# Logging Opportunities in Online Programs for Science (LOOPS): Student and Teacher Learning

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**Questions and Answers**

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1. Logging student actions in software is easy, but mining the data to make inferences about student performance is considerably harder, especially when those interpretations must be presented to teachers to help them assess student understandings. There are few details about the representations of feedback. What is it that teachers will actually see from LOOPS? How should they use this feedback in their classrooms to provide students with formative assessment?

There are three parts to this question—1) how we plan to extract information from the logs that is of value to teachers, 2) how we will represent the information, and 3) how teachers will act on the information. These questions are answered separately below.

**Extracting Information**

We plan to classify student achievement along three dimensions: interactions, knowledge integration, and inquiry skill. These dimensions make sense for teachers, suggest teacher actions, and are technically feasible. As a student works through a learning activity, there will be multiple steps each day that can yield indicators that will be combined into three indices, one for each dimension.

**Interactions**. Many observers have called for more interactive science classes. In our framework interactions are important and necessary but not sufficient for successful inquiry learning. Indicators of student interaction level will include:

- The time spent on each activity and step
- The number of times a model is run
- The number of words in responses to embedded prompts
- The number of interactions per activity
- Total interactions

This dimension includes some straightforward information like the number of times a model is run. It also includes a more complex measure that involves determining what counts as an interaction. We expect teachers will find the interaction index useful to evaluate students. They will view this category of assessment as comparable to the "classroom participation" dimension on which they traditionally grade students. In addition, the interaction index will be valuable in conjunction with the other dimensions.

**Inquiry skills.** One of the most important innovations of this project will bring to the classroom the kinds of indicators of student experiment skills that have emerged from our research in the TELS and MAC projects. In TELS, McElhaney developed four measures of student experimental skill: the number of trials performed, the number of distinct values tested, the range of values tested, and the number of boundary values (i.e. the maximum and minimum on sliders) tested. Horwitz's team monitored the number of tries, percentage of tries that got closer to the goal, and percentage of tries in which only one variable was varied. Both sets of indicators were computed long after the classroom enactment and were thus valuable only to the researchers. LOOPS will perform calculations as the activities are underway and communicate the results immediately to teachers. We will create an inquiry index that will combine these and other similar measures of student inquiry skills into a single inquiry skill index. We will assign weights to the indicators based on their relevance to each activity. Both groups of researchers showed that the measures were all highly correlated, so it is likely that the resulting index will not be particularly sensitive to the weights used. Because this index is computed automatically based on student actions, it will be available to the teacher as an activity is underway.

An example may be helpful at this point. As part of a learning activity on chemical reactions, students will explore a molecular dynamics model of a simple reaction with the overall form $A_2 + B_2 \leftrightarrow 2AB$. The model permits students to control two activation and three dissociation energies. One exploration that is part of an activity challenges students to explain how the reaction rate varies as a function of the activation energies and temperature. To understand this relationship, students will have to run the model several times under different conditions. The software will automatically monitor how many runs were made, whether one variable (one of the two activation energies or the temperature) was changed at a time, whether extreme cases were used, and how much of the "parameter space" was explored. While there is no explicit goal in this case, there are critical points where one or another activation energy is close to the average kinetic energy (kT) of the molecular species. The software will determine and report whether a student made large changes first and then zeroed in on such a critical point and whether they found more than one critical point. Measures such as these will be computed as students use the activity and combined with weighting factors to produce a single index that can be displayed in real time.

**Knowledge Integration.** The goal of all our learning activities is to promote knowledge integration . The best indicator of knowledge integration is accurately bringing two or more normative concepts to bear to solve a problem, but any demonstration of linking ideas would provide evidence of a degree of knowledge integration. The best evidence for knowledge integration requires the teacher to score student productions against a knowledge integration rubric . The software will facilitate this process by making it easy to cycle through all responses to a given embedded assessment, while having easy access to the scoring rubric.

To complement the subjective but crucial judgments of individual teachers, we will also use indicators that can be generated automatically such as links in concept maps or construction of scientific principles using drop down menus, as well as the usual multiple-choice, true/false, and numerical response questions. In addition, we plan to use performance tasks that our "smart graph" and "smart model" technology can score. These might include

- Clicking on specific features of a graph generated by a model such as the maximum, where the velocity was negative, or the point at which equilibrium was reached.
- Clicking on a specific feature of a model such as the time and place where the first ion was generated, or identifying atoms in the vapor phase.

Creating a model of a chemical mixture that could explode, but only if ignited.

For each activity, multiple KI indicators will be generated by the software and by teacher and peer scoring. For any one activity the author will determine the default weights that determine how important each indicator is in determining the index. The software will also enable teachers to alter the weights, in effect creating their own rubric for scoring the activity, as they are used to doing with traditional assessment instruments. Just as we are able to keep track of students' actions, we will also monitor how, if at all, teachers modify our default weightings. The experience gained in the trials of our activities will help us determine the norms for the performance assessment indices for each step.

