Objectives and Theoretical Framework

In scientific disciplines, students experience difficulty understanding the interaction between the component and system levels in a complex system (e.g., Chi, 2005; Hmelo-Silver, Marathe, & Liu, 2007) and the relationships between multiple representations of each level (e.g., Johnstone, 1993; Stieff & Wilensky, 2003). Often, system components do not share characteristics across levels that have different ontologies (Chi, 2005; Duncan & Reiser, 2007). As such, understanding the relationship between representations and concepts is challenging. Students struggle not only to identify relevant information in representations (Cox & Brna, 1995) but also to coordinate information across levels to explain a complex system. Coordinating information across levels is often complicated by '*levels-confusion*' (Wilensky & Resnick, 1999); that is, students mistakenly infer that characteristics applicable to one level are appropriate to another level. In particular, students often demonstrate levels-confusion in chemistry, which concerns learning about multiple levels with multiple representations (e.g., Albanese & Vicentini, 1997). In chemistry levels-confusion is not merely attributable to the challenges associated with reasoning about processes that occur on different scales (Johnstone, 1982; Rappoport & Ashkenazi, 2008). Rather, levels-confusion in chemistry arises when reasoning across levels that differ in ontologies; objects and processes that exist on one level of description do not exist on another level. Thus, levels-confusion in chemistry results not only from the misapplication of characteristics across levels, but also from the misattribution of ontologies across one or more levels.

Although the difficulties associated with understanding the different ontologies among levels can account for levels-confusion, it is unclear how levels-confusion occurs among students who learn chemistry from teachers with strong pedagogical content knowledge and well-designed curriculum materials. Prior analyses of teacher-student discourse practices in science classrooms that examine teachers' epistemic moves and the processes by which interlocuters reach intersubjectivity provide a useful framework to examine how levels-confusion is generated and resolved. First, analyses of shared participatory frameworks and intersubjective states of agreement among discussants (Nathan, Eilan, & Kim, 2008) can illuminate when teachers and students do (or do not) agree on the ontology of levels. Second, understanding how teachers use discursive practices to help students learn chemistry (Lidar, Lundzvist, and Östman; 2006) can provide insight into the specific discursive practices that create and resolve levels-confusion in the chemistry classroom. Of note are the confirming and re-orienting moves that teachers employ to support student-meaning making. *Confirming moves* communicate that students have recognized the correct phenomena and validate students' knowledge. *Re-orienting moves* call students' attention to other information that merit consideration for the activity at hand.

In this proposal, to better understand occurrences of levels-confusion in the classroom we demonstrate the utility of analyzing intersubjectivity and epistemic moves as they occur in one lesson concerning chemical and physical changes. We argue that chemistry teachers, experienced in the domain, reason primarily from a submicroscopic level. However, students, relying on their everyday experiences, reason primarily from a macroscopic level. Specific dialogic interchanges suggest that teachers and students do not readily acknowledge the different perspectives of each other yet specific discursive moves that can mitigate levels-confusion that results when teachers and students are 'speaking across levels'.

Method, Participants & Analytical Framework

Videos from high-school chemistry classrooms were analyzed through multiple phases of close examination. Videos were obtained as part of a design research project developing computer-based chemistry curricula. During the first phase, we reviewed the videos to identify episodes of discussion for close analysis (Erickson, 2006). Specifically, we watched episodes of teaching focused on the introductory concept of the particulate nature of matter. We reviewed 22.5 hours of lessons taught by five chemistry teachers at three different high-schools and identified three episodes of whole classroom discussion for further analysis. We selected episodes in which teachers and students were involved in discussion during a lesson that included references to multiple levels by the teacher. In the second phase, we transcribed the utterances of the interlocutors in the selected episodes. We later added details describing teachers' hand gestures and public inscriptions. These details were inserted and correlated with each utterance to support inferences about meanings and references to levels in utterances with joint consideration of non-verbal expressions.

During phase three, we segmented each class episode into stanzas (Gee, 2005). Within each stanza, we identified the descriptive level (e.g., symbolic, submicroscopic, macroscopic) of each interlocutor by coordinating utterances, gestures, inscriptions, tone and pitch of voice. We attained an interrater reliability measure of .8 on assignment of levels to each stanza. Using Nathan et al.'s (2008) framework, we evaluated intersubjectivity within each stanza by seeking evidence that both the teacher and students referred to a shared level (IS+) or reasoned from distinct levels (IS-). Analysis of stanzas allowed us to investigate the levels to which interlocutors referred in a meaningful block of dialogue and interpret each utterance in relation to proximate utterances and paralinguistic features.

In the final phase we identified the epistemic moves made by teachers as described by Lidar et al. (2006). Confirming moves included the specific utterances, gestures, and inscriptions that teachers made to confirm that students were reasoning about the appropriate level. Re-orienting moves included the set of utterances, gestures and inscriptions that teachers made to guide students to reason about phenomena using a different level than the level currently referenced by the students. Both confirming and re-orienting moves were further classified as implicit or explicit. Implicit moves included indirect references to the level or ontology of the level. Explicit moves included direct references to the descriptive level or the ontology of that level.

Here, we briefly demonstrate the utility of this approach to analyze a class discussion regarding chemical and physical changes in Mr. Darius' classroom at Fieldstone High School. At the time of our study, Mr. Darius had 6 years experience as a secondary chemistry teacher. He had attained a chemistry B.S. and a M.Ed., and he had been teaching at Fieldstone for 2 years. The students in his course were primarily second-year students enrolled in their first chemistry course.

