Understanding the affordances of ritualized activity structures for project-based classrooms

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Abstract: We propose that a common system of "ritualized" activity structures that can be used across project-based classrooms can help both teachers and students develop the skills they need for successful project work and successful learning from project work. We further propose that the ritualized activity structures enacted in Learning by Design™ (LBD™; Hmelo et al., 2000; Holbrook & Kolodner, 2000; Kolodner et al., 1998, 2002) provide a significant starting point. We present the idea of "ritualized activity structures" and discuss those used in LBD, summarize our results, and then attempt to explain their efficacy.

Approaches to science education have increasingly incorporated what we know about how people learn (Bransford, et al., 1999) and what we are learning about the power of inquiry, and are often instantiated as project-based models (CTGV, 1997, Kolodner, et al., 1998, 2002, 2003, Barron, et al., 1998, Gray, et al., 2001). Results provide evidence for the effectiveness of these kinds of approaches to teaching and learning (CTGV, 1997, Kolodner et al., 2002). The authenticity of problems and projects make learning more fun and enduring for students. Repeated, deliberative, iterative, and reflective practice of the skills of real scientists promotes their deep learning. Establishing a community of learners that know how to collaborate and distribute their knowledge construction efforts (Brown & Campione, 1994) has been claimed as essential too. While we know much about what's needed for success, it has been exceedingly difficult to make all of these things happen in classrooms. We propose that a common system of "ritualized" activity structures that can be used across project-based classrooms can provide part of the solution. We further propose that the ritualized activity structures enacted in Learning by Design™ (LBD™; Hmelo et al., 2000; Holbrook & Kolodner, 2000; Kolodner et al., 1998, 2002) provide a significant starting point. We present the idea of "ritualized activity structures" and discuss those used in LBD, summarize our results, and then attempt to explain their efficacy.

"Ritualized" Activity Structures

The science education community wants students to learn science concepts so that they can apply them in new situations and to become skillful in the practices of scientists (see, e.g., Zimmerman, 2000). The aim is for students to be able to participate in these practices both inside and outside the classroom. The research literature on how people learn (see, e.g., Bransford, et al. 1999) suggests that public, deliberative, and repeated practice are essential to promoting individual learning. The literatures on problem-based learning (Barrows, 1986) and Reciprocal Teaching (Palencsar & Brown, 1984) suggest that when the same discourse structures are repeated across problems and articulated and discussed, students will come to recognize the repeated patterns and extract out from them guidelines and expectations for participation. As they gain comfort with the discourse structures, they become better able to concentrate on the content of what they are discussing and reasoning about. The repeated discourse structures of problem-based learning become "ritualized" activity structures for students in PBL and Reciprocal Teaching – activities that are carried out repeatedly taking different content into account.

Many in the project-based inquiry learning community have been engaged in designing activity structures for science learning in middle school. For example, Schools for Thought's (SFT) activity structures are at a strategic level (Barron et al., 1998). Students first go through a problem-based phase of learning where PBL's sequencing and activity and discourse structures are used for addressing a well-defined problem. This is followed by a project-based phase where the knowledge and skills learned during the earlier phase are put to work in addressing a more open-ended challenge. SFT also integrates tactical activity structures – at times when students don't understand a reading, they move into a Reciprocal Teaching mode, carrying out a ritualized set of discourse activities in small groups so as to better understand the text. Northwestern's LeTUS group integrates scripted activity structures to guide students through such activities as conducting an environmental assessment of water quality, creating a model of a process such as the spread of communicable diseases, and analyzing data to construct an explanantion. During each of these activities, prompts and scripts are provided to enable students to navigate through open-ended challenges. Learning by Design™ suggests ritualized activity structures at both the strategic and tactical levels. LBD's strategic activity structures ritualize sequencing of activities (e.g., designing, investigating) and tactical activity structures regularize smaller embedded activities (e.g., exploring materials, designing an experiment, making a presentation). Results show that the combination can serve to enculturate both students and teachers into the practices of LBD and help them know what is expected at any time and how to carry out those activities (Kolodner et al., 2002, 2003).

