How Do Machines Help me Build Big Things?

University of Michigan’s Center for Highly Interactive Computing in Education

NSF Center for Learning Technologies in Urban Schools

NSF/Detroit Urban Systemic Program
How Do Machines Help Me Build Big Things?

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<th>1 class period</th>
</tr>
</thead>
</table>
| Lesson 1/Introduce the Driving Question                   | - Introduce the driving question, *How do machines help me build big things?*
|                                                           | - Brainstorm what students know and what they need to know to address the driving question |
| 1-2 class periods                                          | Lesson 2/Construction Site Walk |
|                                                           | - Introduce the driving question |
|                                                           | - Take the construction site walk |
| 1 class period                                            | Lesson 3/What are Machines? |
|                                                           | - Discuss the types of machines and identify examples |
|                                                           | - Students complete their first new machine design |

<table>
<thead>
<tr>
<th>Learning Set Two/How Do I Move Things?</th>
<th>1 class period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 1/Student Definitions of Force</td>
<td>- Review the design task and the driving question</td>
</tr>
<tr>
<td></td>
<td>- Students observe the class brick demonstration</td>
</tr>
<tr>
<td></td>
<td>- Student definitions of force</td>
</tr>
<tr>
<td>1-2 class periods</td>
<td>Lesson 2/Force and Motion POE</td>
</tr>
<tr>
<td></td>
<td>- Students participate in demonstrations about balanced and unbalanced forces</td>
</tr>
<tr>
<td></td>
<td>- Together, the class formulates a ‘class rule’ about force and motion</td>
</tr>
<tr>
<td>1 class period</td>
<td>Lesson 3/Applying Ideas</td>
</tr>
<tr>
<td></td>
<td>- Students write about how things are moved by their new machines, using the concepts of balanced and unbalanced forces</td>
</tr>
</tbody>
</table>

| Learning Set Three/How Do machines Move Things That I Can’t? | 3-4 class periods |
|                                                           | Lesson 1/The Inclined Plane |
|                                                           | - Students conduct the inclined plane investigation, including collecting, graphing, and analyzing data |
|                                                           | - The class formulates a general conclusion about the trade-off between force and distance from this investigation |
|                                                           | - Students brainstorm questions to further investigate the mechanical advantage of an inclined plane |
|                                                           | 3 class periods |
|                                                           | Lesson 2/The Lever |
|                                                           | - Students conduct the lever investigation, including collecting, graphing, and analyzing data |

*Calendar continued on next page*
<table>
<thead>
<tr>
<th>Learning Set Four/How Can I Make Machines Work for Me?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 class period</strong> Lesson 1/Complex Machines</td>
</tr>
<tr>
<td>• The class works to identify the simple machines in several complex machines and how they work together</td>
</tr>
<tr>
<td><strong>2 class periods</strong> Lesson 2/Developing New Machine Designs</td>
</tr>
<tr>
<td>• Student groups finalize their designs/models and prepare for class presentations</td>
</tr>
<tr>
<td><strong>2 class periods</strong> Lesson 3/Group Presentations</td>
</tr>
<tr>
<td>• Student groups present their final machine designs to the class</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Calendar.cont.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The class formulates a general conclusion about the trade-off between force and distance from this investigation</td>
</tr>
<tr>
<td>• Students brainstorm questions to further investigate the mechanical advantage of a lever</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 class periods</th>
<th>Lesson 3/The Pulley</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Students conduct the pulley investigation, including collecting, graphing, and analyzing data</td>
<td></td>
</tr>
<tr>
<td>• The class formulates a general conclusion about the trade-off between force and distance from this investigation</td>
<td></td>
</tr>
<tr>
<td>• Students brainstorm questions to further investigate the mechanical advantage of a pulley</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 class periods</th>
<th>Lesson 4: Student Investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Students work in groups to develop their own investigations for one of the research questions about the mechanical advantage of one of the simple machines</td>
<td></td>
</tr>
<tr>
<td>• Students conduct investigations for their question about mechanical advantage</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2 class periods</th>
<th>Lesson 5: Investigation Presentations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Student groups present the results of their own investigations about the mechanical advantage of simple machines</td>
<td></td>
</tr>
</tbody>
</table>

