Formulating WISE Learning Experiences

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Abstract: This study reports two cases of computer-supported activity drawn from intact classrooms implementing a Web-based Inquiry Science Environment (WISE) unit in the disciplinary context of global climate change. The two cases contrast balanced and uneven collaboration, and related learning activity. Interactions across scaffolded activity types are also contrasted, finding that narrative explanations provoked greater generativity as compared to other assessment formats. Analyzing the dyadic interactions from a Learning as a Member Perspective (LAMP) (Stevens, 2010), interactive visualizations emerged as much richer sources of learning opportunities, particularly when embedded in inquiry sequences. Design considerations are discussed.

Introduction

Technology enhanced learning commonly involves scaffolds intended to structure student learning through inquiry (Blumenfeld et al., 1991; Edelson, 2002; Quintana et al., 2004). Software scaffolds might guide students through phases of inquiry, such as exploring data, interacting with dynamic visualizations, and reporting findings, or help students track their progress. For instance, the Web-based Inquiry Science Environment (WISE) (Slotta & Linn, 2009) includes an inquiry map. Technology scaffolds may problematize the content (Reiser, 2004) or interrupt the deceptive clarity of a scientific model through activities that cause students to distinguish ideas (J. Chiu & Linn, in press). Pivotal cases, which provide an opportunity for students to restructure their ideas, may be scaffolded as predict-observe-explain sequences, and have been used in WISE units across various disciplinary topics as a means of making science accessible to students.

In a meta-analysis of studies on computer-supported learning, significant advantages were found for collaboration, particularly when completing a difficult task, with mixed-ability groups, and with single-sex groups (Lou, Abrami, & d'Apollonia, 2001). Technology may scaffold collaboration in numerous ways (e.g., Rummel, Spada, & Hauser, 2009)and this has been shown to be beneficial to developing integrated understanding (Bereiter & Scardamalia, 1989). The interactions may be logged when the technology also provides communication for physically distributed collaborators, but in face-to-face interactions between two participants using one computer, de facto collaboration cannot be assumed, even when deliberately scaffolded (Nussbaum et al., 2009). With co-located groups, interactions are reportedly very diverse (Volet, Summers, & Thurman, 2009). In such cases, "reciprocal interaction" (Rummel, et al., 2009, p. 72) may occur when there is symmetry in learning-related interactions (Dillenbourg, 1999). To evaluate the quality of collaboration, various dimensions have been identified: communication, information processing, coordination, interpersonal relationship, and motivation (Meier, Spada, & Rummel, 2007); problem solving contribution, frequency of participation (Barros & Verdejo, 2000); emotional state; collaboration behavior (Barron, 2003; Barron & Sears, 2002; M. M. Chiu, 2008); and sustaining mutual understanding, dialogue management, information pooling, reaching consensus, task division, time management, technical coordination, reciprocal interaction, and individual task orientation (Meier, et al., 2007). Recognizing the potential for students to differently frame learning when learning technologies are brought into a classroom, and particularly when they face a challenging task, Lantz-Andersson notes the need to analyze how students frame their interactions (2009). This study reports research on computer-supported dyadic activity occurring in middle school classrooms. Rather than assuming these are de facto collaborative learning interactions, two cases are presented to consider how students might (not) formulate the interaction as being a (collaborative) learning interaction. The *symmetry of contributions* across two dyads and across different activities is explored.

Global Climate Change

We designed a WISE unit called Global Climate Change, incorporating NetLogo visualizations (Wilensky & Stroup, 2000) representing the earth and atmosphere. The unit was designed according to the four main tenets of knowledge integration, making the content accessible, helping students learn from each other, making thinking visible, and promoting autonomous lifelong learning (Linn & Hsi, 2000). The knowledge integration pattern involves first eliciting ideas- both normative and non-normative, from the student's repertoire, then adding new ideas, then developing and applying criteria to distinguish ideas. The KI pattern foregrounds connections *between* ideas (Linn, 2006).