By "ritualizing," we mean articulating and normalizing a sequence of activities and setting expectations about how and when to carry them out. Though they didn't use the terminology, Reciprocal Teaching and PBL provide the best-known examples of ritualizing within the learning sciences. In RT, a scripted sequence of activities is used to reason through a text; students learn the set through cognitive apprenticeship – the teacher models her reasoning and explains it to the class, students try out the reasoning with coaching from the teacher, over time they develop capabilities of doing the reasoning themselves and coaching each other through. The ritualized sequences of activities provide scripted ways of carrying out or participating in important skills and practices. Experiences with Reciprocal Teaching suggest that "ritualizing" can provide powerful scaffolding and affordances for engaging productively in practices and for making them habitual. They also suggest that there are three key components to effective use of ritualizing:

- rituals need to cover the set of skills and practices we want students to learn,
- rituals need to be integrated with each other into sequencing that allows students to see them as useful to fulfillment of their goals, and
- rituals need to be introduced, repeated, and discussed in ways that allow students to gradually gain competence in their use.

LBD's ritualized activity structures focus on helping students learn three things: scientific reasoning, project practices, and designing. They are designed to help both students and teachers through the difficulties of engaging in hands-on activities in productive ways, making connections between targeted content and project activities, creating a culture that values collaboration, and working relatively independently. Each plays an important role in promoting both learning and successful achievement of the project.

Learning by Design™ and its Ritualized Activity Structures

Learning by Design (Hmelo et al., 2000; Kolodner et al., 1998, 2002) is a project-based inquiry approach to middle-school science that focuses on learning from design challenges. Students learn content and skills in that context. For example, they learn about motion and forces (and about designing and running experiments, justifying with evidence, explaining scientifically, collaborating, and so on) by spending eight weeks iteratively designing, building, and testing a miniature vehicle and its propulsion system. They learn about mechanical advantage by designing and building machines for lifting heavy objects. The design challenge provides reason for learning the science content, and engaging in the challenge provides a natural and meaningful venue for engaging in both science and design skills. The need to make one's design ideas work provides opportunities and reasons for students to identify incomplete and poor conceptions of science content and to debug those conceptions; the iterative nature of design provides opportunities to apply and test new conceptions; and the collaborative nature of design provides opportunities for team work and the need to communicate ideas and results well.

Figure 1 shows LBD's strategic level. Engaging effectively in activities in the design/redesign cycle (on the left) often requires engaging the investigative cycle (on the right), and the results of investigations provide content for application to the design in progress. LBD has students engage in sequences of activities that move them towards successful achievement of a challenge. They engage in a variety of science, design, collaboration, and communication practices. They learn the concepts and skills that are needed for success by identifying a need to learn them, getting experience trying them out, questioning their accuracy, and revising. Ritualized activity structures are our effort to engineer the affordances for these types of learning experiences to unfold.

Two hallmarks of LBD are shown in this figure. First is the series of public discourse forums that are designed to encourage students to actively reflect on what they've been doing, why they did it the way they did, and making their thinking transparent. The second is its focus on iteration – getting repeated chances to attempt the challenge, to design and run an experiment, explain effects, identify new things that need to be learned, and so on.

Students progressively refine and co-construct knowledge about science concepts and critical science practice.

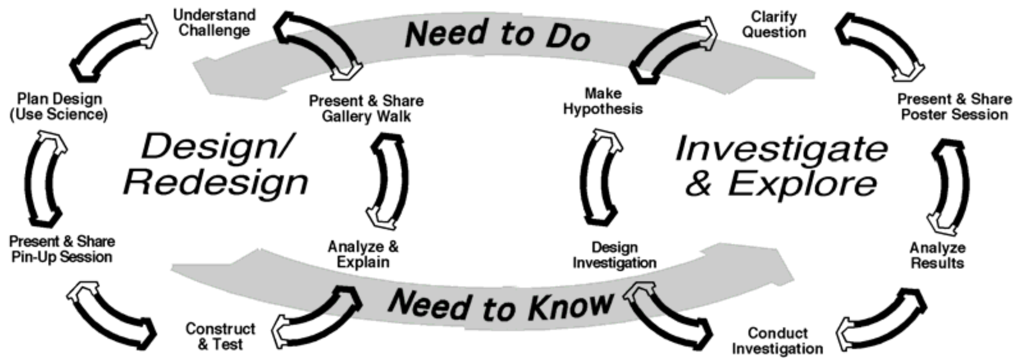

Figure 1. Learning by Design's Cycles

LBD's third hallmark is its carefully-constructed "ritualized" activity structures, designed to contextualize important skills with respect to each other and with respect to their usefulness in a project's success. One cannot see these rituals in the drawing in Figure 1. Rather, LBD's ritualized activity structures are associated with the small activities seen in LBD's cycle. There are two types: action and discourse activities. Action-based activities, such as "messing about" and "designing an experiment," are associated with skills and practices of science and design and promote methodological habit and rigor. Discourse activities are aimed at helping students reflect on and interpret their experiences so that they can identify what they are learning (both content and skills), connect targeted science to their project experience, and connect their actions to their goals.