| Post-test (1 class period) |
Contributors

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Pedagogical Statement

Project-based science can be used to answer students’ and teachers’ questions about the world around them. Investigating real-world questions has long been touted as a viable educational structure; the roots of this idea go back to John Dewey who is often described as the father of progressive education. Project-based instruction is one example of such learning, where the focus is on students investigating real-world problems that are important and meaningful to them. Because of this focus, project-based science is sensitive to the needs of a diverse group of students with respect to culture, race, or gender (Atwater, 1994; Haberman, 1991.)

Project-based science has several fundamental features. First, driving questions or problems serve to organize and drive instructional tasks and activities. Second, students engage in investigations to answer their questions. Third, it involves communities of students, teachers, and members of society who collaborate in discourse about the question or problem. Fourth, technology is used by students to investigate, develop artifacts or products, collaborate, and access information. Finally, the result is a series of artifacts or products that address the question or problem.

Driving Questions
Science classes should have children explore solutions to questions (NRC, 1996). Project-based science calls for a question or problem that is meaningful and important to learners (Blumenfeld, et. al, 1991; Krajcik, 1993). We refer to questions that have these characteristics as driving questions. A question such as "How do machines help me build big things?" is an example of what we call a driving question. Such a question serves to organize and drive activities that take place in a science class. The driving question is the first step in meeting all of the other key features of project-based science. The question sets the stage for planning and carrying-out investigations. Next, technology can be used to investigate this question. As students collaboratively pursue solutions to this question, they develop meaningful understanding of key scientific concepts. Hence, instruction is anchored in real-world situations that students find meaningful, and from which questions emerge and students develop deep understandings. Finally, students can develop products, such as posters, to show what they have learned.

Students Engage in Investigations
One of the hallmarks of science is that of sustained investigation based on important and meaningful questions. In project-based science, students investigate a question over a longer length of time rather than engage in short term activities or investigations that are out of context from real-life situations. Questions such as "What do pets need to stay healthy?" and "Where did the black stuff come from in the bottom of the aquarium?" can provide the basis for long term investigations. These investigations are meaningful to
possibilities of technology not only enhance the physical accessibility of the information, they facilitate its intellectual accessibility as well (Blumenfeld et. al., 1991).

**Artifacts**

Because artifacts show what students have learned, they can be used as forms of assessment that demonstrate students’ deep understanding of science (Marx, Blumenfeld, Krajcik, & Soloway, 1997). Project-based science results in a series of artifacts, or products, that address the driving question and show what children have learned. Oftentimes, students share their artifacts with other class members, teachers, parents, and members of the community.

The creation and sharing of artifacts serves several purposes. First, artifacts are real and motivating. For example, making a display of appropriate habitats for classroom pets is more realistic than taking a test about animal habitats. The creation and sharing of artifacts also makes science class more like real science. Scientists frequently expose their ideas to public scrutiny through the process of publishing and presenting their work at conferences. Presenting an artifact to an audience of peers, professionals, and community members provides a purpose for the investigation and allows students talk with others about their work.

Second, artifacts help students develop and represent understanding. Therefore the development of artifacts is central to a project environment. Because artifacts are concrete and explicit (e.g., a physical model, report, videotape, or computer program) they are shareable and critique-able. Feedback permits learners to reflect upon and extend their understanding, and revise their artifacts.

Third, artifacts allow students to show what they have learned throughout an investigation. They document broad learning – sometimes over an entire school year. Because artifacts represent learning over time, they show how student understanding develops. For these reasons, artifacts are excellent forms of assessment.
Assessment Statement

We view assessment as “the process of collecting, synthesizing, and interpreting information to aid classroom decision making” (Airasian, 1996). Assessments must match the content taught in order for the students to demonstrate what they have learned. The assessments need to consider the learning objectives and the instructional emphasis when they are designed and implemented. Assessments should never include topics or objectives not taught to the students.

