Exploratory Learning Activities in Undergraduate STEM Courses

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Exploratory Learning

Traditional Instruction	Exploratory Learning
1. Lecture 2. Solve Problem	1. Solve Problem 2. Lecture
• Prior knowledge is disconnected • Unaware of knowledge gaps • Focus on superficial problem features	• Prior knowledge is connected • Aware of knowledge gaps • Perceive deep problem features

(DeCaro & Rittle-Johnson, 2012; Glogger-Frey et al., 2015; Loibl et al., 2017; Schwartz & Bransford, 1998)

Studies have found that exploratory learning improves conceptual understanding (Loibl et al., 2017)

- But not always
- Certain design features must be present

Most studies have been done with 2nd-9th grade students

- Many do not have tight experimental control

Research Questions

1. **Does exploratory learning improve conceptual understanding, compared to instruct-then-practice conditions, in undergraduate STEM courses?**
   - What learning mechanisms support exploratory learning?
   - Do exploratory learning activities help underrepresented students?
2. How does a faculty learning community support professional development and use of exploratory learning methods?

Project Design

Year 1 (2021-2022):

- Faculty developed activities
- Students randomly assigned to instruct-first or explore-first conditions
- Tested with two different topics in 11 faculty classrooms (5 courses: Chemistry, Physics, Biology, Calculus, Engineering)

Years 2&3

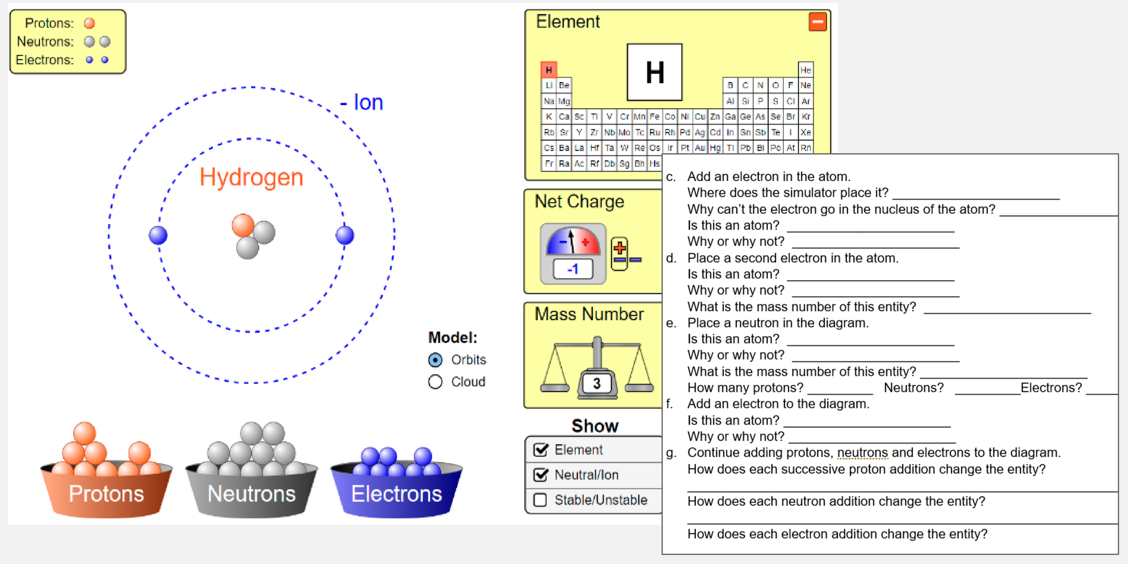
- Will refine or replicate each study

Glogger-Frey, I., Fleischer, C., Grüny, L., Kappich, J., & Renkl, A. (2015). Inventing a solution and studying a worked solution prepare differently for learning from direct instruction. *Learning and Instruction, 39,* 72–87.
DeCaro, M. S., & Rittle-Johnson, B. (2012). Exploring mathematics problems prepares children to learn from instruction. *Journal of Experimental Child Psychology, 113,* 552-568.
Loibl, K., Roll, I., & Rummel, N. (2017). Towards a theory of when and how Problem solving followed by instruction supports learning. *Educ Psychol Rev, 29,* 693-715.
Schwartz, D. L., & Bransford, J. D. (1998). A time for telling. *Cognition and Instruction, 16,* 367–398.