Table 1 shows a selection of LBD's ritualized activity structures. Each includes a scripted sequence of events, and rituals are sequenced with respect to each other. For example, "messing about," a kind of guided exploration, follows presentation of a challenge and short discussion of what its achievement might entail. Small groups are given materials or devices to explore and asked to observe their function, structure, and behavior. They draw pictures and label them, try them out in a variety of configurations, and write down their observations. They do this as a group, so they have to agree on what they've observed. Thus, discussion is part of the writing-down part of messing about. Messing about is followed by "whiteboarding" (from PBL; Barrows, 1986), where the teacher asks small groups for their observations and records them on a class whiteboard that is divided into three parts – facts and observations; ideas and hypotheses; and learning issues. The teacher helps the discussion move towards generating interesting ideas and hypotheses from those observations and a list of what needs to be learned to know if a hypothesis holds. She then helps them identify variables they might test to answer their questions. The sequence of these three rituals aims students towards understanding the challenge they are asked to address. Designing an experiment, running an experiment, analyzing results, and presenting them to the class form another sequence of activities, with rituals associated with experiment design ("design an experiment"), analysis of results ("creating rules of thumb"), presentation of results ("poster session"), and the discussion afterwards ("creating and designing rules of thumb," "whiteboarding"). "Designing an experiment" involves identifying what values to give the variable that is being tested, which variables need to be controlled, how many trials to run, what needs to be measured and how, variables that might be hard to control, and then generating a procedure. In a "poster session," students present their procedures and results to each other and query each other about those results. And so on.

There are several things it is important to notice about LBD's rituals. First is the level at which they are defined. Notice that LBD doesn't simply have a "present and share" ritual; it has three such rituals – poster sessions, pin-up sessions, and gallery walks. Poster sessions come after carrying out and attempting to explain results of an investigation; pin-up sessions come after planning a design and attempting to justify design decisions; gallery walks come after testing a design and trying to explain its behavior. Each presentation type shares its activity sequence: small groups work together to prepare a presentation of what they've been doing and what they learned from it; groups take turns making presentations, taking questions and advice after their presentations; after the full set, the class holds a whole-class discussion where they draw out what can be learned from the whole set of experiences – about targeted science content as well as about the efficacy of practices they are using. But in each, a different kind of presentation is required. When presenting experimental results, it is important to report on procedures used and trends in the data; when presenting ideas, it is important to justify ideas well; when presenting experiences trying out solutions to a challenge, it is important to report on procedures, what happened, and to explain why things didn't work as planned. By separating out these three kinds of presentations and calling them by different names, LBD calls attention to the fact that each focuses on different skills.

Table 1: A selection of LBD's ritualized activity structures

Activity(s) in Cycle	LBD ritual	Type and Venue	Description
Understand challenge	**Messing about**	Action: small group	Explore materials or devices to identify phenomena, promote question asking, and see connections between science and the world; followed by whiteboarding
Understand challenge	**Gathering examples**	Action: Individual	Explore the world for science in practice, record and explain; followed by whiteboarding or rules of thumb
Understand challenge, clarify question, make hypothesis	**Whiteboarding**	Discourse: whole class discussion	Share and discuss experiences, knowledge, observations, ideas, identify what needs to be learned, keep track of class' progress and common knowledge; often followed by rules of thumb
Design investigation	**Design an experiment**	Action: small group	Given a question to investigate (in the form of discovering the effect of a variable), design an experiment where variables are controlled well, with appropriate number of trails, etc.
Analyze results; analyze and explain, present and share	**Creating and refining design rules of thumb**	Action, discourse: small group, whole class discussion	Identify trends in data and behaviors of devices; connect scientific explanations so as to know when the trends apply
Present and Share (Investigate cycle)	**Poster session**	Discourse: Present & Share	Present procedures, results, and analysis of investigations for peer review; followed by rules of thumb
Plan design	**Plan design**	Action: small group	Choose and integrate design components to achieve the design challenge, basing choices on evidence
Present and share (design/redesign)	**Pin-up session**	Discourse: Present & Share	Present design ideas and design decisions and their justifications for peer review
Construct and test	**Test design**	Action: small group	Run trials of constructed device, gathering data about behavior, attempt to explain
Present and share (design/redesign)	**Gallery walk**	Discourse: Present & Share	Present design experiences and explain design's behavior for peer review and advice; followed by whiteboarding and rules of thumb

