INTERACTIVE QUIZ-YOURSELF SIMULATIONS

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Interactive simulations allow the user to manipulate variables and receive instant feedback on how these changes affect the system; they allow students to construct their own understanding.[1] Because students manipulate simulations at their own speed, fewer demands are placed on working memory, and students can focus on understanding.[2] Moreover, students approach simulations differently from the way they approach in-class experiments. Wieman et al.[1] found that students doing an exercise with an interactive simulation mastered the concepts better on the final exam than students who did a laboratory exercise on the same topic. For one topic, 80% of students who used a simulation demonstrated mastery of the concepts, but only 20% of students who did not use the simulation showed the same kind of mastery. Interactive simulations have been used extensively in physics education because of their effectiveness,[1,3,4] and student interactions with simulations have positive effects on learning.[5–7] Podolefsky et al. showed that they promote self-directed inquiry and exploration.[8]

We previously reported interactive simulations that we prepared for chemical engineering courses.[9,10] In those simulations, the user changes the value of a parameter, usually with a slider, and observes how the system responds. Here we describe a different type of simulation that we refer to as quiz-yourself simulations. They are modeled after the three graphic web-apps that Bansagi and Rodgers prepared for ternary phase diagrams and liquid-liquid extraction.[11,12] Their simulations, which play directly in web browsers, require that the user input an answer(s) for each step and then receive the correct answer(s). The user then moves to the next step or re-starts the simulation with different parameter values. Hints are provided for each step. They[12] reported that the class average on a quiz on liquid-liquid extraction was 77% in the year before their simulations were introduced and 91% after their introduction. They also observed that grades on the final exam were 8% higher, and students generally agreed (4.69/5.0, where 5 is agree, 1 is disagree) that the simulations enhanced their learning.

Our simulations, which are listed in Table 1, follow the same format but most were prepared using *Mathematica*. The four simulations at the end of Table 1 are almost the same as the first four simulations in the table, but were prepared with JavaScript and play directly in browsers. The fifth and sixth simulations in Table 1 are almost the same as two of the simulations prepared by Bansagi and Rodgers,[12] and were prepared so we could determine capabilities of *Mathematica* for creating this type of simulation. The *Mathematica* simulations require users to download a free player from the Wolfram Demonstration Project website,[13] although they may play in browsers in the future, since some simulations on the Wolfram site have beta versions that play directly in browsers. The *Mathematica* and web-based simulations in Table 1 are available on www.LearnChemE.com; the Mathematica simulations are also available on the Wolfram site.

A few snapshots of the quiz-yourself simulations are now presented. Figure 1 shows the second step in the "Construct

