Using an Adaptive Collaboration Script to Promote Conceptual Chemistry Learning

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Abstract. Chemistry students often learn to solve problems algorithmically, applying well-practiced procedures to problems. Such an approach may hinder development of conceptual understanding. We propose to promote conceptual learning by having pairs of students collaborate on problems in a virtual laboratory (VLab), assisted by a computer-mediated collaboration script that guides the students through the stages of scientific experimentation by adapting to a particular student's (or dyad's) skills. In this paper, we report on our early steps toward this goal, including technology development and an initial wizard-of-oz study.

1 Research Motivation

Chemistry educators face the challenge of teaching students to solve problems conceptually rather than simply apply mathematical equations. Students struggle in solving problems similar to ones in textbooks or in the classroom, because they do not grasp the similar underlying concepts [1]. Research in chemistry education has suggested that collaborative activities can improve conceptual learning. While there have been very few controlled experiments which have investigated the benefits of collaborative learning in chemistry, evidence that collaboration is beneficial exists in other disciplines, such as physics [2]. This evidence has led us to investigate the potential advantages of collaborative activities for conceptual learning in chemistry.

When learning collaboratively, learners do, however, often not benefit as much as they could, because they fail to engage in productive forms of interaction. This observation suggests supporting students with *collaboration scripts*. By scripting collaboration we mean providing prompts and questions that guide students through collaborative work (e.g., [3]). However, it is possible to *over-script*, i.e., provide too many scaffolds, or overwhelm students with the concurrent demands of collaborating, following script instructions, and trying to learn [4]. To avoid these bottlenecks of collaboration we propose to use *adaptive scripting*: altering and/ or fading scripts depending on the collaborators' need for support. Adaptive scripts can be considered a

form of intelligent tutoring [5] as feedback is provided based on the individual student (or group) performance.

We hypothesize that computer-mediated collaboration within an experimental framework - and guided by a script - can promote conceptual chemistry knowledge. We also believe that *adaptive* scripting will promote conceptual chemistry knowledge even more. This paper outlines our experiences with a wizard-of-oz study that tested the adaptive scripting approach.

2 Technology Development

The implementation of the adaptive scripts into a collaborative setting involved developing collaborative extensions to the VLab chemistry experimentation tool [6], through integration with FreeStyler, an existing collaborative software environment [7]. Our script consisted of experimentation steps inspired by [8] and was implemented in FreeStyler with tabs representing the experimentation steps and additional ordering restrictions.

3 Wizard-Of-Oz Study

We conducted a small wizard-of-oz study that compared an adaptive and a non-adaptive version of our system. There were 3 dyads per condition, and the experimental procedure was standard pre-test/intervention/post-test. The students in both conditions collaborated by using a number of tools that scripted and supported their collaboration within FreeStyler tabs.

In the adaptive condition, a human wizard who observed the students as they collaborated provided adaptive support via prompts sent to the students, to promote explanations, reflection, and help giving/receiving. The wizard used a flowchart to observe and recognize situations requiring a prompt, and to choose and give the appropriate prompt. The flowchart was developed based on the data analysis of the first study and on a literature review of collaborative learning research (e.g., [2]). Examples of adaptive prompts are *"Don't forget to explain your statements and actions to each other."* which was provided by the wizard when a student neglected to explain a statement or action despite a request by his partner, and *"Remember to talk about and reach a consensus on your next activity before moving on."* which was provided when a student started an activity alone before agreeing on previous activities with his partner.

The study results were encouraging. With a possible highest score of 6 points on the conceptual post-test, the adaptive condition mean was M=4.6 (SD 1.63) compared to M=3.5 (SD 2.81) for the non-adaptive condition, showing a tendency toward better conceptual understanding due to adaptive support. A process analysis of screen recordings taken during the experiments showed that the non-adaptive dyads were less likely to correct flaws in their collaborative and script practice. On the other hand, the prompts given to the adaptive dyads, although not always appreciated by the students,

had a clear positive effect on collaboration, motivation, and to some extent on the way the collaborating students followed scripts.

4 Conclusion

We will use the knowledge gained from the wizard-of-oz study presented here to extend the system towards a full collaborative intelligent tutoring system by automating our adaptive feedback. To this end, one of the approaches we will explore is the use of machine learning to create "adaptive detectors", similar to the work of Baker in developing gaming detectors [9]. That is, we will annotate student actions in the VLab for aberrant behavior and apply machine-learning algorithms to identify situations in which prompts are necessary. We also plan to use the collaboration expertise captured in the wizard flowchart as guidance for feedback in particular situations.

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References

[1] Gabel, D. L., Sherwood, R. D., Enochs, L.: Problem-Solving Skills of High School Chemistry Students. Journal of Research in Science Teaching 21 (2), 221--233 (1984)

[2] Hausmann, R. G., Chi, M. T. H., Roy, M.: Learning from Collaborative Problem Solving: An Analysis of Three Hypothesized Mechanisms. In: K. D. Forbus, D. Gentner , T. Regier (eds.) 26nd annual Conference of the Cognitive Science Society, pp. 547--552. Mahwah, NJ, Lawrence Erlbaum. (2004)

[3] Kollar, I., Fischer, F., Hesse, F. W.: Collaboration scripts - a conceptual analysis. Educational Psychology Review, 18 (2), 159-185 (2006).

[4] Rummel, N., Spada, H.: Learning to Collaborate: An Instructional Approach to Promoting Collaborative Problem Solving in Computer Mediated Settings. Journal of the Learning Sciences, 14(2), (2005)

[5] VanLehn, K. The Behavior of Tutoring Systems. International Journal of Artificial Intelligence in Education, 16(3), 227-265. (2006)

[6] Yaron, D., Evans, K., Karabinos, M.: Scenes and Labs Supporting Online Chemistry. Paper presented at the 83rd Annual AERA National Conference, (2003)

[7] Harrer, A. Pinkwart, N., McLaren, B. M., Scheuer, O. How Do We Get the Pieces to Talk? A New Software Architecture to Support Interoperability Between Educational Software Tools. The 9th International Conference on Intelligent Tutoring Systems (ITS-08).

[8] De Jong, T.: Scaffolds for Computer Simulation Based Scientific Discovery Learning. In: J. Elen, R. E. Clark (eds.) Dealing with Complexity in Learning Environments 107--128, London: Elsevier Science Publishers (2006)

[9] Baker, R.S.J.d., Corbett, A.T., Koedinger, K.R., Evenson, S., Roll, I., Wagner, A.Z., Naim, M., Raspat, J., Baker, D.J., Beck, J.: Adapting to When Students Game an Intelligent Tutoring System. Proceedings of the 8th International Conference on Intelligent Tutoring Systems, 392-401 (2006).