While one might think that having three rituals so closely related to each other would overwhelm students and teachers, we've found the opposite – that separating "present and share" into three rituals that each focus differently has been an asset to both students and teachers. The expectation that a presentation is about a particular kind of small-group experience they've just had helps students know what to present and what to ask each other questions about and helps teachers know how to facilitate and focus the discussions. This separation has been an asset in terms of helping students learn scientific reasoning as well. Students and teacher can concentrate on different aspects of scientific reasoning in each ritual. The presentations expected during poster sessions, for example, focus on question being asked, how it is addressed, design of a procedure for investigation, how that procedure was carried out, and analysis of results. This large but coherent set of issues form the crux of investigative reasoning, and poster sessions provide a venue for concentrating on this related set of skills. During pin-up sessions, presentations focus on decisions about how to pursue the project challenge and ask students to show that those decisions are informed by justifying them using evidence from experiments or scientific laws that have been read or discussed previously. Students get practice identifying evidence, using it to make informed decisions, and communicating those decisions to others, and discussions following a pin-up session focus on decision making and use of evidence. Similarly, gallery walk presentations focus on explaining scientifically.

Second, rituals are sequenced in scripted ways. Action rituals are alternated with discourse rituals, which promote reflection. Students take action to prepare for discourse activities in their small groups, reflecting on their activities in ways that allow them to present to the class. They present in discourse activities (poster sessions, pin-up sessions, and gallery walks), where the reflection they've attempted to do as a small group can be discussed and scaffolded and taken to the next level through interaction with teacher and peers. For example, understanding the challenge includes messing about in small groups and gathering examples, each followed by a whole-class whiteboarding session. Designing an experiment, then running it and analyzing results is followed by a poster session. Sequencing tends to move students from small social configurations to big ones and back again, so that groups can learn from each other and bring each other up to pace.

Third, some ritualized activity sequences are designed to be interrupted and returned to. These rituals have public displays associated with them and include, as essential parts, recognizing stopping points, recognizing resumption points, and adapting what's done to how much is known and how far along the project is. Whiteboarding, for example, is returned to on each cycle through designing and after investigation. Early on, the whiteboard's columns are filled in. Later, they are refined based on what else has been learned. Rule of thumb generation and refinement is also an interruptible ritual. During rules of thumb generation, the class works towards identifying trends in experimental results and tests of designs that can help them with subsequent designing and tries to explain each in terms of science principles they are learning. Each time a rule of thumb is used, it is revisited to make sure it is accurate and refined appropriately.

Fourth, there is not a one-to-one relationship between rituals and activities in the cycle. Some activities in the cycle are enacted through a sequence of ritualized activities that follow from each other; some bridge between several activities in the cycle; some are used during several activities in the cycle; some accomplish several purposes. Finally, action rituals and small-group and individual activities are scaffolded, in LBD, by paper-and-pencil or software prompts, while scaffolding during whole-class rituals comes from peers and the teacher.

LBD's Intentions

We designed LBD's rituals to address cognitive needs in learning. We wanted a way for students to get help with debugging their skills. We also wanted them to do the interpretations of their experiences that case-based reasoning suggests turn experiences into accessible and easily applicable cases (Kolodner, 1997). To achieve this, presentations and whole-class discussions were integrated into LBD's sequencing, and we created design diary pages to scaffold the small-group activities students were engaging in (e.g., designing and running experiments). Later, when we learned that students were having trouble connecting their project work to the science they were learning, we designed rules of thumb rituals to play that role.

While we designed these activities based on cognitive needs, we knew that they would promote learning only if they engaged students appropriately; students had to understand why they were engaging in these activities and want to listen to each other and provide each other advice. By integrating discourse activities into the fabric of their project activities, we gave presentations purpose. By using a sort of jigsaw approach where students needed each others' results, we gave students reason to listen to and advise each other. Students engaged with rules of thumb because they made it easier to apply results of investigations to their designs. They were motivated to explain rules of thumb scientifically when they saw them fail and had a need to make them better.

