4) \text{ mol } O_2 \text{ / min}$$

Solve for q_4, the molar flow rate of oxygen gas out of the reactor.

$$q_4 = \left(\frac{54.60 - 2q_1 - q_2}{2}\right) \text{ mol } O_2 \text{ / min} = \left(\frac{54.60 - 2 \times 8.00 - 10.0}{2}\right) \text{ mol } O_2 \text{ / min} = 14.3 \text{ mol } O_2 \text{ / min}$$

Fig. 1c. The solution to the question shown in Fig. 1c.

The reaction to the chemical engineering homework has been primarily positive. An efficacy study performed by Mathew Liberatore of Colorado School of Mines [2] showed that students who used Sapling Learning's Chemical Engineering homework in addition to textbook homework had a statistically significant higher final grade for the material and energy balance course than a group of students who instead took black board quizzes and textbook.

Within the past year 16 schools have used Sapling Learning for material and energy balances homework. Approximately half of those schools using Sapling Learning inquired at some point if Sapling Learning's online homework was available for other courses, specifically thermodynamics and reactor design. Additionally, in a survey of students from 8 universities just completing Sapling Learning's material and energy balances course, 217 out of 263 (82.5%) students would be interested in using online homework from Sapling Learning for other chemical engineering courses.

Although the online homework is an effective learning tool as shown by Liberatore, and both students and faculty are interested in using online homework for more courses, creating online homework for smaller, upper-level courses has not proven financially viable. Consider Sapling Learning's investment and return for the material and energy balances course.

Currently, the material and energy online homework bank contains 140 questions. This amount does not constitute a complete treatment of this course as instructors request and receive new questions each semester. On average it takes 12 hours to generate an idea for a realistic process, solve the question, then author and review the question. Compare this to 2.5 hours for general chemistry and 6 hours for organic chemistry within the same company. (The differences in time between those chemistry questions and chemical engineering is a function of the difficulty of the questions, and the number inherent of steps in the question.) The cost of writing and reviewing 140 questions plus overhead comes to approximately $57,500. For five semesters, this product has been sold for prices ranging between $23.00 to $34.99 per course, depending on if the school is on quarters or semesters. Approximately 2320 students have paid the for homework system over the course of five semesters, producing a revenue of approximately $73,750. Neglecting inflation, this leaves a profit of $16,250, a paltry amount after 2.5 years.

There are a few ways to increase the profit. The first way is to decrease the time it takes to author questions. Any question written for material and energy balances should still have the question planned out and solved. That time is fixed. What is left is the feedback, the number of answer blanks for each step in the question statement, the solution, and the ability to do a tutorial with several steps. If the feedback in minimized, there is only one answer blank, the question is not a tutorial, and there is a solution, the question would be similar to the Blackboard questions that Liberatore used. Those questions did not help his student learn material and energy balance material as well as Sapling Learning questions did [2]. While Sapling Learning's mass and energy balance questions could theoretically be written in a shorter time, they wouldn't be as effective and helpful to students' learning experience, theoretically negating the questions' value.

Another way to increase the profitability is by increasing the number of students using the product. If the number of bachelor degrees in chemical engineering holds roughly constant at 6656[3] in 2010 in the US and Canada, and you assume about 25% of the students who start out in chemical engineering switch majors, approximately 8875 chemical engineering students take material and energy balances each year. In 2012, 1432 students paid for Sapling Learning's material and energy balances. This amounts to a market share of 16%. Clearly there is more money to be had there; however, not as much as you would think. The more schools that use the online homework, the more content requests that occur, reducing the amount of profit. This past year alone, 27 questions were written. So, with increasing enrollment come increased costs.

Finally, the price of the software access could increase. However at the current economic situation around the country, students and instructors already grumble about the price, and raising the cost of the course would likely lose current users.

After undergoing this experience with material and energy balances, it is unlikely that Sapling Learning or any other commercial online homework provider would develop online homework for upper-level classes because the small number of potential adopters does not justify the effort required to start the project.

Fortunately, there are other ways to create online homework without relying on e-learning companies to produce the content by harnessing the power of a community of instructors. Groups of instructors across the country have already collaborated by sharing bioengineering paper and pencil homework questions with each other[4] . Providing an outlet for the same cooperation, Sapling Learning will offer their software and servers to any community wishing to develop online homework for a smaller, upper-level course, under a "nanopublishing" model. Sapling Learning will train the content authors to write online homework questions (original content only) within Sapling Learning's platform. Each author's work will be cited at the top of the question as in Fig. 2, a material and energy balance question created by a professor using the homework system. In addition authors will receive a royalty for each student that attempts the question. In order fo the question to enter the global content bank and available to all instructors, each question must successfully go though student testing , proving that the question is not flawed.

