Development of Interactive Virtual Laboratories to Help Students Learn Difficult Concepts in Thermodynamics

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Interactive Virtual Laboratories

Overview

Student Performance – Same Concept

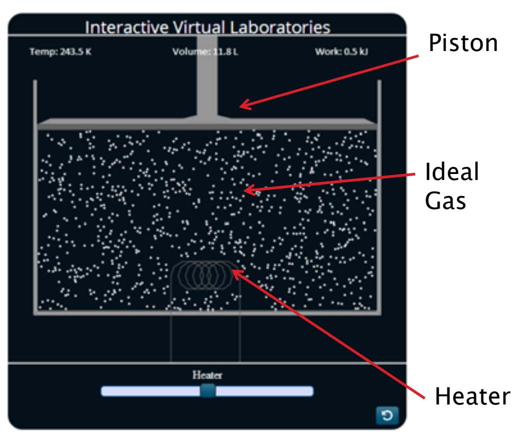
From a previous study, students perform well on computational problems, but poorly on conceptual questions.

Computational Problem

Conceptual Question

Interactive Virtual Laboratories

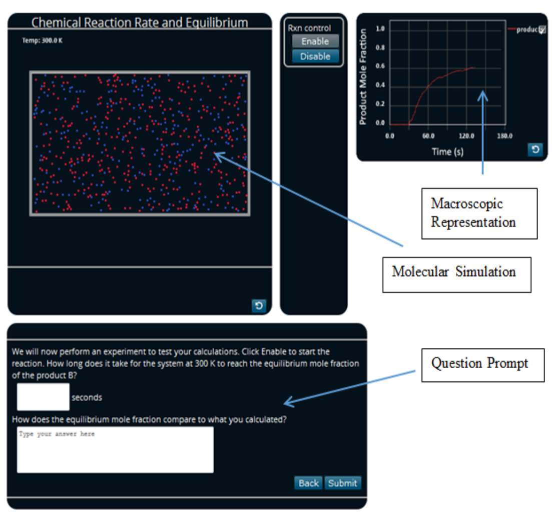
- Two-Dimensional Simulations
- Guided Questions
- Predict-Observe-Explain



Interactive Virtual Laboratories

- So far six IVLs have been built around important concepts:
  - *Pv* Work
  - Reversibility
  - c_v/c_p
  - Hypothetical Paths
  - Phase Equilibrium
  - Reaction Rate vs. Chemical Equilibrium

- **Molecular Simulation**
  - Interactive
  - Conceptual
- **Macroscopic Representation**
  - Graphs
  - Data
- **Question Prompt**
  - Guided Questions



Guided Question Types

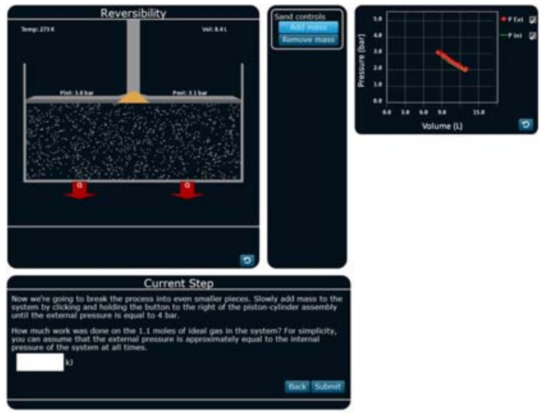
- 4 main question types
  - **Conceptual**
    - ***Prediction*** – Anticipation of effects of a system change
    - ***Interpretation*** of data to explain complex phenomena
  - **Procedural** – Mathematical computation or graphical interpretation; answers typically numerical
  - **Observation**– Observe experimental phenomena from IVL
  - **Reflection** – Comparison results of current problem to previous problems

Example – *Pv* Work

- Through what mechanism does doing work add energy to the ideal gas system?
- Molecules gain momentum (and kinetic energy) when colliding with a moving wall

Example – Reversibility

- What conditions are necessary for a process to be truly reversible?
- Infinitesimally small changes in input (pressure).