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TABLE 1

Quiz-yourself simulations available on LearnChemE

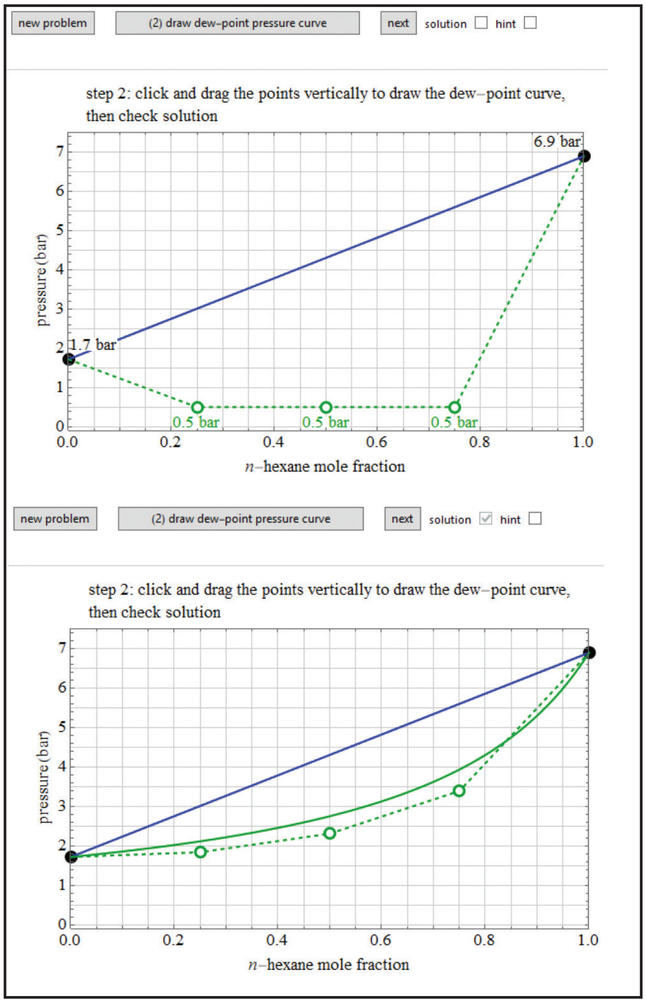
Construct a P-x-y Diagram for VLE
Construct a T-x-y Diagram for VLE
Construct a Pressure-Composition Diagram for Immiscible Liquids
Construction of Temperature-Composition Diagrams for Immiscible Liquids
Construct Single-Stage, Liquid-Liquid Extraction
Apply the Hunter-Nash Method to Liquid-Liquid Extraction
Mass Balances on Absorption and Stripping Units
Construct an x-y Diagram for an Absorption Column
Construct an x-y Diagram for a Stripping Column
Solving Mass Balances on a Distillation Column
Construct a McCabe-Thiele Diagram for Distillation
Construct an x-y Diagram for Flash Distillation
Mass Balances on Evaporative Crystallization
Identify Reversible and Irreversible Expansion and Compression Processes
Construct a Conversion-Temperature Diagram for a Reversible Adiabatic Reaction
Partial Molar Enthalpy and Entropy Quiz
Identify Chemical Potential Plots
Identify Temperature Profiles for Heat Generation/Conduction through Composite Walls
Construct a Pressure-Composition Diagram for VLE*
Construct Temperature-Composition Diagram for VLE*
Construct a Pressure-Composition Diagram for Immiscible Liquids
Construct a Temperature-Composition Diagram for Immiscible Liquids*

* web-based simulations

a P-x-y Diagram for VLE" simulation. Students are shown the graph on the top of Figure 1 and asked to drag the green points to what they believe to be their correct locations. If stuck, students can use the "hint" button. Then, they can check the solution box, and the correct answer (solid green line on the bottom of Figure 1) is displayed along with the student answer (dashed green line). Then, students can select the "next" button to move to the next step. At any time they can select "new problem" and start over with different numerical values.

Figure 2 shows steps 1 and 3 for the "Construct an x-y Diagram for an Absorption Column" simulation. Step 1 requires a mass balance to determine the mass flow rate of gas (V), and the answer is selected with a slider. In step 3, students drag the two orange circles to locations that define the equilibrium line.

Figure 3 shows steps 1 and 2 of the "Identify Temperature Profiles for Heat Generation/Conduction through Composite Wall" simulation. In step 1, the user selects the correct curve out of the five dashed curves for wall A, which generates heat. In step 2, the correct curve is shown for wall A, and the user selects the correct curves for wall B out of the five dashed lines.



step 2: click and drag the points vertically to draw the dew–point curve, then check solution

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Figure 1*. Snapshots of a quiz-yourself simulation that constructs a P-x-y diagram for an ideal solution in vapor-liquid equilibrium. The start of step 2 is on the top, and the result after a student inputs an answer and the solution box is checked is on the bottom.*

The quiz nature of these interactive simulations offers a distinct advantage because students receive instant feedback, which can be used to identify areas where their knowledge is incomplete. These simulations are essentially step-by-step tutorials where a problem that can be displayed graphically is broken into individual sections. Thus, students can practice until they feel comfortable with that particular skill.

