The Activity Summary Board

Adding a visual reminder to enhance a project-based-learning unit

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Project-based learning (PBL) is an instructional approach to science teaching that supports the *Next Generation Science Standards* (Krajcik 2015; NGSS Lead States 2013). In a PBL lesson, students design and solve real-world problems or explain scientific phenomena. Students using a PBL model learn and retain more than those not using PBL (Krajcik and Shin 2014). PBL classrooms have six key features:

- aligning with measurable learning goals,
- focusing on finding solutions to meaningful questions or problems,
- exploring phenomena using science practices,
- engaging in collaborative activities to find solutions to the driving question,
- using learning tools and other scaffolds to support students' learning, and
- creating tangible artifacts that address the driving question.

FIGURE 1

The unit moves from (left to right) the driving question board (DQB) through unit investigations to the activity summary board (ASB).

At the core of PBL is the open-ended *driving question*. The driving question guides all learning tasks inside and outside the classroom, supports and inspires students' curiosity while learning more about the phenomena being explored, and culminates in the creation of a final artifact.

An anchoring phenomenon gives context to the driving question. The driving question and anchoring phenomenon also provide students with opportunities to ask their own questions—which makes the learning process more engaging and relevant for the students (Weizman, Shwartz, and Fortus 2008).

Driving questions can be integrated into the curricular materials at different levels. For example, a broad driving question can provide the stable core investigation for a whole unit. Alternatively, a driving question can either span several days of explorations or merely provide a foundation for a single lesson, such as in a less complex, very specific investigation with a narrow focus.

The driving question board

The driving question board (DQB) serves as a visual organizer for PBL units (Weizman, Schwartz, and Fortus 2008). Teachers use the DQB to display the driving question to remind students of the goal of the unit's investigations. Students write their own questions and comments about the driving question, the phenomena, or anything that arises from subsequent investigations on the DQB. Using sticky notes for this means students' questions, categories, and groupings can be easily added, revised, or moved as more information is acquired during the unit.

Investigations are then completed to give students the experiential data and evidence needed to answer their questions, draw preliminary conclusions, and synthesize enough information to move closer to answering the driving question.

The activity summary board

This article introduces an additional tool, the activity summary board (ASB) (Figure 1). The ASB is a classroom organizational tool that summarizes what students do and figure out in the classroom as they take on the role of scientist or engineer to make sense of the phenomenon or problem. The ASB augments the DQB: Student questions that have been investigated and answered are physically removed from the DQB and then placed on the "Question" side of the ASB (Figure 1). Thus, the ASB provides a visual representation of the students' progress in making sense of the phenomenon.

FIGURE 2

Question formulation technique (Adapted from Rothstein and Santana 2014).

Part 1:

- Ask as many questions as you can.
- Don't stop to judge, discuss, or answer any questions.
- Write down every question exactly as stated.
- Change any statements into questions.

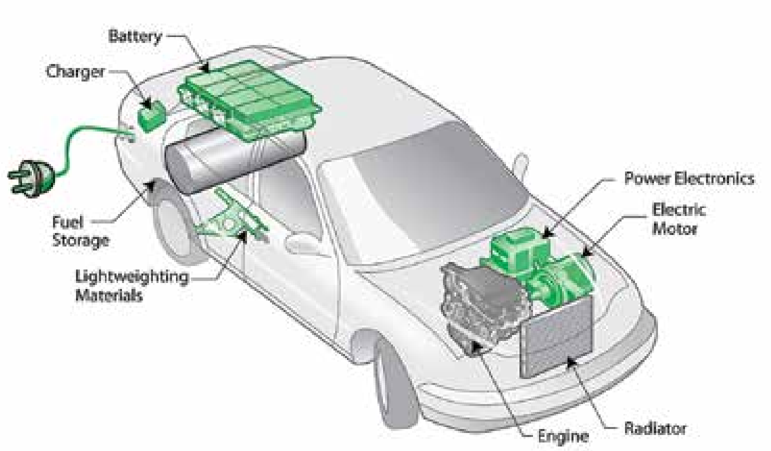
Part 2:

- Categorize questions.
- Prioritize questions.
- Reflect.

Sample physics unit

A two-week physics unit in a classroom of one of the authors illustrates use of the DQB and the ASB. The unit focused on studying and explaining electric motors and was co-developed by science education researchers and physics teachers collaborating as part of an NSF-funded project. The aim of the project was to investigate optimal learning moments in a science class using PBL-based, *NGSS*-aligned curriculum units while measuring:

- student engagement and other affective states, and
- student learning during classroom instruction (Schneider et al. 2016)



Introducing the driving question

The unit began with the teacher introducing phenomena related to electric cars. Students were shown two short videos of engineers discussing the advantages and disadvantages of electric car technology (see "On the web").