Chemistry Study 1 (*N*=218)

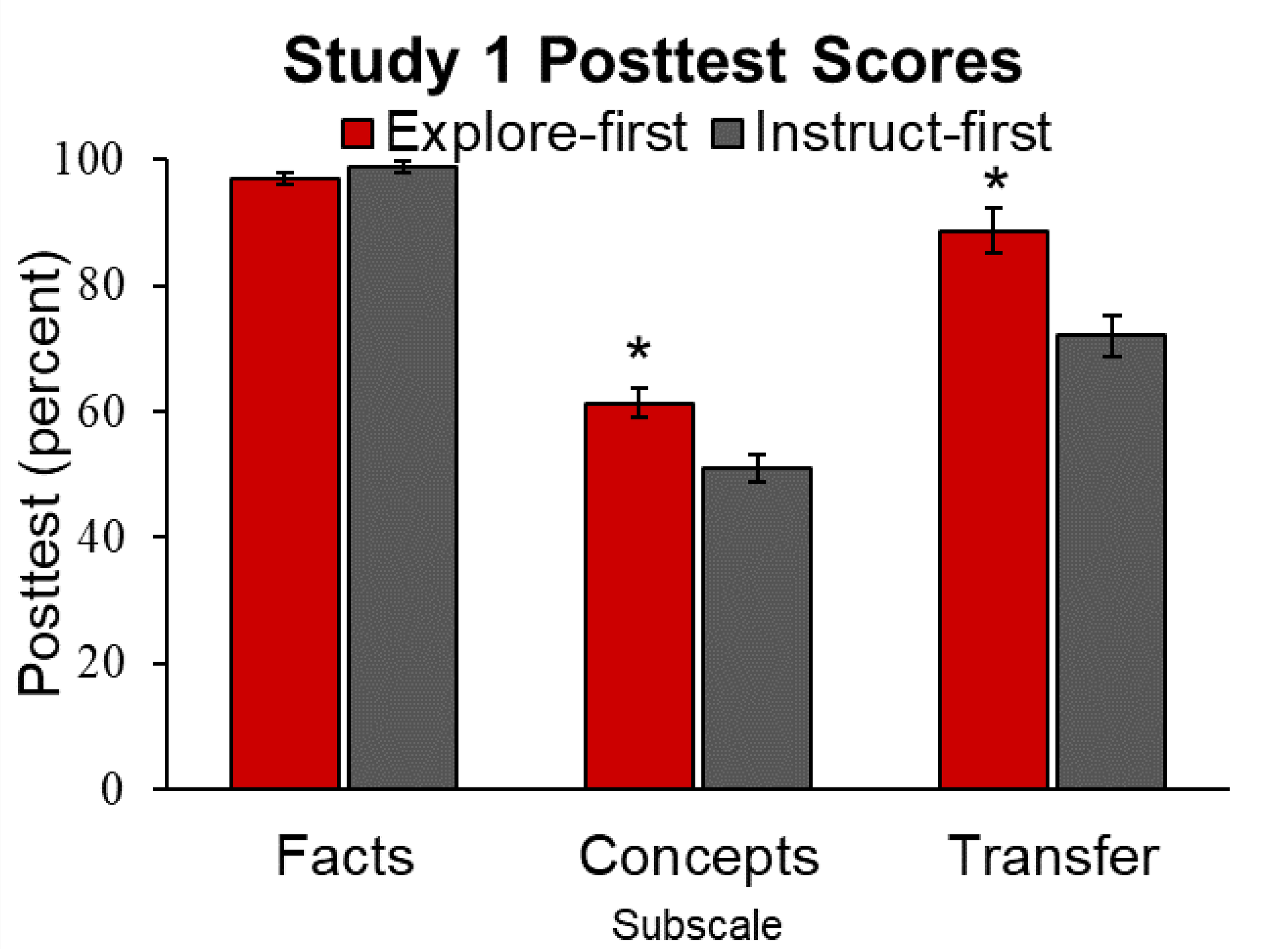
Lecture: Atomic Structure

