Science Teacher Questioning While Students Learn with Simulations

Robert C. Wallon and Barbara Hug

University of Illinois at Urbana-Champaign

Abstract

The purpose of this exploratory study was to classify the types of questions a science teacher used to support students while they learned with a digital simulation that ran on NetLogo software. An audio recording of a high school biology teacher's interactions with students was transcribed, and teacher questions were interpretatively categorized using Mortimer and Scott's (2003) framework. Teacher questions were also inductively categorized as primarily relating either to using the software or developing conceptual understanding. More authoritative rather than dialogic questions were used, especially when the teacher provided support for using the software. One implication is the importance for students to receive training on simulation software features so that the teacher can dedicate more time to developing conceptual understanding. This paper discusses other implications related to curriculum development and professional development, including the potential benefit of engaging teachers in an analysis of their own questioning types as a professional development activity.

Keywords: simulations, science education, teacher questioning

Science Teacher Questioning While Students Learn with Simulations

Introduction and Background

Point. Click. Run an experiment. It's easy for science teachers to provide students “inquiry” learning opportunities by using simulations. Simulations are "dynamic computer models that allow users to explore the implications of manipulating or modifying parameters within them" (Honey & Hilton, 2011, p. 2). They allow students to “observe, explore, recreate, and receive immediate feedback about real objects, phenomena, and processes that would otherwise be too complex, time-consuming, or dangerous” (Bell & Smetana, 2007, p. 23). In addition to these benefits, many simulations are freely available online.

But can simulations inspire learning as effectively as more traditional or hands-on inquiry methods? Smetana and Bell (2011) sought to answer this question by conducting a review of 61 studies on the use of simulations in K-12 and college science classrooms. They concluded that "simulations can be as effective, and in many ways more effective, than traditional (i.e. lecture-based, textbook-based and/or physical hands-on) instructional practices in promoting science content knowledge, developing process skills, and facilitating conceptual change" (p. 1337).

Simulations need "high-quality support structures" in order to be effective pedagogical tools (Smetana & Bell, 2011, p. 1357). Smetana and Bell included teacher direction and questioning on a list of support structures necessary for effective teaching with simulations. They concluded that "the teacher is critical for the successful implementation of instructional technologies and computer simulations in particular" (p. 1359). In the 2011 National Research Council report, *Learning Science Through Computer Games and Simulations*, Honey and Hilton recommended that future research on simulations include studies of how "external scaffolds provided by a teacher, mentor, peers, or other instructional resources support science learning" (p. 124).

Researchers have recently begun to pay more attention to the impact of classroom discourse on student learning in science (Alozie, Moje, & Krajcik, 2010; Scott, Mortimer, & Aguiar, 2006). Mortimer and Scott (2003) have developed a framework for analyzing discourse in science classrooms that classifies interactions between teachers and students along two dimensions. On one dimension talk can be classified as Interactive or Noninteractive, and on the second dimension talk can be classified as Authoritative or Dialogic. The combination of dimensions results in four possibilities: (a) Interactive/Dialogic, (b) Noninteractive/Dialogic, (c) Interactive/Authoritative, or (d) Noninteractive/Authoritative. Using this framework, Scott, Mortimer, and Aguiar (2006) analyzed discourse in the context of "teacher-led lessons" (p. 627). Our work presents a new opportunity to apply Mortimer and Scott's framework while also responding to the call for research on the role of teacher scaffolding in learning with simulations (Honey & Hilton, 2011). We present here a study that investigated the question: What types of questions does a science teacher ask to support student learning with simulations?

The purpose for doing this study was to categorize the types of questions a science teacher used to support students while they learned with simulations. Using simulations has become a common practice in secondary science classrooms, and the practice is likely to grow as the *Next Generation Science Standards* advocate for students engaging in the scientific practice of "developing and using models" (NGSS Lead States, 2013). Communicating the findings of this study to practitioners could help them provide intentional supports via strategic questioning of their students while they engage in learning opportunities with simulations. We believe that this study is also of interest to science education researchers because of the recent growth in digital learning technologies.