Then, in a classroom discussion, students debated whether electric cars would become common during their lifetimes. Students discussed current models of electric cars and brought up barriers to consumer adoption of the technology, including initial expense, limited range of the vehicles before battery recharging is needed, and the time needed for recharging.

Students agreed that the driving range between charges would have to be increased if electric cars were to ever replace cars with internal combustion engines. The teacher then guided the discussion to how scientists and engineers might overcome such challenges. This eventually led to the teacher writing the driving question for the unit on the board: "How can I make the 'best' (most efficient) electric motor?"

Developing the driving question board

Once the unit's driving question was established, students experimented in groups of three or four with small DC toy motors to help them develop their initial questions and ideas. Students connected a toy electric motor to a battery and tried to pick up various loads of paper clips attached to a string wound around the shaft of the motor.

During the experiment, students made observations and asked their peers and teacher about the operation of their toy motor using a "question formulation technique" (Figure 2 and student handout under "On the web").

Students' questions included: "Why does the motor get warm?" "Is there a maximum number of paper clips the motor can lift?" and "Why is the paper clip attracted to the motor casing?" The teacher did not evaluate the questions at this stage, only reminded students to think about the driving question: "How can I make the 'best' (most efficient) electric motor?"

To get students to ask questions more closely addressing the driving question, the teacher provided the following guiding questions: "What do you know about motors?" and "What do you need to know about motors to answer the driving question?" The student groups worked to form as many questions about the phenomenon and driving question as possible. Later, some of these questions were answered through student investigations, which helped them develop an answer to the unit's driving question.

The teacher asked the groups to place their top four questions on individual sticky notes that could be added to the DQB along with the driving question. As the groups shared their top questions with the class, the teacher asked them to propose categories for their questions. For example, a group that asked, "How do you measure efficiency?" proposed placing this question under a category titled "Efficiency." Another group suggested the category "Energy" for one of their questions: "How does electricity make the car move?" Another group asked "How can we reduce friction in the car?" and suggested this be placed in the "Efficiency" category, explaining that reducing friction would help improve overall efficiency. The discussion on which category to place each question also helped other groups better understand what was meant by "efficiency." The students placed their questions on sticky notes on the DQB sorted into the categories they created.

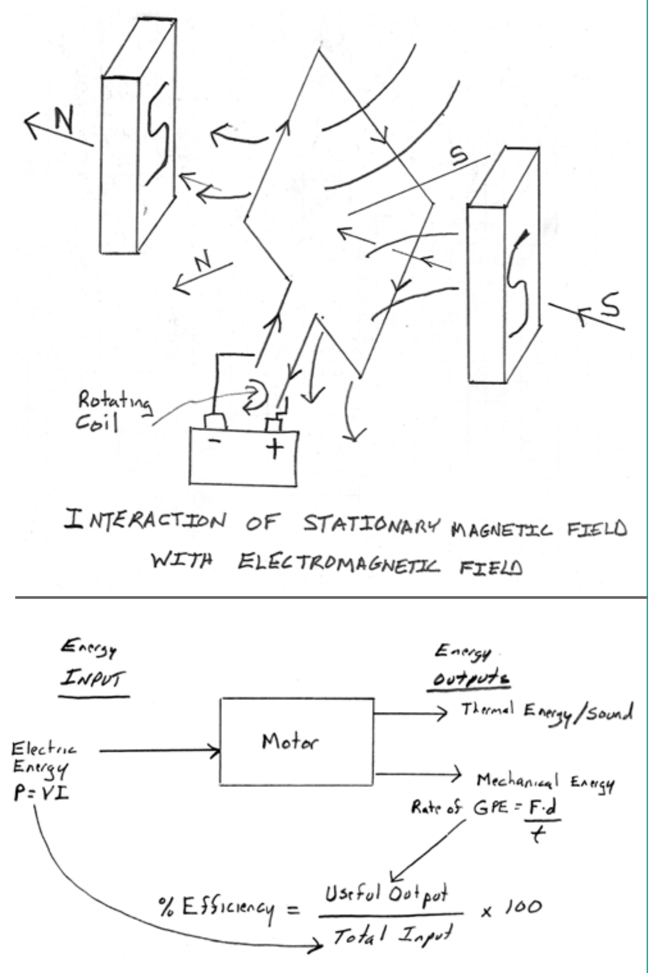
Using the driving question board

Once the teacher and students had co-created the DQB, the questions helped guide instruction throughout the unit. Important questions that did not initially appear on the DQB were added later as the unit progressed, based on guidance from the teacher and as students' activities changed their thinking. Students thereby revised their initial impressions on their own, rather than having a concept introduced by the teacher before any hands-on exploration.

For example, students needed to discuss magnets, coils, and wires to answer the driving question, even though specific questions related to those topics did not at first appear on the DQB. The teacher placed a more general question on the DQB: "What's inside an electric motor?" This led students to think about the inner workings of an electric motor and to ask: "Why is there so much wire in a motor?"

