Talking Is Thinking: Supporting Student Sense-Making Through Discourse and Assessment

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Learning in the classroom is highly influenced by the experiences a teacher plans for students.[1] Concerned that students were not achieving adequate conceptual knowledge during traditional undergraduate physics courses, the authors used the Making Sense of SCIENCE[2] curriculum to tailor a course for 21 pre-service elementary teachers at the University of Mississippi. The organization of instruction, facilitation practices, discussion opportunities, and assessment of content are all important aspects of the learning process.[1] We found the changes we implemented significantly impacted the learning of students enrolled in this course.

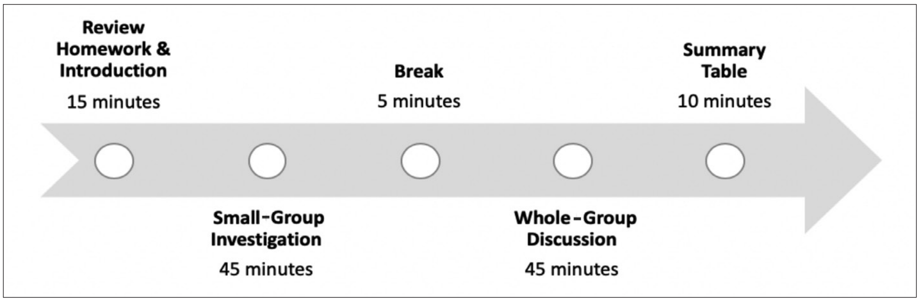

Fig. 1. Class structure and timeline.

Introduction

Reimagining undergraduate physics instruction is not a new idea as many instructional concepts used in the current course have been implemented in other well-known constructivist approaches over the years.[3-6] For example, the Investigative Science Learning Environment (ISLE) method uses many of these processes—including phenomena, multiple representations, purposeful introduction of vocabulary, and small group discussions—to promote interactive learning.[3] University Modeling Instruction (UMI) focuses on using multiple models to build mental constructs through the introduction of phenomena and leading into student discourse to organize student thinking.[4] Physics and Everyday Thinking (PET) incorporates prior learning, multiple interactions with learning tools, and specific expectations in the science classroom to build the complex processes of learning.[5] Ambitious Science Teaching (AST) is an instructional model many have adopted for the science classroom that focuses on engaging students in purposeful scientific talk to make sense of the world they are studying.[6] We chose to use Making Sense of SCIENCE as we felt the facilitation guide for instructors was one of the best we had seen or used and thought this would support future instructors of this course well.

Instructional model

Although traditional science courses follow a lecture-lab-assessment-repeat pattern,[7] each day in this course begins with an investigation completed in small groups (Fig. 1). Like UMI, labs are embedded within this course instead of occurring separately from instruction. Classes meet twice a week for two hours each session. Students read content notes before class to provide background knowledge for investigations while session reviews are read after class to solidify their learning. Throughout the year, each lesson is designed to help students form big picture connections by having them relate content to the driving question for this course, "What do forces, matter, energy, and waves have to do with the interactions that happen in our world?" Whole-group discussion follows small-group investigations and brings together ideas raised in small groups while making learning visible through charts and summary tables. Like the PET curriculum, this course involves interactions with learning tools and with other students to encourage construction of physics concepts. Although end-of-unit assessments are still used, formative assessments occur throughout the lesson to facilitate learning as needed.

Within this course social constructivism serves as a guiding framework for how students learn.[8] It suggests students learn best by interacting with others to make sense of new concepts, thereby constructing their own learning.[8] Specifically, situated learning recognizes that learning is contextualized within experiences, including the social, ethical, and historical norms under which these interactions occur.[6] It asserts that an individual's understanding of a concept is constantly under construction and is influenced by every experience encountered.

Facilitation practices

Promoting student collaboration and allowing students to carry discussions for the majority of class time can seem daunting; however, this is the result of more than just content-related instructional planning. To truly facilitate learning, teachers must choose to be the "guide on the side" in response to ongoing examination of student interactions. Resisting the urge to constantly address the whole group with direct instruction allows students the chance to struggle through their own thought processes and reach conclusions they will be able to defend in class discussions.

The facilitator guide for the course emphasizes several best practices in science education that fall into two main categories: developing a community of inquiry and supporting sense-making (Table I).[9] Developing a community of inquiry includes establishing group norms, working to connect with

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Table I. Guiding principles to support student sense-making.

Principle	Description	Example
Focusing on evidence-based conversations	Refer to data, talk from evidence, repeat phrases from student work	*I noticed that you mentioned the phrase "…" which leads me to believe "…"*
Making student thinking visible	Encourage detailed descriptions of student thinking	*Encourage students to reference charts while they are explaining an idea. Ask students to relate their ideas to previous comments.*
Soliciting multiple ideas	Allow time for many answers from different viewpoints, encourage the sharing of several representations and mental models	*Increase wait time after asking for student responses. Always solicit one more response before moving on.*
Separating individuals from ideas	Document shared ideas (both right and wrong) on chart paper, discuss ideas without referencing those who contributed them	*Notice how the third idea on our list recognizes this aspect but the first one did not address it.*
Exploring ideas with words, actions, images, and symbols	Encourage different forms of communication while sharing ideas	*Draw a picture. Create a diagram. Simulate a process.*

Table II. Examples of discourse moves.