Interactive Virtual Laboratories

- Embedded within AIChE Concept Warehouse
- Can be accessed on laptops using web browsers
- Student responses and answers collected in Concept Warehouse database

Methods

- Eight student participants
  - 4 completed the *Pv* Work IVL
  - 4 completed the Reversibility IVL
- Students observed using "think aloud" protocol – voice and screen capture video recorded
- Semi-structured interviews of students after completing IVL for perceptions and conceptual understanding

Methods

- Student approaches to completing IVLs examined
  - What approaches did students take?
  - Which approaches allowed students to be successful?
- Student feedback examined
  - What did students like about the IVLs?
  - What did students dislike?

Methods

- Approaches divided in two
  - Conceptual-based
  - Equation-based
- Conceptual-based
  - Focused on molecular phenomena represented in simulation to answer complex questions
- Equation-based
  - Focused exclusively on mathematical relationships between variables to answer questions

Conceptual-based

- "Oh, it's when it hits the moving wall. That's what will cause it to speed up because when the wall's moving, it smacks into it…"
- "It causes a temperature change in many molecules because it increases the average speed of all the molecules distributed inside the container when they all hit the slowly approaching wall."

Equation-based

- "Energy of the system is delta U over dt plus delta of kinetic energy over t plus delta of potential energy over time, and that's equal to heat plus work. And this is an adiabatic process, so heat is zero."
- "Since n, Cv, and negative external pressure are constant, delta T must be increasing as the closed system gets compressed more (delta V increases)."

Results

- Students tended towards one of two approaches:

Conceptual-Based	Equation-Based
• Focused on physical phenomena modeled by simulation • Successful in understanding threshold concepts • Successful in answering numerical questions	• Focused on mathematical equations relating important variables • Unsuccessful in understanding threshold concepts • Could only correctly answer some numerical questions

Results

- IVLs do not force students to approach problems conceptually
- Students who typically take an equation-based approach continue to do so when using the IVLs
- IVLs do not reward students who take an equation-based approach

Results - Feedback

- Feedback was very positive
- Students particularly enjoyed dynamic representation of molecules and concepts
- Students said the IVLs helped them understand the concepts behind frequently-encountered equations
- Suggested a possible hint feature

Classroom Implementation

- Reaction Rate vs Equilibrium IVL used in junior-level chemical engineering thermodynamics class
- After finishing, students were asked to assess the IVL on:
  - Engagement
  - Learning
  - Usability
  - Value

Classroom Implementation

Statement	Average	5	4	3	2	1	Construct
Time passed quickly during the Interactive Computer Simulation	3.69	17	37	25	8	1	engagement
The Interactive Computer Simulation was a fun activity	3.61	7	47	25	8	0	engagement
It was useful to discuss aspects of the Interactive Computer Simulation with students in my group	4.11	25	50	9	3	0	learning
The Interactive Computer Simulation helped me understand the principle(s) that the instructor wanted me to learn	3.91	9	63	15	1	0	learning
Observing the molecules' behavior helped me learn	3.69	9	53	13	10	1	learning
I could successfully complete the activity without really understanding the material (reverse)	3.57	2	7	27	40	10	learning
The Interactive Computer Simulation was easy to use	4.04	23	47	10	5	0	usability
I understood the questions that I was asked to answer during the activity	3.98	15	55	15	1	0	usability
I had technical difficulties with the Interactive Computer Simulation (reverse)	3.75	6	11	8	36	26	usability
The Interactive Computer Simulation was worth doing	3.84	10	58	14	5	0	value
I would like to see Interactive Computer Simulations for other topics in the curriculum	3.82	14	48	20	5	0	value
I would have preferred a regular studio activity instead of the Interactive Computer Simulation (reverse)	3.28	4	12	30	38	3	value

In Conclusion…

- IVLs reward students who approach them conceptually
- Positive student feedback to the IVLs
  - Powerful visual tool
- Some students approach IVLs using an equation-based method
  - Unable to fully answer conceptual questions

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Questions?