We've sequencing LBD's rituals according to project and cognitive needs. Natural sequencing that goes with designing and investigating provided a first sequencing. Our understanding of the need for students to reflect on and interpret their experiences in order to learn from them led us to the interleaving of action-based rituals and discourse rituals at LBD's strategic level. In addition, we learned that we needed to sequence mini-challenges early in the year that would provide both students and teachers the opportunity to experience the need to engage in important skills and practices. Very early in the year, for example, students attempt a simple challenge in small groups, show their results to the class in a gallery walk, then try again and show their results again (Holbrook &

Kolodner, 2000). The second time through, they notice all the copying. They also notice how much better their designs are as a result of hearing the ideas of others. The teacher helps them to recognize how much they learned from each other but that fairness requires giving each other credit. They engage in similar mini-challenges to introduce them to the need to control variables, measure accurately, run procedures in a consistent way, and so on. While students are not yet able to engage in ritualized activities with expertise at the end of the launcher, they come away from these launcher activities with the want to collaborate and an appreciation of many of the practices scientists engage in (Gray et al., 2001; Kolodner et al., 2002).

The ritualized activity structures we've designed for LBD provide a variety of powerful affordances and scaffolding in support of student and teacher learning of skills and practices. From a cognitive perspective, the rituals provide scripts that, once participants have internalized them, afford easily sequencing through repeated activities. The rituals are designed so that, in conjunction with an engaging project challenge, they provide powerful affordances for engaged participation and for providing scaffolding at just the right times. Scripted sequencing of rituals affords being able to predict what activities come next, helping teachers to manage the complexity of the classroom and students to become more able to independently carry out project activities.

Evidence for ritualized structures' impact on learning outcomes

Students who have participated in LBD pilot and field tests have learned science content as well or better than those learning under more traditional methods and they have learned many of the skills of scientists and designers well enough to collaboratively carry them out along with their peers. Our analyses show that LBD students engage in collaboration, communication, informed decision making, and design of investigations in a far more expert manner than their matched comparisons (Kolodner et al., 2002). Through repeatedly engaging in the practices of scientists and designers, students in LBD classrooms begin to take on these practices.

Students are gradually introduced to LBD's activity structures during a "launcher unit" early in the school year (Holbrook & Kolodner, 2000). Ritualized activity structures are repeated over the course of the launcher unit and throughout the course of content units students engage in. For example, students design experiments and hold poster sessions 6 or more times over the course of 15 weeks of LBD units; they plan designs and hold pin-up sessions at least 4 times; and they have many many gallery walks, whiteboarding, and rules of thumb sessions. We observe in classrooms throughout the year, and we collect formal evidence of learning at the end of the launcher unit (a month or so into the school year) and again after students complete content units (each is 8 to 10 weeks long), in the form of video-taped performance assessments. Both reveal effects of participating in ritualized activities (Kolodner et al., 2002). Our quantitative analysis of codings of videos show that LBD students are rated significantly higher than comparison students on self-checks, science practice, distributed efforts, negotiations, and use of science terms (see Table 2), beginning to become better after the launcher unit and with significance after 8 to 12 weeks of learning content.

It is also interesting to look at the behavior of students. The following statements, taken from performance analysis videos, are typical of LBD students after only the introductory launcher unit:

> "Wait, we have to follow these guidelines (pointing to the instructions from the task)."
> "What are you counting as a swing?...Back and forth or back and forth then back?"
> "You can pull it to here...yeah, but we don't know where here is, we have to be able to measure that."
> "We should test w/ washers...yeah like 10, 20, then 30 washers...and then time to see how long it takes to stop." "Should we use 10 or 15 seconds?...I think 15 b/c when you actually have something in the tray w/ mass...good point." "This is a model, remember, not the real thing." "Somebody's hard (push) might be somebody else's soft (push)."
> "Repeat test again...how many times...until data are consistent."
> "You could add a variable, such as wetting the piece of rubber."

More interesting is their behavior in the classroom (Kolodner et al., 2002). We see that by a month into the school year, students are reminding each other what they need to be doing at different times and how to carry out skills and practices robustly . By two and a half months into the school year, they are able to adapt the ritualized activity structures they've learned to new situations. Early in the year, for example, they will ask for gallery walks when they have something interesting to show the class or have reached an impasse and want the class' help. By two and a half months into the year, they simulate gallery walks on their own, making their way around the classroom in an informal way to teach and learn from their peers. We've noticed differences in teacher capabilities since introducing rituals as well. With a general-purpose "present and share" activity structure, teachers had a hard time knowing when it was time to call for such a session and what to focus on in what students were showing. With three differentiated "present and share" rituals, teachers go into the classroom far more confident of their roles and better prepared to facilitate (Kolodner et al., 2003).