The research question was approached from a social constructivist perspective. Specifically, the question relates to the concept of the zone of proximal development, which Vygotsky (1978) defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance..." (p. 86). Based on this concept we assumed that teacher questioning guided students to higher levels of problem solving while they learned with a computer simulation in a science class. This assumption is consistent with the research that says the teacher's role is important for the effective use of simulations in science class (Smetana & Bell, 2011).

Methods

This study was conducted in a mid-sized high school located in a small town near a small Midwestern city. The school student population was predominately white with less than 10% minority students and no race and ethnicity subcategory larger than 5%. The school low-income level was around 25%. The study involved one class of 20 level 2 Biology students.

Students worked with simulations (see *Figure 1*) that were part of a project-based unit that used planarians to teach about biological concepts such as stem cells and regeneration (Project NEURON, 2012).

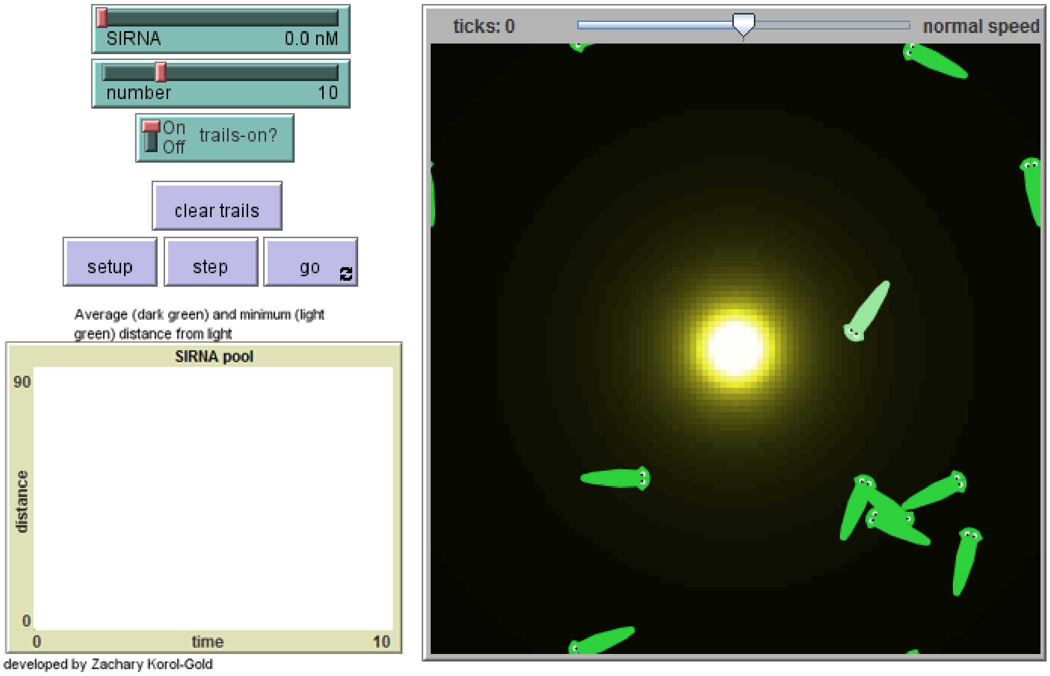

Figure 1. Planarian RNAi experiment 1 NetLogo simulation.

Data were collected from a lesson where students explored the concept of RNA interference (RNAi) using a series of three simulations on NetLogo, an agent-based modeling environment (Wilensky, 1999). RNAi is a technique in molecular biology that can reduce the expression of a gene. Students manipulated variables in the simulations to observe effects on planarian behavior. Planarians are flatworms that have been used extensively as model organisms in the study of regeneration. Students worked on Acer AspireOne laptop computers that were brought to their normal classroom, and they worked in pairs or groups of three at desks that were clustered around the room. The teacher constantly rotated to different groups in the room to provide support to students. The lesson took approximately 40 minutes of one class period to complete.

Audio was recorded throughout the lesson at each student group, and audio of the teacher's interactions with students was also recorded. For this study, audio from the teacher's interactions with students was transcribed. Once transcribed, each of the teacher's questions to students and relevant surrounding text was designated as an episode, and an episode was the unit of analysis.