Assessments can never appraise everything that students learn in class; they can only estimate what students have learned by sampling tasks from a much larger possible range of tasks. We try to address this limitation by giving students several opportunities to show what they have learned through different media (e.g., answering tests and quiz items, completing student sheets, collaborating in groups, presenting projects).

Assessment can include formal and informal assessments. Formal assessments examine products such as written or oral responses (Pellegrino, 2001). According to Pellegrino informal assessments are “intuitive, often subconscious, reasoning teachers carry out everyday in classrooms.”

We strive to make all of the assessments formative in nature. According to Black and William (1998) formative assessments encompass all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged. The feedback component of assessments is critical. However, many assessment have to be summative in nature in order to measure what student have learned at the end of some set of learning activities and to assign a grade.

In the LeTUS projects, there are many opportunities for assessment. These include formal assessments like tests, quizzes, artifacts, student sheets, and presentations. These assessments can also be informal and include checks for student understanding like classroom questioning and assessment conversations.

Many assessments require students to select answers to questions, others require them to construct new responses. Because students can respond to constructed response assessments in many different ways, teachers need to present guidance about how they will score answers. We provide this guidance through rubrics. In the LeTUS projects, we have provided rubrics to help students understand how they will be assessed and to provide a tool for teachers to do their assessments. The rubrics in different projects will follow a common set of guidelines, but they will be customized to the specific learning objectives and science content that the project addresses.
References


The Teaching Guide and Student Materials
This curriculum guide is divided into two sections: the Teaching Guide and the Student Materials. The Teaching Guide includes all of the information needed by teachers to enact this project, including planning and preparation, background information, and detailed lesson plans. Located after each lesson plan are the relevant student worksheets and reading materials with suggested student answers.

Following the Teaching Guide is the Student Materials section. This section includes copies of all student worksheets, reading materials, and assessments suitable to be photocopied and distributed. These pages are sequenced in the order that they are first used during the project.

The Driving Question
This unit is structured around a “Driving Question” – How do machines help me build big things? This Driving Question is consistent with existing curriculum frameworks, including district and state guidelines; encompasses real-world questions that students find meaningful; engages students in inquiry over an extended period; and during the project students develop the knowledge and skills necessary to answer the question.

Learning Sets
In this project, the Driving Question is divided into four related sub-questions. Learning Sets are organized around a sub-question that contains related concepts and activities. The purpose of the sub-questions is to facilitate students in constructing a response that demonstrates their emergent understanding.

Learning Sets and Subquestions in this project:
Learning Set One
What Are Machines and How Are They Used?
Learning Set Two
How Do I Move Things?
Learning Set Three
How Do Machines Move Things That I Can’t?
Learning Set Four
How Can I Make Machines Work for Me?

Learning Sets last 1-3 weeks, depending on the complexity of the concepts being presented. Each Learning Set begins with an overview and purpose, a calendar, and background content information.

Learning Sets are further divided into lessons that include specific activities focusing on a single concept. They provide information about the topic of the learning set and, ultimately, the driving question. Lessons last 1-4 class periods and contain detailed plans for enacting the activities.

Teacher Reflection Pages
These pages are located at the end of each learning set to support the teachers in adapting the project to their specific classroom.

Icons
Throughout this unit, icons (pictures) are used to represent key aspects of the project, such as teaching strategies, content information, technology, and anchoring experiences. These icons, found in the margins, are meant to help teachers enact the project by highlighting and providing helpful hints.
**Icons**

**PRINCIPLES**

**Driving Question**
The activity relates to the project’s Driving Question.

**Technology**
Indicates when technology is being used.

**Inquiry**
Components of the inquiry process.

**Assessment**
Artifacts to be collected and/or evaluated.

**Collaboration**
Students working together to learn.

**Anchoring Experience**
Learning event which the students will revisit throughout the Learning Set and/or project.

**SUPPORT**

**Teaching Strategy**
Suggested instructional techniques and classroom organization strategies.

**Expected Student Outcome**
Possible student answers or questions.

**Content Information**
Relevant information to the topic for the unit.

**Reader**
Suggested uses of the student reading material.
Project Overview

The Driving Question
How do machines help me build big things? This question drives student inquiry through this project. As students investigate how machines function to help people build large structures, they construct and develop an understanding of forces, motion, and the trade-off between force and distance that occurs when using a simple machine. Because students are investigating how they can use machines, they are naturally led to question how machines function to make their lives easier and how they can design new machines to improve their functioning.