Table 5: Selected Typical Results of Performance Assessments for 2000-2001: Means and Standard Deviations for Comparison and Learning by Design Students after the Launcher (1 month into year) and after a 2-month unit

Coding Categories	2000-2001 Typical Comparison (post launcher)	2000-2001 Typical LBD (post-launcher)	2000-2001 Typical Comparison (end of year)	2000-2001 Typical LBD (post content unit)
Self-checks	1.00 (.00)	2.10 (.74)* $t\,(7) = 2.925$	1.30 (.67)	3.88 (1.03)* $t\,(7) = 5.548$
Science Practice	1.20 (.50)	2.30 (.45)* $t\,(7) = 3.326$	1.40 (.89)	3.75 (1.32)* $t\,(7) = 3.188$
Distributed Efforts	1.38 (.48)	2.40 (1.14)	1.70 (.84	3.00 (.00)* $t\,(7) = 3.064$
Negotiations	1.25 (.29)	1.90 (1.03)	1.40 (.65)	2.88 (1.03)* $t\,(7) =2.631$
Prior Knowledge adequate	1.88 (.25)	1.70 (.67)	1.60 (.89)	3.88 (.75)* $t\,(7) = 4.059$
Prior Knowledge	2.00 (.00)	2.30 (.45)	1.60 (.89)	3.75 (.87)* $t\,(7) = 3.632$
Science Terms	1.38 (.48)	1.50 (.48)	1.50 (.87)	2.88 (.63)* $t\,(7) =2.650$

* = $p < .03$; ** = $p < .02$; ***= $p < .01$
N= groups where most groups consisted of 4 students each.
(Means are based on a likert scale of 1 - 5, with 5 being the highest rating)
Reliability for the coding scheme ranged from 82-100 percent agreement when two coders independently rated the tapes. For this set of data, a random sample of four - five tapes were coded for each teacher from one class period. Approximately 60 group sessions are represented in this table, representing 240 students.

Closing remarks

Our intention was that the package of activities in LBD would result in classes becoming communities of learners who productively build knowledge together, as Brown & Campione (1994) suggest is critical to collaborative learning. Our intention, too, was that through the repeated collaborative practice of important skills, they would internalize skills and practices and be able to carry them out on their own. Ritualized activity structures afford critically evaluating efforts towards real problem solutions. A collaborative perspective on knowledge building is made transparent through repeated sequencing and enactment of present and share rituals. Individuals come to see themselves, we think, as part of a larger ecological system where the relationship to the other is valued. The multiple perspectives engendered when true collaboration and mutual discourse occur becomes internalized in individuals who then see utility in such practice. Both classroom behavior and performance assessments provide evidence that this is happening.

Some might worry that the ritualized nature of LBD's activity structures would promote boredom over time or inhibit students taking on of independent habits. On the contrary, our evidence shows that LBD students take on the ritualized activities as their own, leading to kinds of self-regulation needed for informed problem solving and reasoning. One of the most difficult challenges for project-based approaches is that of helping students develop "habits of mind". Self regulation is one aspect of habits of mind that is especially difficult to foster for middle school students. Even college students often fail to use this meta-cognitive skill. The ability of LBD students to engage in self checks, negotiations and distributed efforts indicates that they are developing self regulation in their learning and practice of science. We believe that the discussions that are part of ritualized activities in LBD are critical to this move toward independent thinking. Ritualized activities in LBD are not merely scripted and are not mindless. Rather, they are designed around real needs in problem solving and scientific reasoning, and the interleaving of activities and discourse affords discussion of the purposes of each of the activities they are doing and best practices for carrying them out. This understanding of the reasons they are engaging in rituals, along with the discussions of how to achieve success, we think, promote individual engagement with targeted skills and practices and the development of expertise and habits of mind.

The possibilities for action (affordances) and the guided enactments of these actions/activities (scaffolding) constitute a system of elements that we've seen lead to the kind of culture that is critical to sustaining rigorous scientific discourse and practice. As in other ecologies, it seems that the relationship between individuals, groups, and the learning environment contributes to positive learning outcomes. None would be able to accomplish such learning outcomes by itself.

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