Then each episode was interpretively classified as either (a) Interactive/Dialogic, (b) Noninteractive/Dialogic, (c) Interactive/Authoritative, (d) Noninteractive/Authoritative, or (e) Noninstructional. This initial classification of teacher questions was based on characteristics described in the literature (Scott, Mortimer, & Aguiar, 2006). To summarize, an episode was coded as interactive if there was a meaningful verbal exchange between teacher and student. An episode was coded as noninteractive if only the teacher talked, and there was no meaningful response from the student. An episode was coded as authoritative if the teacher's question was used to convey one perspective or one right answer. An episode was coded as dialogic if the teacher's question was used to convey multiple possible perspectives. Episodes that did not fit the categorization described in the literature and served other purposes such as classroom management were classified as Noninstructional.

Each instructional question was also classified as relating to either (a) use of the software or (b) learning the intended concepts. This second classification resulted from the initial inductive analysis of the transcript. An episode was coded as relating to software if the teacher's question was primarily concerned with highlighting some feature of the software. An episode was coded as relating to the concept if the teacher's question was primarily concerned with developing students' conceptual understanding.

Both the first author and the second author independently coded each episode and then resolved all discrepancies through discussion. A tally of each question’s classification was made in Microsoft Excel, and then totals were tabulated.

Results

In this study, the science teacher asked 58 questions while students used simulations. The most prevalent type of question asked was classified as Interactive/Authoritative, followed by Interactive/Dialogic, Noninteractive/Authoritative, Noninstructional, and Noninteractive/Dialogic, respectively. Approximately 35% of the instructional questions related to using the software, and approximately 65% of the instructional questions related to developing conceptual understanding. The number of each type of question is listed in *Table 1*.

Table 1
Classification of Teacher Questions

	Question focus		
Question type	**Software**	**Concept**	**Total**
I/D	1	15	16
N/D	0	2	2
I/A	10	14	24
N/A	8	5	13
N	--	--	3

Note. I/D= Interactive/Dialogic. N/D= Noninteractive/Dialogic. I/A= Interactive/Authoritative. N/A= Noninteractive/Authoritative. N=Noninstructional. Each instructional question was also classified as relating to using the software (Software) or developing conceptual understanding (Concept).

Discussion and Implications

Examples of dialogue from the transcript that were classified in each category are listed in *Table 2*. Interestingly, most questions that supported students' use of the software were authoritative. Just as interesting, most of the Interactive/Dialogic and Noninteractive/Dialogic questions appeared to guide development of students' conceptual understanding. The Interactive/Authoritative questions, which were asked most frequently, were used to guide both students' use of the software and development of their conceptual understanding.

Table 2
Example teacher questions from each category in which they were classified.

Question type and focus	**Example Teacher Question**
Interactive/Dialogic, Concept	Teacher: So what do you think is happening with this siRNA?
Noninteractive/Dialogic, Concept	Teacher: Talk more about that. What's been affected? Is it just speed? Do they have a problem with their photoreceptors? Is it something to do with orientation? How they move? What can you tell?
Interactive/Authoritative, Software	Teacher: Down here is the graph. Did you notice that?
Interactive/Authoritative, Concept	Teacher: So did the amount of the RNAi actually make a difference?
	Student: Yeah. The higher, the less their photoreceptors were.
	Teacher: Right, so it's actually inhibiting the gene.
Noninteractive/Authoritative, Software	Teacher: When you go down you can compare these are the control brown planarians, and these are going to be the four different experimental treatments. Okay?
Noninstructional	Teacher: Am I overwhelming you guys with all the work?

It is not surprising that so many questions were Interactive, given the arrangement in which the teacher rotated to different groups of students while they worked with the simulations. It was surprising, however, to see the abundance of questions that were Authoritative. Even though Dialogic discourse is rare in science classrooms, the structure of the activity seemed inviting to the consideration of multiple perspectives (Scott, Mortimer, & Aguiar, 2006). One possibility is that more Dialogic discourse could have occurred between students while they worked, while interactions with the teacher were more Authoritative. Another possibility is that despite being open-ended, the simulations were designed to work within certain parameters, which may have constrained the possibility for consideration of multiple perspectives. One should note that Dialogic discourse should not be valued over Authoritative discourse as Scott, Mortimer, and Aguiar (2006) argue that both types of discourse are necessary for meaning making in school science. But because Dialogic discourse was strongly associated with attempts to develop students' conceptual understanding in this study, future research can examine the outcomes of shifts toward more Dialogic discourse while students learn with science simulations. Additional data analysis is currently being set up in order to explore this possibility. Audio recordings of individual student groups will be examined for the type of conversations that followed different types of teacher questions.