Methods

The participants of this study were two dyads drawn from two different intact middle school classrooms implementing the WISE Global Climate Change unit. The dyads were video recorded as they worked through the unit over seven days in 30-40 minute class periods. A high definition video camera was positioned behind each dyad, creating a record of the computer screen, computer usage, gestures that occurred between the two students, and direction the students faced. Thus, in most cases, students' faces were not recorded. Lapel microphones provided high quality audio recording of the conversations, even in the context of a crowded, noisy classroom. Finally, log files provided time-stamped sequences of actions on the computers. Videos were transcribed, including gestures visible between the students and actions taken with the computer, and all names were replaced with pseudonyms. Interaction analysis (Jordan & Henderson, 1995) focused on identifying moments in which students formulated the activity as being about learning, adopting a Learning as a Member Perspective (LAMP) (Stevens, 2010). Stevens argues that learning must "be shown to be a mutual concern of participants" (p. 84). This "endogenic" perspective on learning is useful for understanding the interactions that take place in a middle school classroom using "learning technology." Cases were not drawn with respect to their representativeness of the larger sample, but rather sought for their particularizability (Donmoyer, 1990); thus dyads were deliberately selected from a larger corpus based on individually-completed post-unit interviews. Cases were sought in which both students, and in which only one student could provide coherent explanations of what they had learned. A constant comparison method was used (Vogt, 2002), contrasting the two dyads, and contrasting the interactions across different activities in the unit (Table 1) to understand ways participants *might* or *might not* formulate their activity as collaborative learning.

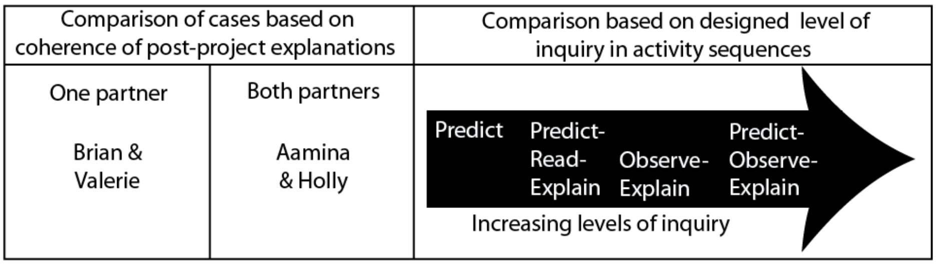

Figure 1. Dimensions Compared across Cases and across Activities.

Students first completed a pretest (Activity 1) in which they made various predictions including a narrative detailing the role of energy, then completed an activity designed to introduce a few key concepts (Activity 2). The remaining activities involved a sequence of interactions with NetLogo visualizations that let them experiment with variables to learn about global climate change (Table 1). Interactions with the first five activities are reported here.

Table 1: Five activities and their structure.

Activity	*1*	*2*	*3*	*4*	*5*
Predict	X	X	None	X	X
Observe	None	Text and figures	Solar radiation NetLogo	Albedo NetLogo	Atmosphere NetLogo
Explain	None	X	X	X	X

Results

Brian and Valerie: Uneven Collaboration

In their post-unit interviews, Brian provided a coherent explanation, including mechanisms and evidence, for global climate change, whereas Valerie struggled to explain even simple relationships from the unit, leading to a question of the origins of these two partners' very different understanding. For this case, gender roles may seem particularly salient. In transcript 1, for instance, as Brian and Valerie write a story to explain how the earth is warmed by energy, Valerie quickly abandons an accurate idea, then prompts Brian to provide a correct answer, which is arguably less accurate than her answer, then she affirms his answer. Although this interaction is not rich in terms of learning, it does lead Brian to hesitate and break ("and it moves? (.) How does it move?") from the routine process observed when answering more traditional multiple choice assessments, in which he quickly identifies the an answer and is confident on what is expected in terms of explaining his answer ("Yeah.

((indicating an answer)) And then say, like, that is the one we chose because, one day, means that global, global climate is heating up. It would have to be a long period of time.").

Transcript 1

B: ((reading)) 'Write a story to explain to Gwen how the earth is warmed by energy. Be sure to include: Where energy comes from::, How energy moves, Where energy goes, How energy changes/transforms.' °okay ° So ener:: energy (0.9) ((beginning to type as he speaks)) comes (.) from (2.1) the (1.8) sun (2.2) and it moves (1.2) How does it move?

V: ((shifting computer towards herself)) It moves (.) in waves ((looks at B for confirmation, then very quickly shifting)) Just kidding! ((covers face, both laugh)). Um, you should know this.

B: Well, you should also.

V: I already did, I (inaudible) waves. ((she pokes him in the arm, then smiles))

B: I don't. (2.4) Energy comes from the sun and it moves (1.5) in rays.