**Representing Information**

The Student Progress Tool will include continuously update data on each student's performance so a teacher can tell at a glance from a matrix where each student, student group, or class stands. While the details of the user interface for this tool have yet to be developed, it is likely to have the following structure.

**Columns**. The horizontal axis will represent the learning content. Each unit will be divided into week-long activities, and each activity divided into steps. The number of columns shown will be able to be expanded or collapsed using twisties so that the teacher can see summary data for an activity or unit, or expand some or all activities to show data on individual steps. Other options will enable the teacher to see only those steps that have inquiry skills or KI performance data, since these will not be computed for every step in an activity.

**Rows**. The vertical axis will represent students. This axis will show summary data for all students, each student group, or each class, as well as detailed data for each student. Teachers will be able to sort rows by individuals or groups according to several criteria such as average KI or inquiry skill, effort, or overall progress.

**Cells**. Each cell will be able to display data using different formats depending on how much detail the teacher wants. The most compact display will be an icon with color, shape, and size attributes linked to the three indices. (For color-blind teachers, an emoticon may be substituted for color.) The values will be generated by each student and step, but averages over students or steps will be displayed, depending on the settings for the columns and rows. For more detail, other displays would be available providing more data at the level of the indicators and, for the data, student artifacts. Student predictions in the form of sketches or words, drawings, and explanations of their ideas will be easily accessed.

**Acting on the Information**

The feedback provided teachers creates a range of opportunities to intervene. The nature of the interventions depends of the time scale. The following section expands on a discussion in the technology section of the supplementary documents.

**During class** teachers will have very limited time to analyze student progress. The iconic representation will be most helpful in this case, because the patterns of shapes and colors will convey valuable overviews that can be quickly grasped as pictures. Just by looking at the matrix, teachers will be able to identify groups or individuals who need help because they are lagging, leaping ahead without understanding, or plodding along with poor experimental skills. Students or groups who are excelling will also be easily identified by their good inquiry skills and high KI scores. The teacher can react to these data by:

Changing group assignments. The collaboration tool will simplify creating, altering, and disbanding student groupings. Group assignments might be changed on the fly to help lagging students, to attack new questions, or simply to encourage reflection.

Communicating with students. The teacher will be able to use the *collaboration tool* to send messages, images, and files to individual students, groups, or the entire class.

Interacting with groups or the entire class. The *dashboard* tool will allow the teacher to interrupt the small group work to pose a whole class question, diagnostic item, discussion, demonstration, or mini-lecture. Students will be able to send text, data, and drawing responses, which the teacher can scan as thumbnails or view individually. The teacher can select one response, combine data, or use the software to pick a response at random and display it to selected groups or the entire class for discussion.

These interventions can be very specific, focused on particular inquiry skills, steps, or content.

**During daily reflections**, which occur between class sessions, teachers will have more time to dig into the data and to score student productions. Teachers will be able to drill down in the matrix to see individual progress and artifacts. The teacher can use these data to:

Identify student ideas that can serve as building blocks. Teachers can note student responses that could help others and ask the group with the promising ideas to explain their views.

Select student specialists who could guide others. Students could qualify as specialists in a topic or activity and help others complete their work.

Discuss student ideas that need additional attention. Teachers could identify student ideas that deserve class attention because they conflate related ideas or because they represent an important distinction that has been overlooked.

Create and disband student work groups. Teachers can modify group assignments to ensure students learn from each other.

Select instructional strategies. Some activities will have alternative treatments or UDL settings. The teacher will be able to assign alternative activities to individuals or groups.

Alter lesson plans and calendar. The lesson planning tool will make it easy for teachers to adjust the pace and content of the unit to respond to student progress.

In summary, the ability to log student information and guide teachers to use it effectively can transform the nature and specificity of formative assessment. The logging tools provide teachers with information that is usually impossible to get or difficult to extract from complex data sets. Teachers can communicate the information directly to students in the form of formative feedback, use it to refine their instruction, or use it to customize the curriculum. In our research we will refine our measures and display technologies based on user responses. We will use student learning outcomes as a guide to selecting the most promising indicators of student progress and representations of student activities in the classroom. We will revise our indicators and curriculum materials to make them effective in communicating to teachers as well as to students.

2. You cited the oft referenced work of Black and Wiliam, but don't say how that work can shape the ways that feedback will be conveyed to teachers. It would be helpful if you would connect principles from Black and Wiliam's work with specific goals that LOOPS will address. The authors offer a number of specific suggestions that form the basis of conversation between the teacher and the students, but none of these were described in your proposal. How you would use their suggestions could be illuminating.

The importance of the work by Black and Wiliam lies in the fact that they were among the first to draw attention to the learning gains made possible by formative feedback. Their work on this began with a massive review of the literature which formed the basis of their best-known paper .