This study has several implications for the use of simulations to teach science. First, it is important to train students to use the simulation interface. Almost all of the teacher's supporting questions that related to using the simulation software were Authoritative. If students were more familiar with the simulation software, the teacher could spend more time engaged in Dialogic discourse.

Second, analysis of one's questioning types could be a valuable professional development activity for teachers. A teacher cognizant of the content of his or her questions could be sure to follow up a software question with a conceptual question (*e.g.,* Now that you know how to increase the number of mutant planarians, why do you think they are behaving that way?). Knowledge of discourse styles could also help teachers intentionally use questions that would help students develop conceptual understanding.

Third, curriculum developers should support teachers in using Dialogic questions. One way is to provide Authoritative support to students with technological scaffolds (Quintana et al., 2004). Another way is to provide examples of Dialogic questions that teachers could use to help students consider multiple perspectives in the context of the learning activity.

This study is limited by the fact that it involved one teacher. Different teaching styles and amounts of experience may influence the types of questions a teacher asks.Another limitation of the study is that it involved analysis of teacher questions only. The framework could also be used to analyze student questions (Scott, Mortimer, & Aguiar, 2006). We are currently planning to examine student group audio transcripts because we are interested in the possibility that students may engage in more Dialogic discourse with one another than with the teacher. A limitation of audio recording is that some communication is nonverbal and thus, undetectable unless video is also recorded. Additionally, structuring the unit of analysis around the teacher's questions captured the vast majority of teacher-student interactions, but it did not include simple, direct commands.

Certainly additional research is needed into the supports that science teachers provide students while they learn with simulations. Future work can have a larger impact by including measures such as student group discourse styles and student learning outcomes.

Acknowledgements

The simulation described in this research was developed by Zachary Korol-Gold.

Research reported in this publication was supported by the Office Of The Director, National Institutes Of Health of the National Institutes of Health under Award Number R25OD011144. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

Alozie, N. M., Moje, E. B., & Krajcik, J. S. (2010). An analysis of the supports and constraints for scientific discussion in high school project-based science. *Science Education, 94*, 395-427. doi: 10.1002/sce.20365

Bell, R. L., & Smetana, L. K. (2007). Using computer simulations to enhance science teaching and learning. In R. L. Bell, J. Gess-Newsome, & J. Luft (Eds.), *Technology in the secondary science classroom*. Arlington, VA: NSTA Press.

Honey, M. A., & Hilton, M. (2011). *Learning science through computer games and simulations*. Washington, DC: National Academies Press.

Mortimer, E. F., & Scott, P. H. (2003). *Meaning making in secondary science classrooms.* Maidenhead, UK: Open University Press.

NGSS Lead States. (2013). Next generation science standards: For states, by states (Appendix F). Washington, DC: The National Academies Press.

Project NEURON. (2012). What can I learn from worms? Regeneration, stem cells, and models. Retrieved from https://neuron.illinois.edu/units/what-can-i-learn-from-worms

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences*, *13*, 337-386. doi: 10.1207/s15327809jls1303_4

Scott, P. H., Mortimer, E. F. & Aguiar, O. G. (2006), The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. Science Education, 90, 605–631. doi: 10.1002/sce.20131

Smetana, L. K., & Bell, R. L. (2011). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education, 34*, 1337-1370. doi: 10.1080/09500693.2011.605182

Vygotsky, L. S. (1978). Interaction between learning and development. In *Mind in society: The development of higher psychological processes*. (pp. 79-91). Cambridge, MA: Harvard University Press.

Wilensky, U. (1999). NetLogo. Evanston, IL. Retrieved from http://ccl.northwestern.edu/netlogo/