However omni-relevant gender may be to these interactions, we can also observe other, perhaps more subtle, differences in how they interact as they move across the unit, engaging with inquiry activities that elicit their ideas, add new ideas, prompt for reflection and criteria-generation, or distinguishing ideas. Across these interactions, the roles the two students adopt vary, as do the interactions they have in relation to differing types of assessment steps and across sets of inquiry activities. For instance, Brian vacillates between two primary roles, teacher and learner. However, much of Brian's "teaching" is not framed by an inquiry perspective. We can see various instances in which Brian adopts a teacher-as-task-master role, prompting Valerie to read aloud ("You read that part"), trying to get her back on task ("So some of 'em get deflected and some go in the earth and then -- Valerie!" and "So the purple ones -- Valerie! -- the purple ones are radiation"), giving directives related to being a good student ("Let's listen to her ((the teacher))"), and correcting her spelling and pronunciation. For instance, as she is sounding out *infrared,* he says *inferred* and thereafter they talk about inferred energy. Some of Brian's prompting of Valerie is about learning ("Don't just guess").Valerie sometimes formulates her role matched to Brian's, as a task-completer, checking a box as instructed, typing what Brian says, and taking his directives. However, there is also evidence for Valerie formulating the situation to be about learning. When she asks a question (Transcript 2), Brian is busily engaged with his own learning and does not acknowledge her question (meaning he sometimes switches to a learner role). They attend to different aspects of the NetLogo visualization, such that although they are both in learner-roles, their learning cannot be considered collaborative.

Transcript 2

B: And then some go in the earth and create those little things or some (.) and then they go out in heat rays (3.9) Whoa. (1.9) Look how fast they're going! ((Nudges V, they both laugh briefly. They click *watch a sunray* and follow its progress))

V: ((pointing to the screen)) Uh-huh. Cool. ((inaudible)) could never go that fast.

B: (16.9) Watch a sunray. Oh so those are the sunrays. ((pointing to sunrays)) That one went in but now it's ((his finger traces an expected path with the energy leaving the earth but the energy stays in the earth)) But now?

V: [What about that green line? ((pointing to land surface))]

B: [Now] Now it's doing conduction and now it went out as a heat ray. Okay.

As Brian and Valerie work on the albedo NetLogo, which is more inquiry-oriented than the previous activities, their interaction shifts as they both adopt learner roles (Transcript 3). While Brian remains unsure of what type of energy is being represented, Valerie simply describes the shapes (e.g., purple triangles) but in doing so, recognizes an important relationship that Brian had missed, that the "purple triangles" (infrared radiation) become sparse when there is high albedo. In this case, attending to differing aspects of the visualization is productive, at least for Brian who integrates his own understanding with Valerie's observation when answering an Explain prompt (Transcript 4).

Transcript 3

B: It looks like the energies are ((pointing at the screen)) or whatever that ((indicating yellow triangles)) the solar radiation goes down, then up.

V: Ummhmm ((agreement))

B: ((clicks *reset*, then clicks *farms* again)) Farms.

V: Or like when the yellow ones are going down the purple ones are going up ((pointing up towards ceiling then down)) and when the yellow ones are going up the purple ones are going down

B: Farms ((clicking *reset* then *farms* again)) Most of 'em (1.4) aren't getting absorbed=

V: =Umhm.
B: Er:: well. °Depends° (((21.0) clicks *desert* then clicks *reset* them clicks *desert* again, V leans in, B clicks *watch a sunray* and it reflects, clicks *watch a sunray* and it is absorbed)) So this one, for desert, it's going down. (10.2) Just keeps on going down (8.1) Okay! (((19.1) clicks *reset* then clicks *ice*, then clicks *ice* repeatedly- he does this each time- click-click-click-click-click then *reset*s, then clicks *ice* again. Drags *slider* again making albedo first low then back to high)) Okay it's ((referring to temperature)) going down. Look at it go.
V: Wow. (12.9)
B: ((clicks *watch a sunray*, which reflects))
V: There's like, no more purple ones.
B: Oh, ye::ah.(1.7) Not a lot of 'em are getting absorbed (.) It's reflecting it.

Transcript 4
V: ((reading)) 'Which of the following environments had the most [ener.
B: [Oh! The purple things! Well it wasn't the ice. The ice barely had any!

Aamina and Holly: Balanced Collaboration

In their post-unit interviews, both Aamina and Holly provided coherent, elaborated explanations for global climate change. The interactions between Holly and Aamina are very different from those between Brian and Valerie. Holly and Aamina modify each other's ideas (transcript 5, in which they are answering the same question presented in transcript 1) and negotiate their understanding. This interaction appears much more collaborative, and more frequently seems to be about joint learning.