FIGURE 3

Models and drawings that appeared on the activity summary board: a diagram used to understand and calculate efficiency (top) and a model for the interaction of static magnets and an electromagnetic field (bottom).



Questions that arose during students' investigations were added to the DQB, which in turn led to further investigation. This process of figuring out, or sense making, is quintessential to PBL in the classroom. Promoting this type of student autonomy by asking and investigating student questions can increase overall engagement and create an atmosphere in which students actively participate in the the lessons.

Transitioning to the activity summary board

Refining the questions on the DQB advanced the unit and encouraged students to move toward an explanatory model to investigate and respond to the driving question. To track their progress, the teacher moved the sticky notes with students' questions to the ASB and listed the particular investigation the class performed to help answer each question. Also written on the ASB was a summary of the big ideas or takeaways that students discovered in their investigations, as well as several student-drawn models (Figure 3).

This growing body of knowledge on the ASB helped to engage students with the material. Students realized the importance of exploring their questions to generate the big ideas needed to address the driving question. Figure 4 (p.34) shows an example of an ASB taken from the unit on electric motors.

At the end of the unit, students were able to use the acquired knowledge and practices to answer the driving question: "How can I make the "best" (most efficient) electric motor?" Students created a detailed model of the energy flow in the motor and used that to change their motor design to increase efficiency. The detailed model as well as the revised motor design served as the unit's tangible product and was used for formative assessment of students' learning.

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Benefits of PBL

PBL helps educators engage students in science and engineering practices, integrating disciplinary core ideas and crosscutting concepts to solve real-world problems and make sense of phenomena. Using one of the key features of PBL—the driving question—along with the driving question board and activity summary board, the teacher can scaffold subsequent investigations using a visual reminder of the unit's goal and progress made over several lessons.

Moving students' questions from the DQB to the ASB tracks students' learning throughout the unit, giving them a sense of ownership of the figuring-out process at the core of PBL and inquiry-based science. ■

ON THE WEB

Student handout: *www.nsta.org/highschool/connections.aspx*

Videos on electric car technology: *www.youtube.com/watch?v=QVgbESEIP_I*, *www.youtube.com/watch?v=PvtmeYOOiSw*

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FIGURE 4

The activity summary board (ASB).

Student question	Classroom activity/ investigation	Big ideas from the activity/ investigation
What is inside of an electric motor?	Take apart a toy motor.	Components include magnets, coil of wire, metal plates, axle, and power supply.
How does a motor work? How can I build an electric motor?	Build a simple homopolar motor.	Electromagnetism—something happens when electric current goes through a coil of wire.
Why is there so much wire in the toy motor? Why is the wire used in the toy motor so thin?	Explore the magnetic fields around a coil of wire. Interaction between a coil of wire and stationary magnet mounted on a toy car.	Electricity flowing through a coil of wire creates a magnetic field. More loops in the coil of wire creates a stronger field. Change the polarity of the coil by changing the direction of electron flow.
How do electromagnets create movement? How are the components of an electric motor related to each other? How do you convert electricity to mechanical energy?	Build models of the interaction of magnetic fields between coil of wire and stationary magnets.	Interaction between the magnetic fields will allow the coil to rotate. The more loops in the coil, the stronger the magnet.
What factors affect a motor's efficiency? What is efficiency?	Measuring energy inputs and outputs of a system.	% efficiency = useful output/total input x100
How could I reduce friction? Is there a certain ratio of wire to the size of the coil that works best?	Build an electric motor.	Some motors work better than others. Why?
Why did the motor get hot? Why does the coil spin clockwise sometimes and counterclockwise other times? Does it matter how the stationary magnets are mounted?	Build explanatory models to make predictions.	Models can be used to help explain phenomena.

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standards

HS-PS2 Motion and Stability: Forces and Interactions

HS-PS3 Energy

Performance Expectations

HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
Planning and Carrying Out Investigations Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	Students carry out investigations to determine the cause-effect relationship between a coil of wire and stationary magnets.
Using Mathematics and Computational Thinking Create a computational model or simulation of a phenomenon, designed device, process, or system.	Students use formulas for potential energy and kinetic energy and work to create a formula to measure efficiency of their motor. This calculation is entered into a spreadsheet so that they can easily explore the efficiency of many motors built in class.
Constructing Explanations and Designing Solutions Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	Students complete investigations to develop an understanding of how a motor works. They use this understanding to design and build an electric motor and compare its efficiency to the motors their classmates build.
Disciplinary Core Ideas	
PS2.B: Types of Interactions Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	Students explore the interaction between magnets and an electric field to construct an explanation of how an electric motor works.
PS3.B: Conservation of Energy and Energy Transfer Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.	Students use the idea of conservation of energy so that they can create a mathematical model of the efficiency of the motor that they build.
Crosscutting Concept	
Energy and Matter Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	Students use the idea of energy flow to model the energy flow into the motor, within the motor, and out of the motor to understand what efficiency is and how it can be improved.