Discourse Move	Description	Example
Probing	Eliciting various student experiences and initial ideas on a topic; making student thoughts public but not evaluating them	*What experiences have you had with … ? What did you notice happening? Can you tell me more about … ?*
Pressing	Holding students accountable for their thinking	*Can you provide evidence for that thought? Why do you think that way? What equipment and data would we need to prove what you're claiming?*
Re-voicing	Rephrasing a student's statement for clarity or to connect common and scientific language	*When DeShawn talked about warm air rising and cold air sinking, he was describing convection.*
Prompting	Helping students use the language of science with one another	*Can anyone restate Anna's idea in your own words? Does your idea raise any questions about what Melea shared earlier?*
Putting an idea on "hold"	Respecting off-topic comments while keeping the discussion moving forward	*That's an interesting thought and one that will tie in more with our next chapter. For now let's keep discussing this aspect.*

students, creating an inviting tone, and being comfortable with disequilibrium. To support sense-making, the guide suggests five principles for instructors to follow: focusing on evidence-based conversations, making student thinking visible, not stopping at one idea but soliciting multiple ideas for the group to consider, separating individuals from ideas, and exploring ideas with words, actions, images, and symbols. The instructors in this course strove to develop a community of inquiry for the class and to implement these five principles on a daily basis.

Emphasizing & facilitating discourse

As in other pedagogical approaches such as UMI, ISLE, and AST, discourse plays an important role in the design of this course. Many teachers assume they are prompting students to think by asking questions, but the type of responses they are eliciting from students might not be encouraging deep thought. Without purposeful planning, it is common to fall back on the *initiation-response-evaluation (I-R-E)* pattern of talking to students, as described in Ambitious Science Teaching, where teachers hold control of the conversation.[6] I-R-E typically involves the teacher asking a question with a right answer, a student answering the question straightforwardly, and the teacher evaluating whether the student answered correctly or incorrectly. Table II describes the following specific discourse moves: probing, pressing, re-voicing, prompting, and putting an idea on "hold."[6] There may also be specific discourse moves that are appropriate for small-group and whole-group situations.

Small-group discourse moves

As in previously mentioned instructional models (ISLE, UMI, PET, AST), the purpose of small-group discussions is to let students engage and struggle with understanding the content. Because this approach to instruction differs from traditional lecture, students often feel stuck and need guidance to move forward in their conversations. The course facilitation guide describes situations to help instructors identify where students may have difficulty and provides suggestions to help students move the discussion forward. One strategy includes the connect, empathize, influence, and monitor approach. Instructors should connect with students (i.e., "Other groups have struggled with this concept also"), empathize (i.e., "Maybe the instructions are a bit confusing"), influence their process (i.e., "Let me point out the tricky spots"), and monitor (i.e., "Revisit the group to ensure they have moved forward").

Another example of a small-group discourse move is to show your willingness to help by asking, "How can I help?" when you see a group struggling. Empathize by recognizing that others have also found that concept difficult and offer, "I'm sure we can figure this out together." Influence their process by asking them to talk through how they arrived at their current understanding so you can catch any missteps along the way. Monitor the group through

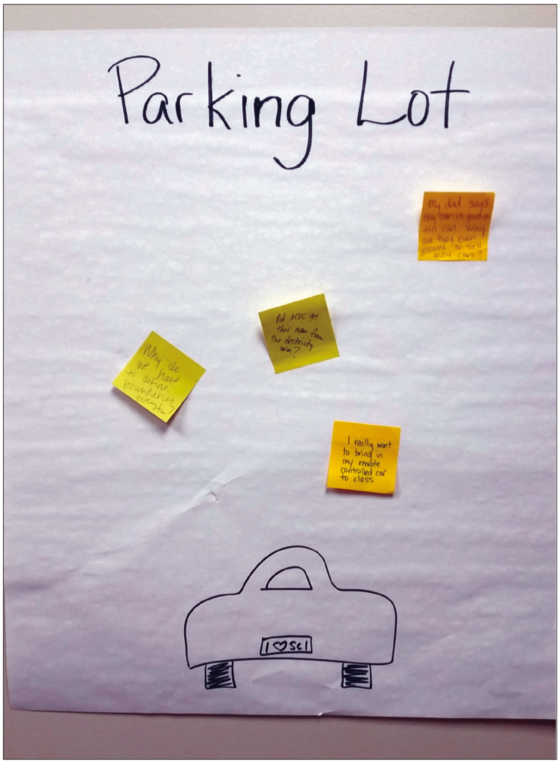

Fig. 2. Parking lot.

observation and ask if they would be willing to share with the whole group how they corrected their thinking.