Transcript 5
A: How energy moves:::s, um, ((taps fingers on edge of computer)) How does it move? Or where does it move? Oh where energy goes. How does it move? Hmm?
H: It moves through radiation? ((looking at A)) (29.7)
A: ((typing)) And then where energy goes?
H: Through the earth's atmosphere.
A: ((typing)) It enters earth's atmosphere::re (.) as heat? ((types))
H: (22.1) Or visible light?

Although the computer use appears to be imbalanced, with Holly more commonly in control of the keyboard, an important difference between the two dyads was observed; whereas Brian assigned tasks to Valerie who generally completed them as instructed, when Aamina directed Holly, she sometimes negotiated the task, or deferred it. For instance, when they begin the activity on albedo, the girls skip past the Observe step, believing it to be a repeat of the earlier NetLogo. When they reach the Explain prompts, Holly realizes they have missed something ("Let's go back"). However, when they reach the NetLogo, Aamina persists in thinking "We already did this," until Holly shows her the NetLogo (Transcript 6).

Transcript 6
A: We already did this. ((reading)) 'What happens to global temperature when you select an environment.'
H: ((scrolling down to the NetLogo, skipping directions))
A: Oh! So you can! ((Pointing at environments)) Let's do ocean.
H: Let's see. ((clicks *ocean*))
A: Let's hit run and then ocean.
H: ((clicks *run*))
A: Ocean.
H: ((clicks *ocean* again then *slows* model speed down))
A: Try to hit one of these ((pointing to environments)) I don't know what it's on right now.

As they continue to work with the NetLogo, Aamina offers directives which Holly accepts or defers. Aamina makes no attempt to take the computer control from her, but occasionally expresses uncertainty (Transcript 6, "I don't know what it's on right now.") in response to Holly's actions. Holly is less vocal than Aamina, but it is the negotiation of the interactions that makes this dyad seem more collaborative. There is evidence that the girls formulate this activity as a learning activity. When Aamina prompts Holly to return to the Explain step (Transcript 7, "So the global temperature decreases? Ok. I think we can go back to 4.4"), Holly acknowledges the suggestion but instead begins a new investigation (Transcript 7, "Yeah. So forest ((clicks *forest*)) Let's reset it and then watch it on forest"), indicating that she was still trying to understand the NetLogo.

There is also evidence that that although they, like Brian and Valerie, attend to different things in the NetLogo, they achieve coordination. For instance, Aamina notices that the NetLogo provides the percent of light each environment reflects (Transcript 7, "Oh! It tells you the albedo up here") while Holly is trying to determine this same information through the *watch a sunray* function. Once this information is shared, both girls move through the environments, sometimes with Aamina prompting, sometimes with Holly clicking. As they do so, they achieve a joint understanding and together conclude correctly that ocean has the lowest albedo.

<u>Transcript 7</u>

H: So, desert. ((clicking *desert*)) Desert. ((clicks *watch a sunray*)) and then ((pointing at screen)) so ice was, like, whitish.
A: Uhhh:::
H: ((clicks *farms*))=
A: =ummhmm=
H: =farms ((clicks *watch a sunray*)) (5.3)
A: So farms doesn't do that much.
H: Farms doesn't do it so we just have to check that one ((indicating and clicking *forest* then clicks *watch a sunray*))
A: Actually I think forest does it less than farms. And the ocean?
H: ((clicks *ocean* several more times, then clicks *forest* then *ocean*))
A: So the global temperature decreases? Ok. I think we can go back to four point four ((the explanation step that prompted Holly to return to the observe step))
H: Yeah. So forest ((clicks *forest*)) Let's reset it and then watch it on forest ((clicks *reset* then clicks *forest* several times, clicks *reset* several times, then clicks *forest* several times then clicks *watch a sunray*))
A: Oh! It tells you the albedo up here ((pointing)) for each one. That's forest, now try ocean.
H: ((clicks *ocean*))
A: Five percent ((still pointing, but moves finger over to *farms*))
H: ((clicks *farms*))
A: Farms 40 percent ((moves finger to *desert*))
H: ((clicks *desert*))
A: Desert's seventy-five percent
H: ((clicks *ice*))
A: Ninety-five percent=
H: =So they're=
A: =so the least has=
H: =ocean=
A: =yeah.

