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Communication

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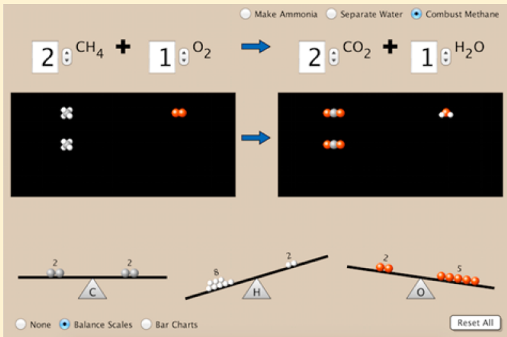
ConfChem Conference on Interactive Visualizations for Chemistry Teaching and Learning: Using an Interactive Simulation To Support Development of Expert Practices for Balancing Chemical Equations

Yuen-ying Carpenter,* Emily B. Moore, and Katherine K. Perkins

University of Colorado Boulder, Boulder, Colorado 80309, United States

Ⓢ *Supporting Information*

ABSTRACT: An in-class guided-inquiry activity utilizing feedback from a PhET interactive simulation offers an opportunity to foster student learning via an inquiry-based approach. Here, student groups in a preparatory chemistry course leveraged representations in the *Balancing Chemical Equations* simulation to define and develop successful practices for nonredox equation balancing without explicit instruction. This communication summarizes one of the invited papers to the 2015 Spring ConfChem: *Interactive Visualizations for Chemistry Teaching and Learning* ACS CHED Committee on Computers in Chemical Education online conference held from May 8 to June 4, 2015. Discussions therein highlighted the importance of recognizing student challenges, broader disciplinary context, and a diversity of problem-solving approaches in the learning and teaching of chemical equation balancing.



KEYWORDS: *High School/Introductory Chemistry, Internet/Web-Based Learning, Inquiry-Based/Discovery Learning, Nomenclature/Units/Symbols, Curriculum, Collaborative/Cooperative Learning, Constructivism*

While the ability to balance a chemical equation is foundational to the study and practice of chemistry, the topic is often taught traditionally, via direct instruction, followed by drill-and-practice. Here, we focus on supporting students in developing individualized approaches to equation balancing, using a guided-inquiry activity facilitated by the PhET interactive simulation, *Balancing Chemical Equations*.[1]

■ CLASSROOM CONTEXT AND RESULTS

The 50-min guided-inquiry activity described here targets undergraduate students in Preparatory Chemistry, a course for students identifying as underprepared for General Chemistry. Students worked in 12 groups of 2–3, using activity worksheets and a shared laptop with the simulation. No directions were provided on how to use the simulation. The instructor facilitated whole class discussions soliciting student ideas and balancing strategies as the activity progressed.

Part I of the activity focused on the Introduction screen of the simulation and prompted students to compare the total number of molecules and atoms on each side of three equations once balanced. Part II used the Balancing Game screen of the simulation and asked students to develop and practice balancing strategies within their groups. By the end of the activity, all student groups had demonstrated an operational definition of a balanced chemical equation and successfully balanced equations of varying difficulty.

Student Use of Representations

Throughout the simulation, both symbolic and pictorial (molecular) representations are available to students. We analyzed student groups' screen-capture recordings for verbal or mouse gesture cues indicating which representations students leveraged while balancing. Although student groups new to balancing leveraged the molecular-scale pictorial representations throughout, all groups engaged with the concurrently available chemical symbols. This alternating use of both disciplinary representations not only supported newer students in balancing, but also provided practice in mentally coordinating these two representations.

In addition to these canonical representations, the simulation also offers an optional "balance scale" representation to focus students' attention on the number of atoms of each element. These balance scales were actively leveraged and referenced by 40% of groups during equation balancing on the Introduction screen. For students with no prior exposure to balancing, this nontraditional representation seemed invaluable, as it immediately cued them to target equal numbers of atoms of each element on either side of the equation.

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CONFCHEM: EMERGENT DISCUSSION THEMES

This paper was discussed May 15–21, 2015, during the Spring 2015 ConfChem online conference, Interactive Visualizations for Chemistry Teaching and Learning,[2] hosted by the ACS DivCHED Committee on Computers in Chemical Education. During this discussion, several themes emerged from practitioners and researchers. (See the Supporting Information.)

Participants debated how challenging equation balancing was for students, as well as what aspect rendered the practice challenging: unfamiliarity with chemical formulas, weak arithmetic foundations, or features of certain chemical equations. Given how significantly students leveraged the simulation representations, the predominant challenge in this context appeared to be the equations themselves. Indeed, in both this study and in data shared by one the discussants, specific equations proved notably more difficult for students than others, despite being considered of comparable challenge by the instructors.

Several participants also commented that chemical equation balancing is an inherently contextual practice, rooted in a broader disciplinary framework that might not be best served by teaching and practicing this skill in isolation. For example, since students leverage static representations in this simulation, the instructor must later connect this practice to a dynamic view of chemical processes. Indeed, the simulation described here uses only static representations specifically to focus student attention on interacting with the coefficients and attending to relationships between representations; however, these visual representations can then be integrated with greater ease into the topics and ideas that follow. Several resources were suggested by participants to support the integration of this activity, and of balancing practices, into a more holistic chemistry curriculum.

Finally, participants debated the relative merits of traditional vs inquiry-based instructional approaches to student problem-solving in cases such as equation balancing, where numerous algorithmic strategies have been proposed.[3] Both approaches require a similar time investment in-class and lead to successful balancing within that time frame. However, memorized algorithmic practices may be disadvantageous on longer time scales, as students have been previously observed referencing half-remembered heuristics as if they were absolute rules for the process of balancing.[4] Moreover, the preference for traditional or inquiry-based teaching of balancing strongly reflected individual instructors' secondary learning goals. The approach highlighted here was favored by participants who wanted to emphasize the diversity of available problem-solving strategies in this and other curricular topics.

While each of these discussion themes revealed diverse and divergent perspectives on the best instructional approaches, these debates highlight how analysis into student representation-use can provide valuable data to help educators understand the development of student practice, regardless of their teaching context.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00546.

Full text of the original paper and associated discussions from the ConfChem conference (PDF)

Copy of the activity annotated with facilitation tips for instructors (PDF)

AUTHOR INFORMATION

Corresponding Author

*E-mail: yyscarpe@ucalgary.ca.

Notes

The authors declare no competing financial interest.

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REFERENCES

(1) The simulation is freely available online at http://phet.colorado.edu/en/simulation/balancing-chemical-equations (accessed Dec 2015).

(2) American Chemical Society, Division of Chemical Education, Committee on Computers in Chemical Education. 2015 Spring ConfChem: Interactive Visualizations for Chemistry Teaching and Learning. http://confchem.ccce.divched.org/2015SpringConfChem (accessed Dec 2015).

(3) See, for example, (a) Porter, S. How should equation balancing be taught? *J. Chem. Educ.* **1985**, *62*, 507–508. (b) Tóth, Z. Balancing Chemical Equations by Inspection. *J. Chem. Educ.* **1997**, *74* (11), 1363–1364. (c) Hutchings, L.; Peterson, L.; Almasude, A. Pre-matrix balancing of challenging chemical equations with a simple formula register and middle school arithmetic. *J. Math. Sci. Collab. Explor.* **2007**, *9*, 119–133.

(4) Nyachwaya, J. M.; Warfa, A.-R. M.; Roehrig, G. H.; Schneider, J. L. College chemistry students' use of memorized algorithms in chemical reactions. *Chem. Educ. Res. Pract.* **2014**, *15*, 81–93.

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