Whole-group discourse moves

Keeping larger groups focused during classroom dialogue presents a different set of challenges. In this course, we kept students sitting in their small groups throughout the whole-group discussion. Doing so allowed us to provide space for students to consult with one another as needed throughout the whole-group discussion. As part of the discussion, students were also participating in developing and creating public records from their investigation. Keeping public records can support student thinking as they can refer back to those records and continue their learning of a concept.[6] It also provides focus for the discussion and may help with keeping students engaged and on task.

While whole-group conversations can be very rich, off-topic comments can quickly derail the direction of the discussion. The instructor should acknowledge input from each student but ultimately exert the authority to include it in the current conversation or save it for another time. One discourse move to keep things on track is putting an idea on hold through the use of a “parking lot” (Fig. 2). When a student makes an off-topic comment, guide them to write it on a sticky note and place it on the parking lot poster. Be sure to address these at the end of each day or at the start of the next class. This ensures students see their ideas are valued while building a community of inquiry and moving the discussion forward.

A parking lot is a space set aside in the classroom for students to post questions they have. These can be tangential questions that do not need to be immediately addressed, questions students don’t want to ask out loud, or questions that come up when class is finished. Teachers can also suggest students post a question in the parking lot if they think a question may confuse other students or if they need more time to think about it before answering. These questions should be addressed at the end of the class or the beginning of the next class, but do not necessarily require a long answer. However, if ideas need to be put on hold for longer, that is completely appropriate. It is just important to communicate that delay in answering the question with students.

Another common issue instructors face when facilitating whole-group discussion is encouraging all students to respond thoughtfully when asking non-rhetorical questions. Many students simply play the game of school and have grown accustomed to letting specific students answer all the teacher’s questions. Teachers can easily fall prey to the assumption that the class understands a concept simply because their questions are being answered quickly. To ensure all students have time to think and respond appropriately, teachers can increase the amount of time they wait before allowing students to respond by 5, 10, or 15 seconds. If no one is willing to answer in the whole-group setting, using think-pair-share can provide the opportunity for all students to share their thoughts. After a few minutes of peer-to-peer sharing, open the floor again to whole-group responses.

Assessment

In traditional science courses, assessment occurs at the end of a chapter on a traditional multiple-choice test or through clicker questions embedded within class. These assessments often require little critical thinking from students and do not help them make connections in their learning. Part of the instructional shift in this course involved including formative assessments throughout the lesson and assessing conceptual understanding on summative assessments.

Summary tables

One example of the formative assessment used in the course is the summary table. At the end of each class, students had the opportunity to engage in metacognition and write in their summary tables. During this reflection exercise, students individually recorded what they learned from each activity, how this learning helped them answer the driving question of the course, and how instruction supported or hindered their learning. Instructors read each student’s summary table and gave feedback before the next class. This informed instructors of where students were struggling and helped students build confidence and feel supported in their learning.

Summative assessments

Although recall questions were included on each summative assessment to measure factual knowledge, open-ended questions were also used so students could explain concepts in their own words. Students were provided opportunities to draw their thinking in addition to writing a narrative in response to these items. Many students successfully chose to convey their thinking in this manner, performing better on conceptual, open-ended questions than on recall questions.

How did it work?

Students involved in this course showed significant gains in their understanding of waves, forces and motion, energy, and overall physical science content knowledge.[10] Students in this course also maintained their level of understanding in waves, energy, and overall physical science content knowledge one semester later, showing their retention of the material. The only significant gain in the control course was on the concept of energy. There were 21 students in the treatment course and 18 students from the control course who agreed to participate in the research. Content knowledge was measured through the validated Making Sense of SCIENCE Assessment that was aligned with the content and curriculum taught in both courses.

Interview data from students participating in this course showed that investigating in small groups before discussing as a whole group, having a meaningful textbook, and building big picture connections impacted their understanding of the physical science content. By embedding the lab at the beginning of each day, students had concrete learning experiences to draw from as they collaboratively made sense of abstract concepts during small-group and whole-group discussions. Reading content notes before class helped situate students' learning for the day, and science reviews provided further clarification of concepts covered in class that directly related to students' experiences. Because this course was designed to help students build meaningful connections across topics in their summary tables, students were able to make more sense of the material they were learning and see the interconnectedness of different topics.

Conclusion

The organization of course instruction, facilitation practices, discussion opportunities, and assessment of content each played an important role in our students' ability to make sense of science content. The authors found that incorporating science investigations at the beginning of class, utilizing discourse moves in both small-group and whole-group settings, and formatively assessing throughout each class resulted in greater retention of conceptual understandings over time. Making the shift from a lecture-lab-assess model to investigate-discuss model with assessment throughout is one change all teachers can make to support student sense-making in the science classroom.

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