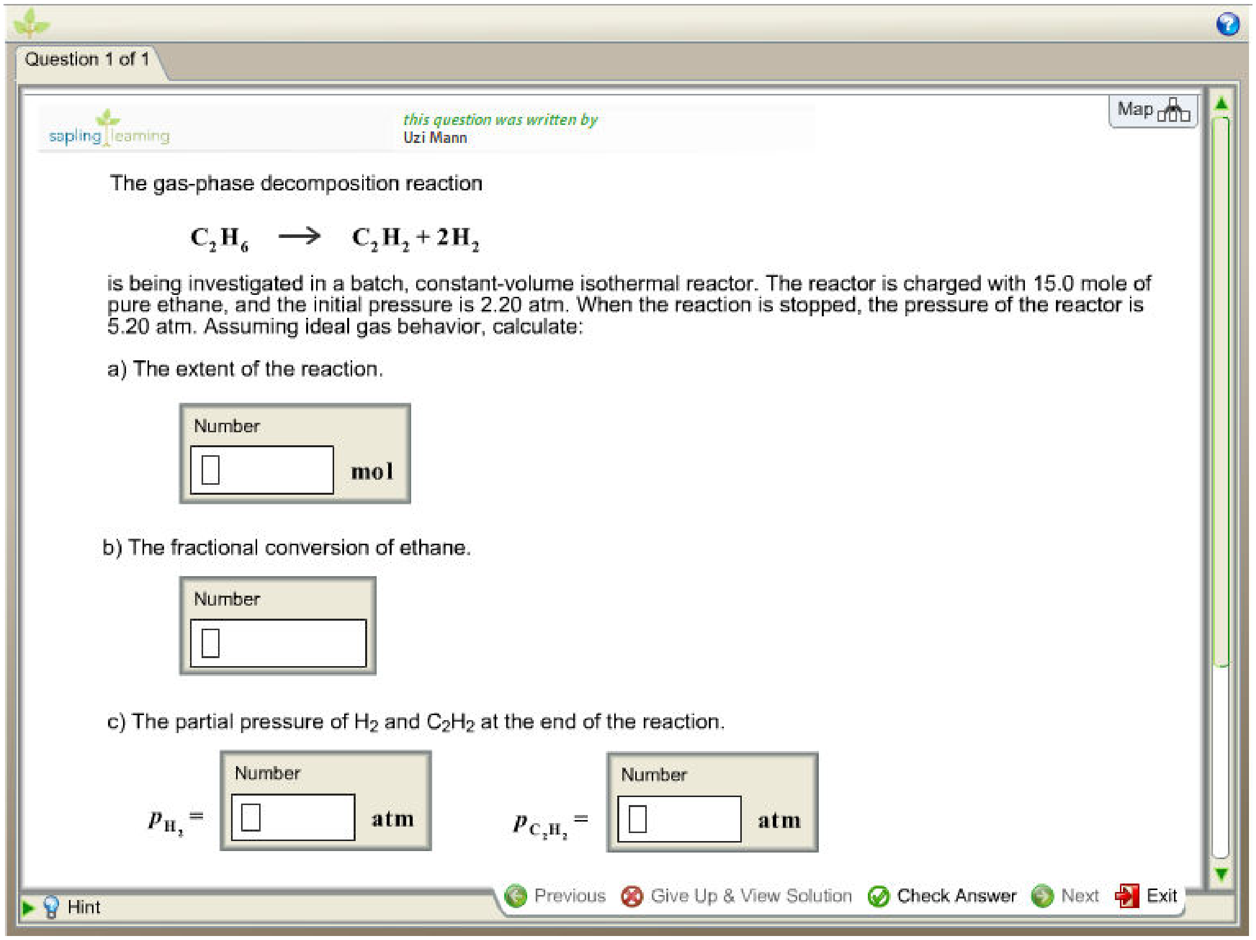


Fig. 2. A material and energy balance question authored by an instructor at Texas Tech under the Nanopublishing model.

It is not financially feasible for e-learning companies to tackle content for smaller courses. Therefore, a solution must come from the instructors who are interested in those courses. By working together, faculty from across the country can create a library of upper-level, online homework questions that use sophisticated answering modules, contain complex feedback, and utilize a platform that has been proven to raise students' grades.

Bibliography

1. Felder, R and Rousseau, R, *Elementary Principles of Chemical Processes*, 3ed.,Wiley (2005)

2. Liberatore, M, “Improved Student Achievement Using Personalized Homework”, *Chem. Eng. Ed.*, **45**(3) 184 -190 (2011)
3. “Profiles of Engineering and Engineering Technology Colleges”, 2010 ed., American Society for Engineering Education
4. Bioengineering Educational Material Bank. Available at: http://www.engr.sjsu.edu/~bioemb/index.php [cited 2012 Jan. 12]