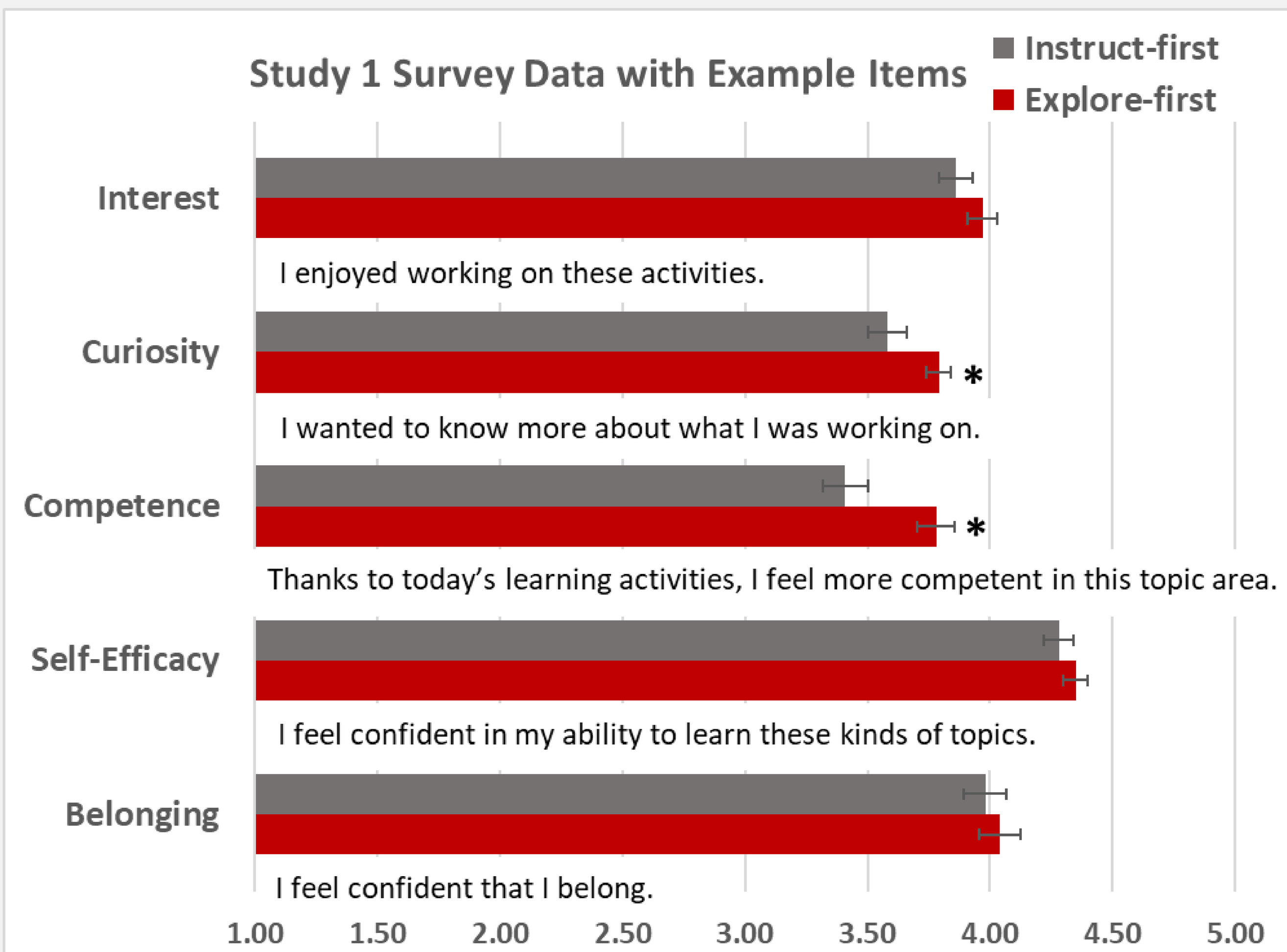
Activity: Online Simulation with Worksheet