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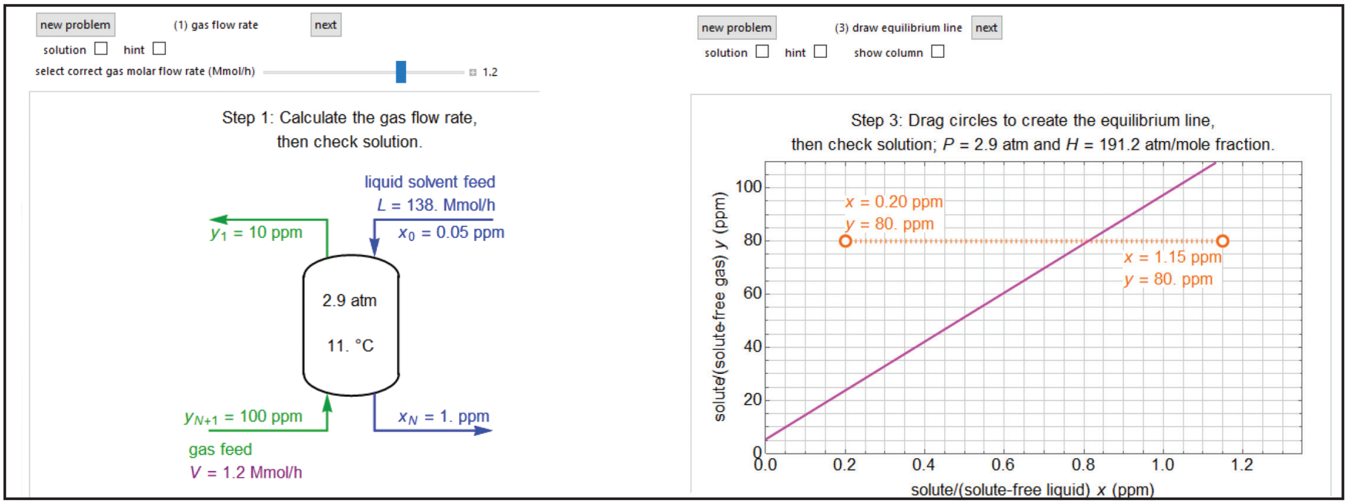
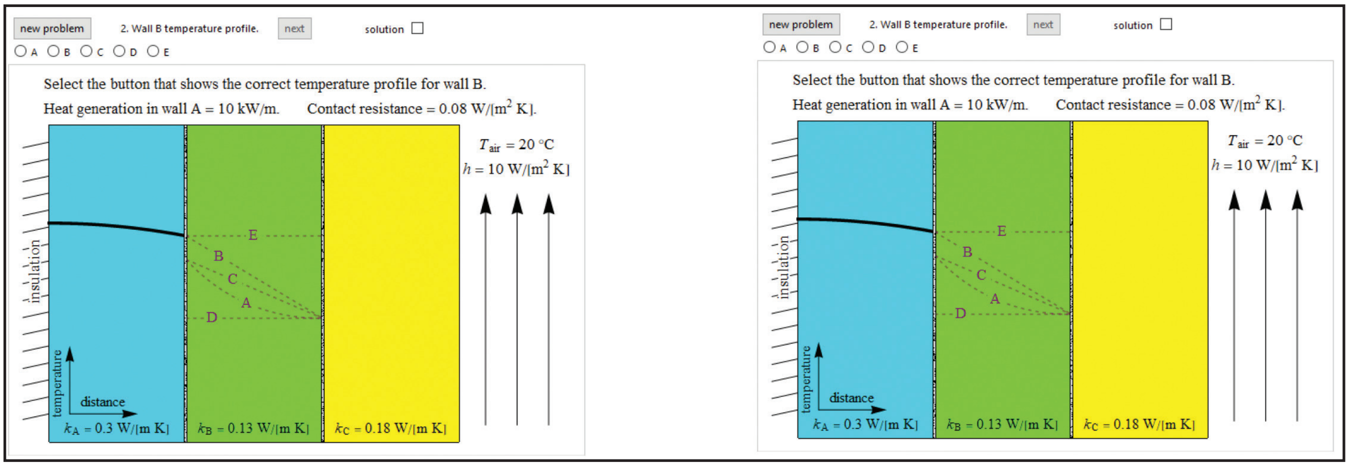


Step 1: Calculate the gas flow rate, then check solution.

Step 3: Drag circles to create the equilibrium line, then check solution; P = 2.9 atm and H = 191.2 atm/mole fraction.

Figure 2. *Snapshots of a quiz-yourself simulation that constructs an x-y diagram for an absorption column. Step 1 is on the left and step 3 is on the right.*



Select the button that shows the correct temperature profile for wall B.

Heat generation in wall A = 10 kW/m. Contact resistance = 0.08 W/[m^2 K].

Select the button that shows the correct temperature profile for wall B.

Heat generation in wall A = 10 kW/m. Contact resistance = 0.08 W/[m^2 K].

Figure 3. *Snapshots of a quiz-yourself simulation for heat conduction through a composite wall. Heat is generated in wall A. Step 1 is on the left and step 2 is on the right.*

ematica-based quiz simulations were prepared by Rachael Baumann and Neil Hendren. The web-based quiz simulations were prepared by Paul Chrastina. Professor Janet deGrazia provided suggestions for improving some of the simulations.

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