Analysis & Results

At the outset of the discussion, Mr. Darius offers a simple heuristic to determine whether a chemical or physical change has occurred. He states, "the idea is that with chemical changes it's hard, very, very difficult to change it back...with physical changes we can often reverse them back." Although this same heuristic can be found in many chemistry textbooks (e.g., Wilbraham, Staley, Matta, & Waterman, 2000), it does not make explicit reference to any descriptive level.

Consequently, Mr. Darius' students begin to question which level is relevant in the discussion, and Mr. Darius attempts to resolve their confusion be elaborating on two phenomena: making orange juice and exploding fireworks.

Mr. Darius: SQUEEZING oranges to make orange juice? That would obviously be (..)
Students: ((several shouting)) Physical.
Mr. Darius: PHYSICAL, tastes the same. Fireworks EXPLODING?
Students: ((several shouting)) Chemical!
Mr. Darius: CHEMICAL. Why?^
S5: [Because there's a difference in the (?)
S6: [They're exploding!
S7: [EXPLODING!
Marla: [It's exactly the same] as squeezing oranges.>

The students mainly respond that juicing an orange is a physical change and exploding fireworks is a chemical change. Mr. Darius echoes the responses to validate their answers. In this case, Mr. Darius makes implicit confirming moves that the students' are reasoning about the phenomena correctly, but he offers no clear direction on what level is appropriate. In this series of initiate, respond, and evaluate triads, the class has seemingly entered intersubjectivity (IS+) on the ontology of chemical and physical changes. Mr. Darius assumes his students share his ontology (e.g., "that would obviously be") despite the fact that neither he nor the students have made their reasoning explicit. It is only when Mr. Darius asks the class to explain the reason why 'fireworks exploding' is a chemical change that we see more evidence that the class has failed to reach intersubjectivity (IS-). In response, the students' produce teleological explanations (e.g., "They're exploding.") with no appeals to the submicroscopic level, and Marla notes that the fireworks example is "exactly the same as squeezing the oranges." Indeed, on a macroscopic level the act of squeezing an orange and exploding a firework shares some features: both result in irreversible changes to the macroscopic appearance of the original objects, however, these changes result from fundamentally different processes.

Another student, Brian, shouts an incomprehensible question to Mr. Darius that initiates an interchange that further reveals the extent of levels-confusion among the students.

Brian: (?)
Mr. Darius: OH-that's a very good question! So the idea right here is this. He asked a very/ very good question. I can't take the orange juice and make an orange again. (..) You're probably right. You can't reform the orange back to what it was. But when you taste the orange and when you taste the juice does it taste the same?^
Brian: Yup.
Mr. Darius: It does taste the same right?^ So it is really/ really/ the difficulty is correct. So he is correct/ It is very, very difficult to get the orange back. When you squeeze it/ Oh^, how do I get the juice back into the orange!?^ But the thing is that you're basically tearing it apart. (.) You're not really changing the identity of it. It's still an ORANGE. By the way, fireworks exploding what's an indication that it's a chemical change?^
S9: 'Cause there's an explosion.

Mr. Darius: There's an explosion. So I see fire. Can I get the chem/ can we get the bomb back? Once it explodes, that's pretty much it.

In this interchange, Mr. Darius has claimed that making juice from an orange is a physical change, yet Brian disagrees because an orange, on the macroscopic level, cannot be reformed into an orange once it has been juiced. Thus, Brian reasons this phenomenon must be a chemical change according to the prior reversibility heuristic. Mr. Darius employs an explicit confirming move to acknowledge that Brian's reasoning about the macroscopic level is correct (e.g., "how do I get the juice back into the orange?). Mr. Darius then appeals to the submicroscopic level with an implicit re-orienting move to the relevant ontology of particles (i.e., "you're not really changing the identity of it"). Instead of relying on the macroscopic properties of the orange, Mr. Darius tries to convey that the submicroscopic level is the more valid descriptive level to use for evidence. Mr. Darius provides strong evidence that he himself is reasoning from the submicroscopic level when he begins to mentions particles directly (i.e., "chem[icals]"). Assuming that his explanations have brought the class into agreement (IS+), Mr. Darius revisits the firework example and his students indeed appear to agree on the relevant ontology. However, we believe that even though Mr. Darius and his students have reached some surface-level agreement, they continue to reason from different levels (IS-).

Conclusions and Implications

By adapting the analytical framework of Nathan et al. (2008) and Lidar et al. (2006), we have demonstrated that teachers and students face significant challenges reaching intersubjective agreement about the ontology of chemistry and the level relevant to a given discussion. Teachers and students enter discourse spaces predisposed to reason from different levels comprising distinct ontologies, yet each does not readily acknowledge the lack of intersubjectivity in their discussion. This present work illustrates how specific discursive moves can foster (e.g., explicit re-orienting moves) and hinder (e.g, implicit confirming moves) intersubjectivity. In different ways, teachers can encourage students to consider phenomena and processes that occur on the submicroscopic level, as well as discourage students from considering macroscopic phenomena. Primarily, our analyses indicate that the distinct levels of reasoning maintained by teachers and students are often tacit. Students and teachers appear to understand one another as they assume the other is reasoning on the same level. We argue that professional development opportunities and curriculum interventions can help teachers make levels of reasoning explicit in the chemistry classroom. In the presentation, we will fully examine two more cases and the entirety of Mr. Darius' discussion as well as offer potential methods to address levels-confusion in whole class discussions.

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