Representing Learning and Collaboration

Models of the dyadic interactions were constructed for the three activities containing NetLogo visualizations (Figure 3). To approximate the symmetry of participation, conversational moves and actions taken (e.g., clicking *ocean*) were covered by grey rectangles, approximating the relative length of turn (and with one members' utterances mirrored). Utterance length in seconds could have been used, but neither method is without flaws; as such the resultant representations are low fidelity models that allow for quick visual check for symmetry. Thus, time progresses from top to bottom, allowing the viewer to quickly judge symmetry, and reducing the likelihood of perceiving one member as positive and one as negative.

Overlain on this, are vertical bars representing computer control; when two bars of equal saturation are present, the computer was being shared, but when one of the vertical bars is of lesser saturation, the computer control was contested. Boxes indicate when students were interacting with a NetLogo visualization, and the sequences of activity are aligned by onset of the Observe phase of activity.

Finally, at the outer edges of the bounding boxes, are blebs indicating points in the transcript in which the students appear to be formulating the interaction as a *learning interaction.* For example, the interactions in transcripts two, three, five and seven were coded as cases in which the participants formulated their interaction as a learning interaction. Not all co-occurring learning interactions are collaborative because in some cases, particularly with Valerie and Brian, the questions they pose or seek to answer are not in a shared problem space. While the accuracy may be low, this approach provides a simple way to visualize potentially interacting dimensions as they unfold over a sequence of activity.

These representations (Figure 3) highlight both the differences between the two dyads, as well as differences across the steps. Most of Valerie's control of the computer is during explanation phases, and a much greater percentage of her interactions with the computer occur as contested, either because she is carrying out Brian's instructions, or because she is struggling to keep/gain control. Although some of the time Holly is in