Build an Atom PhET Simulation
(Source: https://phet.colorado.edu/en/simulations/build-an-atom)

Instruct-First Condition	Explore-First Condition
Lecture	**Activity**
Activity	Lecture
Activity Review	
Survey	
Posttest	

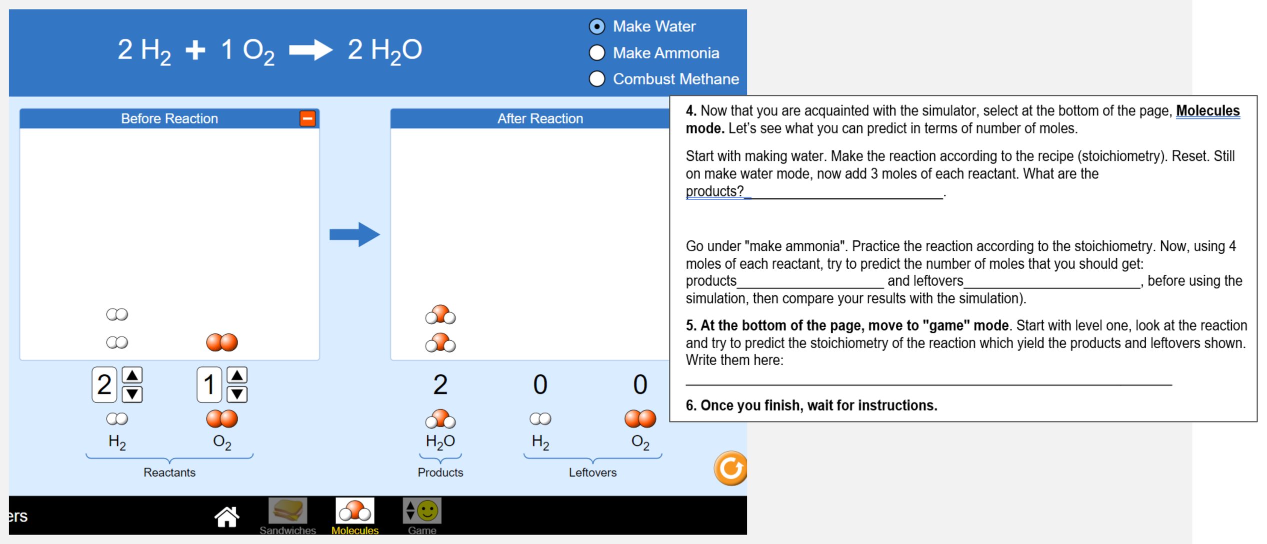




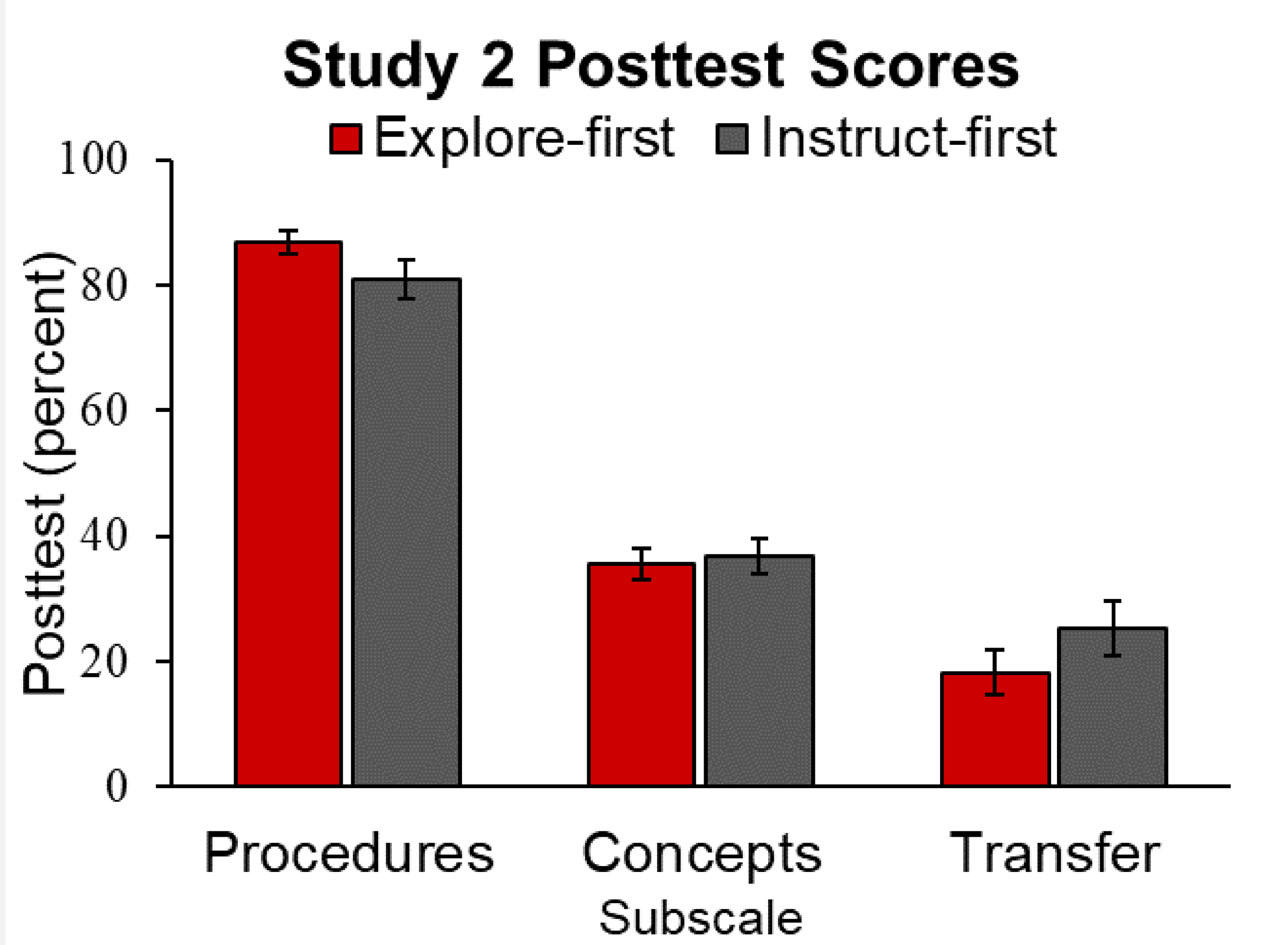
Chemistry Study 2 (*N*=326)

