Comparison of Specific and Knowledge Integration Automated Guidance for Concept Diagrams in Inquiry Instruction

Kihyun Ryoo, UNC Chapel Hill, 309E Peabody Hall, Chapel Hill, NC 27599, khryoo@email.unc.edu
Marcia C. Linn, UC Berkeley, 4611 Tolman Hall, Berkeley, CA 94720, mclinn@berkeley.edu

Abstract: This study compares two types of automated adaptive guidance for concept diagrams to improve middle school students' science learning in web-based inquiry instruction. Specific guidance tells students precisely what to improve, while knowledge integration guidance suggests revisiting a specific visualization to locate useful information. The results suggest that knowledge integration guidance is more effective in helping students distinguish among multiple ideas and develop more coherent views than specific guidance.

Introduction

Formative guidance plays an important role in improving inquiry learning (Shute, 2008), but many teachers often lack the time or resources to provide appropriate guidance to individuals (Ruiz-Primo & Furtak, 2007). Advances in automated scoring technologies can help teachers by providing timely and flexible guidance on individual responses in a variety of web-based settings, but the design of effective automated guidance remains underexplored. Most automated guidance is specific, identifying incorrect ideas or providing correct answers on problems (Chase & Houmanfar, 2009). This type of guidance could help students fix their responses, but it may encourage students to change their answers without improving their understanding of the concept. Designing guidance that promotes inquiry processes could support students in distinguishing the newly acquired ideas from their initial views to formulate a more coherent understanding of complex scientific processes. For instance, guidance that suggests ways for students to improve their work, such as by pointing to a helpful resource, can prompt students to actively identify gaps in their knowledge and search for relevant information to revise their work (Chi et al., 2001). In this study, we compared specific guidance to inquiry-oriented guidance aligned with knowledge integration (Linn & Eylon, 2011) to help middle school students revise student-generated concept diagrams and improve their understanding of energy flow in life science in web-based inquiry units.

Methods

202 students from eight 7th grade classrooms were assigned to either a *specific* guidance (N=109) or a *knowledge integration (KI)* guidance condition (N=93). They worked in pairs for 13 days on two web-based inquiry units on photosynthesis and cellular respiration. Designed following the knowledge integration framework (Linn & Eylon, 2011), the web-based units consist of inquiry activities that help students develop an integrated understanding of energy flow in life science (Ryoo & Linn, 2014). Before, immediately after, and three months after the study, all students individually completed pre-, immediate post-, and delayed post-tests online. 30 students who missed one or more tests were excluded from our analyses.

At the end of the second unit, students were asked to create a concept diagram showing how plants get and use energy from the sun using a computer-diagramming tool called MySystem (Ryoo & Linn, 2014. This formative assessment activity requires students to make connections among various energy concepts to demonstrate their integrated understanding of how energy flows in life science. Once students submitted a diagram, MySystem immediately generated automated adaptive guidance based on scientifically valid connections among core energy ideas in students' responses and encouraged students to revise their diagram. The specific guidance identified precisely what to improve in the diagram, whereas the KI guidance suggested going back to a relevant visualization step to locate the evidence needed to improve the diagram (see Figure 1).

Results and Discussions

We scored each pair's initial and final diagrams using a KI rubric designed based on elaborated links among normative energy ideas. To examine the effects of specific (pair n=55) and KI guidance (pair n=47) in helping students revise their concept diagrams, we compared the two conditions' final diagram scores using an analysis of covariance (ANCOVA), taking their initial diagram scores as a covariate. The results revealed a significant main effect of condition, $F(1,99)=6.64$, $p<.05$, $\eta_p^2=.06$, indicating that the KI group performed significantly better on the final diagrams than the specific group. More specifically, 70.2% of the KI group took advantage of the guidance to add target energy concepts and successfully improved their depiction of energy flow. However, 52.7% of the specific group did not make any changes that led to improved understanding. Although specific guidance told students exactly which energy ideas to add or fix, students still had to determine how to visually represent those ideas using icons, colors, and labels in their diagrams (see examples in Figure 1).