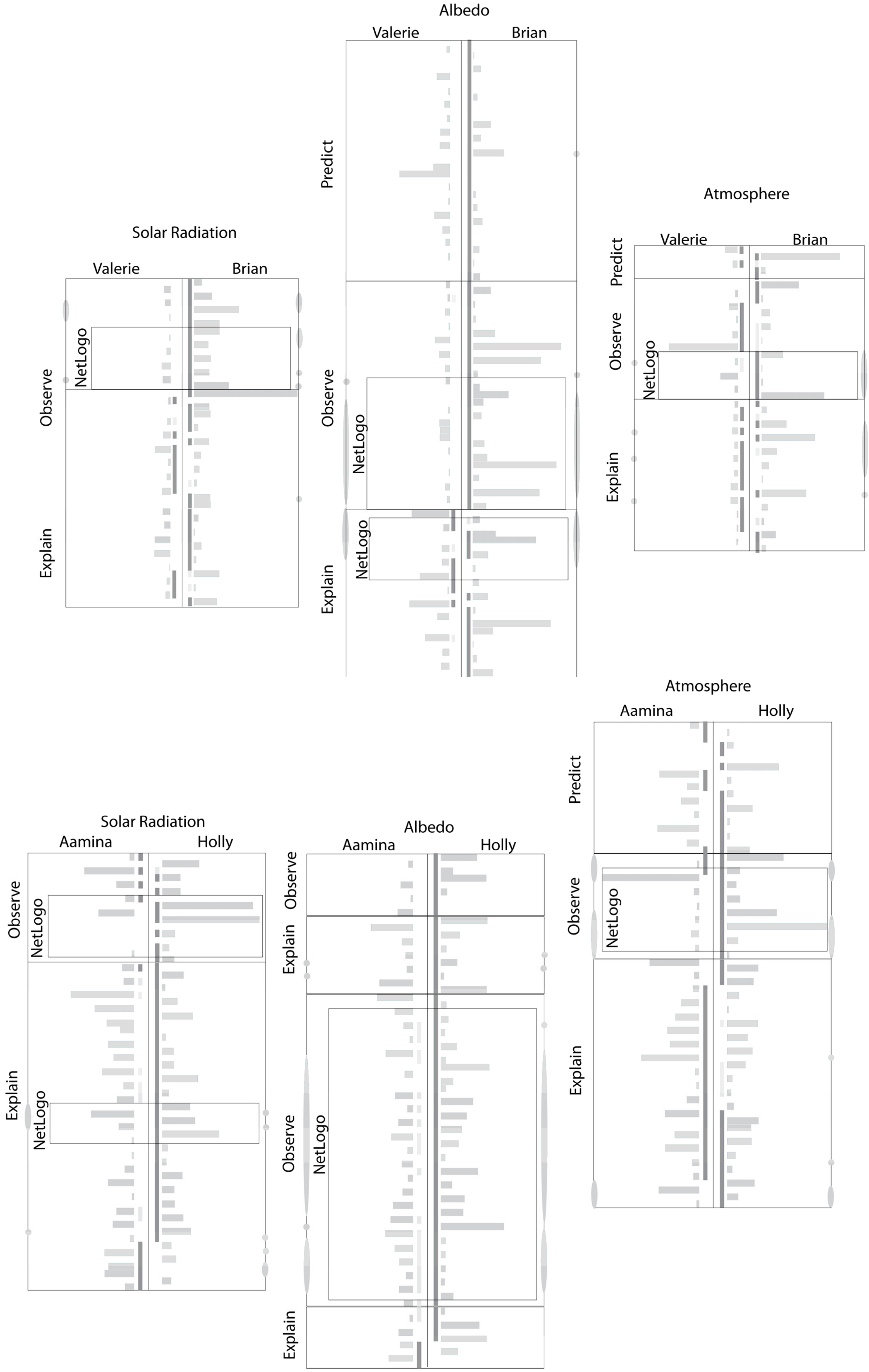

Figure 3. Representations of the Interactions across Predict-Observe-Explain Sequences.

control of the computer (punctuating their exploration of the albedo NetLogo, for instance) this is moderated by her willingness to resist, to renegotiate with her partner. It is also clear that Brian's turns are longer than Valerie's, whereas greater symmetry is seen in the turns taken by Aamina and Holly. Though Aamina is more vocal than Holly, because Holly negotiates computer control, she also contributes, making the interaction more symmetrical.

In both cases, the participants tend to formulate the interactions as learning while using the NetLogo visualizations, particularly when they are working with the more complex albedo and atmosphere NetLogos that are scaffolded by a series of predictions and explanations. In the case of Brian and Valerie, though they concurrently formulate the activity as learning, they do so in an asymmetrical manner, such that only Brian pursues the questions he poses. For Holly and Aamina, though they attend to different aspects of the NetLogo, they jointly pursue questions, resulting in interactions that can be considered to be both collaborative and learning.

Discussion and Implications

As has been noted elsewhere (Volet, et al., 2009), the interactions observed were diverse. In examining symmetry (Dillenbourg, 1999), or "reciprocal interaction" (Rummel, et al., 2009, p. 72) many dimensions provided relevant information for understanding the collaboration. In both cases, computer control is asymmetrical, as are verbal contributions, yet only in the case of Brian and Valerie was the learning distinctly asymmetrical. By adopting a Learning as a Member Perspective (LAMP) (Stevens, 2010), the asymmetry is understood to be consequential for Brian and Valerie; even when both formulated the activity as learning, they held different learning goals, and with Brian both controlling the computer and dominating the conversation, Valerie rarely pursued her questions, and her turns with the computer tended to occur during explanation phases, but functionally she did not explain her ideas; rather, she typed Brian's explanations. Given that teachers commonly encourage students to take turns "driving" the computer, it would be useful to provide guidelines to ensure that both students interact with complex simulations. A simple-to-implement solution might be to include an even number of steps between those containing NetLogo visualizations, though this would not likely have helped in the case of Brian and Valerie. Perhaps, in this case, the findings that mixed-gender groupings tend to be less beneficial is relevant (Lou, et al., 2001). Scaffolding students through a jigsaw activity in which partner is responsible for information that must then be integrated might support better collaborative learning as well, but further work is needed to understand whether such activity would actually interrupt unbalanced collaboration as seen with Valerie and Brian.

In addition to differences across the two dyads, the LAMP framing revealed differences in interactions by the type of prompt and level of inquiry. The narrative assessments are associated with more generative activity compared to the more traditional multiple choice plus explain prompts, the former of which tended to result in more attempts at negotiation, the latter of which were routinized and did not, in these particular instances, provoke discussion. Students have schema for answering such questions, and even when selecting incorrect answers and providing shallow explanations for their answers, students appeared confident in their responses.

The NetLogos that were scaffolded with predictions and observations tended to be associated with learning. While the initial questions students explored tended to be about clarifying the models, as in the first NetLogo, the explanation prompts encouraged the students to revisit the NetLogo visualizations to explore further. What emerges is that the more complex tasks tended to be when students formulated the activity as learning, and also that Holly, Aamina, and Brian all benefited from the observations of their partners, which relates to why previous research has noted an advantage to collaborative learning when completing a difficult task (Lou, et al., 2001).

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