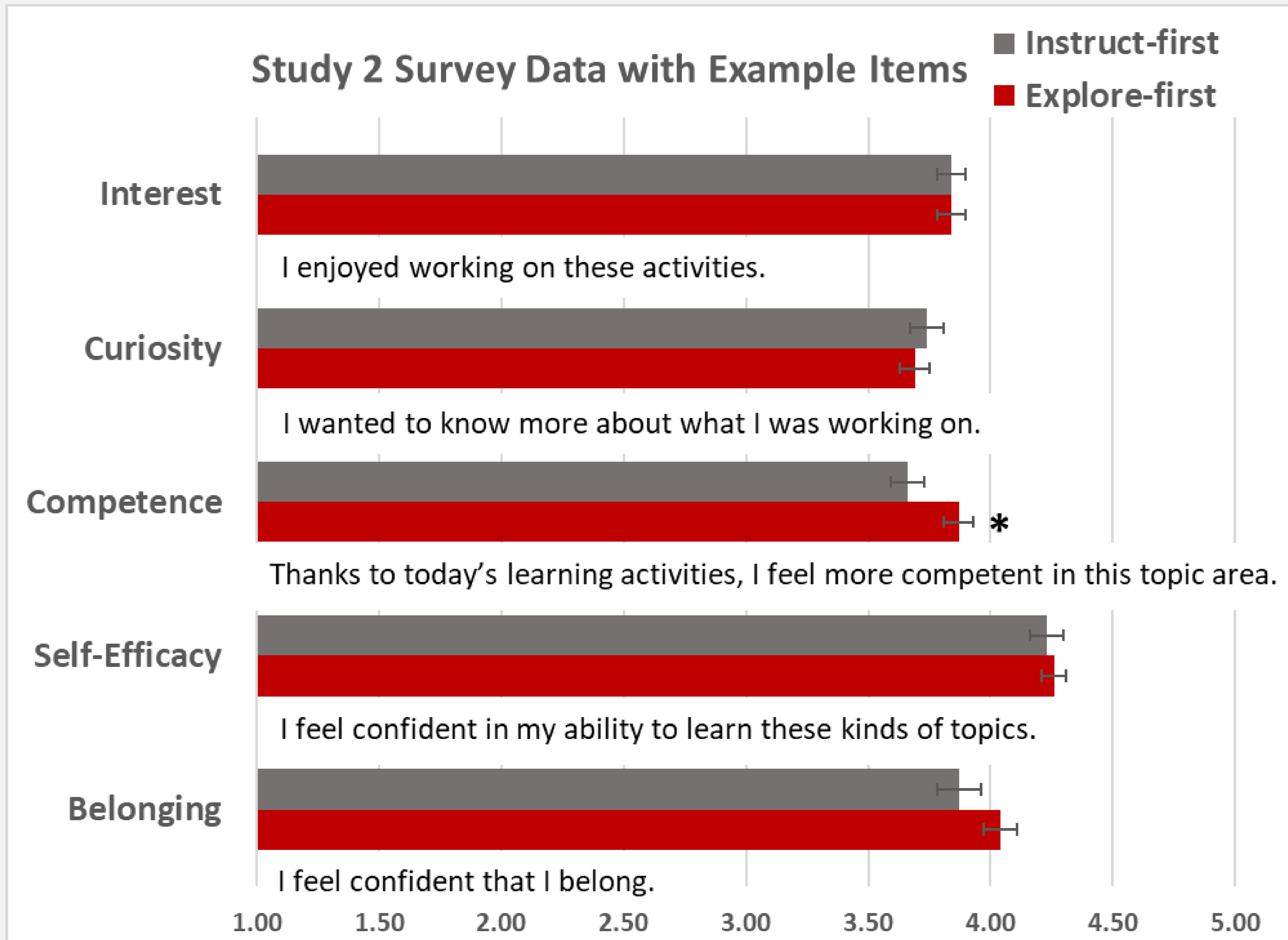
Lecture: Stoichiometry

Activity: Online Simulation with Worksheet



Reactants, Products, and Leftovers PhET Simulation
(Source: https://phet.colorado.edu/sims/html/reactants-products-and-leftovers/latest/reactants-products-and-leftovers_en.html)





Conclusion

Exploring before instruction benefitted learning and motivation

Study 1

- Concept learning
- Transfer
- Curiosity
- Competence

Study 2

- Competence

Students may need more guidance

- **First exploratory learning study in first-year undergraduate chemistry**
- **First to use simulations as exploration activities**
- Will refine and test further
- Will build a theoretical framework including characteristics needed to design exploration activities

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