To better understand why KI guidance was more successful than specific guidance, we analyzed each

pair's log data. We focused on how they used the guidance to revise their diagrams. As expected, the KI group (74.5%) was more likely to revisit visualization steps, as recommended in the guidance, than the specific group (3.6%), $F(1,100)=117.04$, $p<.001$, $\eta_p^2=.54$. Despite the recommendation, 25.5% of the KI group revised their diagram without revisiting. When comparing students who revisited and did not revisit visualization steps in the KI condition, we found a significant effect of revisiting visualizations, $F(1,44)=4.47$, $p<.05$, $\eta_p^2=.09$, indicating that students who revisited made higher learning gains than those who did not. This suggests that KI guidance encouraged students to revisit visualizations to reintroduce important key concepts, which allowed students to identify gaps in their initial understanding and actively search for useful information to improve their work.

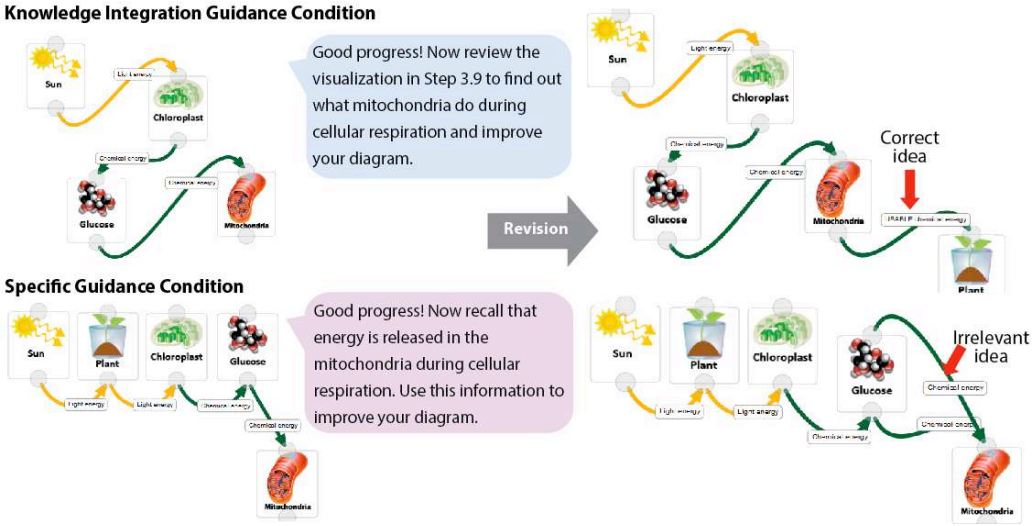

Figure 1. Initial and Final Diagram Examples of Two Pairs by Condition.

To examine the effects of specific and KI guidance on individual students' learning, we conducted ANCOVA on the immediate and delayed post-tests with pre-test scores as a covariate. The results revealed a significant effect of condition for both the immediate, $F(1, 169) = 8.92$, $p < .01$, $\eta_p^2 = .05$, and delayed post-tests, $F(1,169)=5.44$, $p<.05$, $\eta_p^2=.03$. The KI group demonstrated a significantly more durable understanding of energy flow in life science than the specific group by connecting multiple energy concepts. Benefits of revisiting visualizations were also observed on the immediate post-tests, $F(1, 79) = 6.76$, $p < .05$, $\eta_p^2 = .08$. Students who revisited visualizations in the KI condition continuously performed better on the post-tests than those who revised their diagrams without revisiting the visualization steps. However, the difference between the two groups was not statistically significant on the delayed post-tests, $F(1,79)=2.37$, $p=.13$, $\eta_p^2=.03$.

Conclusions

This study shows the value of automated adaptive guidance that promotes inquiry processes for students and clarifies how middle school students took advantage of such guidance to improve their work, compared to specific guidance. The results of the study suggest that knowledge integration guidance can serve students learning by encouraging them to diagnose problems with their responses and use evidence from the unit to revise their work. This study offers promising directions for the design of automated guidance that can encourage students to autonomously sort out their ideas and improve their science learning.

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