Building Ideas
The driving question of this project leads students to investigate forces, including forces that students themselves apply to an object as well as resisting forces that naturally occur in our world, such as friction and gravitational pull. As students look more closely at the specific simple machines, they investigate how each machine functions differently and can be used in a variety of circumstances. In addition, they discover the commonalities among the simple machines and develop the relationships between force applied and distance moved that dictate the categorization of these devices into a group called collectively ‘simple machines’.

Engagement in Inquiry
Student understanding is facilitated by actively engaging with the phenomena. During the project, students ask questions, make predictions, conduct experiments, and draw conclusions based on their findings. Learning technologies are an integral part of the inquiry process. Specifically, learning in this project is supported by the use of force probes. Using force probes helps the learner visualize the phenomena of applied force as a real-time display of their effort appears instantaneously as they push and pull. The technology provides a unique opportunity for students to learn about force, motion, and simple machines in a manner that is relevant to their lives and the real world.

Journals
During this project students are asked to keep journals. These journals are areas for students to record and keep track of their developing understanding and ideas that work towards their final artifact. Journal writing assignments are recommended for home sessions at several points throughout the project.

Final Artifacts
At the conclusion of the project students construct a final artifact. Students choose the format and focus of their artifact. Also, students present their designs and models for new complex machines, using data from their research and previous investigations to support their claims of the success of this machine.
Detroit Public Schools Core Curriculum Outcomes
Content Standards 6th Grade
Explain how objects can be moved by the application of forces, including the use of simple machines.

Inquiry Standards 6th Grade
Identify questions that can be answered through scientific investigations.
Communicate scientific procedures and explanations.

Michigan Curriculum Framework Science
Benchmarks
Using Scientific Knowledge to Understand Physical Science - Motion of Objects
PMO.M2. Relate the motion of objects to unbalanced forces in two dimensions.
PMO.M5. Design strategies for moving objects by application of forces, including the use of simple machines.
PMO.E4. Identify and use simple machines and describe how they change effort.
PMO.E5. Manipulate simple mechanical devices and explain how their parts work together.
PMO.H1. Analyze patterns of force and motion in the operation of complex machines.

Constructing New Scientific Knowledge
C.M2. Design and conduct scientific investigations.
C.M4. Use metric measurement devices to provide consistency in an investigation.

Reflecting on Scientific Knowledge
R.M1. Evaluate the strengths and weaknesses of claims, arguments, or data.
R.M3. Show how common themes of science, mathematics, and technology apply in real world contexts.

National Science Education Standards
Content Standard A: Science as Inquiry Abilities necessary to do scientific inquiry
• Design and conduct a scientific investigation.
• Use appropriate tools and techniques to gather, analyze, and interpret data.
• Develop descriptions, explanations, predictions, and models using evidence.
• Think critically and logically to make the relationship between evidence and explanations.
• Communicate scientific procedures and explanations.
• Use mathematics in all aspects of scientific inquiry.
Understandings about scientific inquiry

• Different kinds of questions suggest different kinds of scientific investigations.
• Current scientific knowledge and understanding guide scientific investigations.
• Mathematics is important in all aspects of scientific inquiry.
• Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigation.
• Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.

Content Standard B: Physical Science

Motion and Forces

• If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object’s motion.
• The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.

Content Standard E: Science and Technology

Abilities of technological design

• Design solution or product.
• Implement a proposed design.
• Communicate the process of technological design.

Understandings about science and technology

• Perfectly designed solutions do not exist.
• Technological designs have constraints.

Content Standard F: Science in Personal and Social Perspectives

Science and technology in society

• Science and technology have advanced through contributions of many different people, in different cultures, at different times in history.

• Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes, and government agencies.

AAAS Benchmarks for Science Literacy

The Nature of Science

1A. Some scientific knowledge is very old and yet is still applicable today.

1C. Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.

1C. Scientists are employed by colleges and universities, business and industry, hospitals, and many government agencies.

1C. Computers have become invaluable in science because they speed up and extend people's ability to collect, store, compile, and analyze data, prepare research reports, and share data and ideas with investigators all over the world.

The Nature of Technology

3A. Tools are used to do things better or more easily and to do some things that could not otherwise be done at all. In technology, tools are used to observe, measure, and make things.

3A. Throughout all of history, people everywhere have invented and used tools. Most tools of today are different from those of the past but many are modifications of very ancient tools.
3A. Measuring instruments can be used to gather accurate information for making scientific comparisons of objects and events and for designing and constructing things that will work properly.

3A. Technology extends the ability of people to change the world: to cut, shape, or put together materials; to move things from one place to another; and to reach farther with their hands, voices, senses, and minds.

3A. Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. But they usually have to take human values and limitations into account as well.

3B. Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of the materials being used, are unavoidable.

3C. Throughout history, people have carried out impressive technological feats, some of which would be hard to duplicate today even with modern tools. The purposes served by these achievements have sometimes been practical, sometimes ceremonial.

The Physical Setting
4F. The greater the force is, the greater the change in motion will be.

Habits of Mind
12B. Find the mean and median of a set of data.

12B. Determine what unit an answer should be expressed in from the units of the inputs to the calculation.

12C. Inspect, disassemble, and reassemble simple mechanical devices and describe what the various parts are for; estimate what the effect that making a change in one part of a system is likely to have on the system.

12D. Organize information in simple tables and graphs and identify relationships they reveal.
## Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A video of a construction site</td>
<td>1</td>
<td>Suggestions include: segments from the Building Big video series (shown on the Discovery Channel), There Goes a Bulldozer (with the sound off), or specials from the Discovery Channel or The Learning Channel that show large buildings being built.</td>
</tr>
<tr>
<td>Bricks</td>
<td>1/group, approx 10/class</td>
<td>Pick up at a masonry store or chain stores like Home Depot. Try to use smaller paver bricks or bricks with mortar holes in them.</td>
</tr>
<tr>
<td>Force probes with computer and DataStudio software</td>
<td>2/station</td>
<td>Check with the computer specialist in your school building or Deborah Peek-Brown, total number of probes depends on number of computers available.</td>
</tr>
<tr>
<td>Spring scales</td>
<td>1/group</td>
<td>Scale need to have a range from 0-50 NEWTONS (not grams). Order from common supply companies.</td>
</tr>
<tr>
<td>Ramps and fulcrums</td>
<td>1/group, 10 in a class set</td>
<td>Order from local resource.</td>
</tr>
<tr>
<td>Pulleys</td>
<td>1/group</td>
<td>Order from common supply companies. Larger pulleys are easier to work with.</td>
</tr>
<tr>
<td>Meterstick or meter tape</td>
<td>1/group</td>
<td></td>
</tr>
<tr>
<td>Clipboards</td>
<td>1/student</td>
<td>Optional; for the construction site walk.</td>
</tr>
</tbody>
</table>
### Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculators</td>
<td>1/group</td>
<td>Optional</td>
</tr>
<tr>
<td>Trash bucket or can</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>String</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber bands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhead transparencies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Additional Materials

<table>
<thead>
<tr>
<th>Additional Materials</th>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toy machine models</td>
<td>1 set per class</td>
<td>Young children’s toys, such as Matchbox cars for construction machines.</td>
</tr>
<tr>
<td>Small erasable white boards (2’ x 2’)</td>
<td>1 per group</td>
<td>Purchase large board and request it to be cut.</td>
</tr>
<tr>
<td>Legos, toy construction kits, cardboard, crayons and markers.</td>
<td></td>
<td>Assorted materials for students to draw or build their final new machine designs. Also use whatever other resources are available in your room.</td>
</tr>
</tbody>
</table>