Subsequently, when they tested their ideas in real classrooms they promulgated the following strategies:

**Better questioning.** Teachers focused on their classroom questioning strategies to avoid memorized responses and to deepen the conversation.

**Feedback through grading.** Teachers increased written feedback provided, sometimes dispensing with grades or delaying them.

**Peer assessment and self-assessment.** Teachers were encouraged to clarify instructional goals and grading rubrics, sometimes using peer and self-assessment. This strategy was designed to increase student metacognitive knowledge.

**The formative use of summative tests.** Students were encouraged to reflect more actively and deeply in preparation for tests.

Black et al implemented these ideas with 26 math and science secondary teachers in two school districts in England and achieved positive results with an effect size of .32. One important feature of their approach was that it depended heavily on professional development. Another was that it emphasized co-design, as researchers and teachers collaboratively determined which actions to employ and how to do so. Prior research conducted by WISE and TELS has also demonstrated the importance of professional development and teacher co-design . LOOPS will continue this line of work. Our professional development efforts are also consistent with those of Black and Wiliam, in the areas of emphasis on questioning, written feedback, and formative assessments.

Black and Wiliam studied textbook-based instruction. Our situation is fundamentally different and has the potential to result in larger gains. LOOPS will support a far richer conversation between teachers and students, as well as between teachers and mentors, than is possible without technology. As described above, our assessment will provide far more detailed data on student interactions, inquiry skills, and knowledge integration than is possible through traditional instruction.

We are deeply committed to professional development in support of the formative feedback we will provide. Although the technology creates new opportunities for feedback, the teacher remains central to our vision of teaching and learning. LOOPS professional development will focus on formative feedback, and will engage teachers actively in planning new instructional strategies that utilize the new technologies and new information from students. Teachers must be enabled to understand the technology, to grasp the new opportunities for assessment and instruction, and to plan their own implementations.

Following our prior work, as well as that of Black and William, we will help teachers focus on asking effective questions and providing timely feedback. A key difference from Black and Wiliam is that LOOPS will provide technologies that enable these strategies to be more frequent, effective, timely, and pervasive.

One important outcome of this project will be information about how much professional development is required. An innovation that requires extensive prior preparation from teachers might have limited impact. We are committed to providing tools and instructional designs that can minimize the up-front PD costs. Drawing on the wealth of existing high quality materials from our prior research, LOOPS will be able to design materials that are readily adopted by teachers and effective for student learning.

In later phases of the project, we will begin adding the semantic and strategic information from teachers' accumulated use into the dashboard tool, giving teachers access to specific advice from peers, as well as a sense that their own usage will be helpful to those who follow. For example, one teacher may specify advice of the form "When the data said this, I did the following, because…" We may find other ways to elicit and deliver teacher advice and findings within the LOOPS environment. These kinds of thoughtful, data driven interventions could provide ongoing, just-in-time guidance to lessen the need for extensive formal professional development up front.

Black and Wiliam make the point that assessments that rank students (especially if the rankings are made public) sometimes cause lower achieving students to "give up" and contribute to a more or less universally held perception that they are "dumb" and incapable of learning. Our assessments will be confidential, continuous, and aimed at helping the student improve his/her performance by reflecting on feedback.

We will explore the relationships between language-based assessments and those that require drawing models or interacting with visualizations. The visually-presented activities that LOOPS features can also implement the general precepts of Black & Wiliam (e.g., importance of self-assessment) but the role of the teacher will be different. For example, the teacher can take aside all the kids who messed up the identification of the onset of the chemical reaction, and run through it again for them, pointing out the importance of that first bond formation and the fact that the resulting molecule gains energy from it.

While our proposal did not specifically address the use of Black and Willem's peer- and self-evaluation strategy, these are also consistent with our own prior efforts, and will be integrated into TELS materials. For example, the WISE 'Show-and-Tell' system allows peer exchange and critique, including teacher participation. This strategy will contribute to better student understanding of the goals of instruction and can reduce the teacher grading burden. If at all feasible, we will make the teacher scoring tools—rubrics, access to instructional goals, and stock answers—selectively available to students for teacher-determined assessments. For peer review, automatic random assignment of students or groups will be available.

The formative use of summative tests is not specifically part of the LOOPS proposal, but it is an excellent strategy suggested by Black and Wiliam that is integrated within our overall approach. Students definitely need good review and test preparation skills and their increasing metacognitive understanding will likely improve these skills. Our instructional materials are always closely linked to standards and assessments, and the activities are designed to provide practice with multiple-choice questions.

LOOPS will reflect many of the ideas in Black and Wiliam's work, which is fundamentally about engaging teachers in becoming more aware of student thinking and supporting deeper student reflection while increasing the range of opportunities for deeper thinking. LOOPS will significantly advance this agenda because we will provide new forms of conversation between students and teachers, better data about student thinking, and new forms of student expression.

**Citations**