Acknowledgments

Project Team:

Directors
Rodney L. Custer, Illinois State University
Michael K. Daugherty, University of Arkansas

Curriculum Specialists
Jenny L. Daugherty, University of Illinois

Art Director and
Layout Design
Cindy M. Curtis, Illinois State University

External Evaluator
John T. Mouw, Professor Emeritus, Southern Illinois University

Any opinions, findings, and recommendations or conclusions expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation.

The purpose of this guide is to inform teachers, professional development providers, and teacher educators of the most suitable approaches, methods, and techniques for delivering the ProBase curriculum units. The ProBase Professional Development Guide serves as an addition to the separate unit-specific Instructor and Student Guides. The historical and theoretical basis for the curriculum’s development and practical tips and techniques for implementing the curriculum in the classroom are explored in this guide. The guide begins with an overview of the project, including its development and testing in the field. Next, an overview of the ProBase curriculum format is explored. Finally in separate sections, essential theoretical components and issues related to the ProBase curriculum are explored in detail, comprising the bulk of this guide. Throughout these sections, practical tools and techniques will be provided to help teachers and trainers effectively deliver the ProBase curriculum.
Table of Contents

Introduction ................................................................. 5

Backward Design ......................................................... 15

Standards-Based Curriculum ........................................ 33

Constructivism ............................................................. 49

Problem-Based Learning ............................................... 67

Engineering Concepts .................................................. 79

Cooperative Learning ................................................... 95

Assessment Strategies .................................................. 113

Implementation Issues .................................................. 123

Appendix ..................................................................... i
The National Science Foundation-funded ProBase Curriculum is a standards-based curriculum series designed for upper-level high school students. The ProBase Curriculum offers constructivist, engineering-related activities and materials. The curriculum series consists of eight separate nine-week learning units, which can provide two years worth of learning experiences (as shown in Figure 1). Each of the learning units have both Student and Instructor Guides, which deliver core technological concepts through hands-on, problem-solving activities. The Instructor Guide is very prescriptive providing detailed lesson guides, discussion points, resource lists, and tips for setting up lab experiments and lessons. Meanwhile, the Student Guide is very constructivist in nature—requiring the student to seek out the required information and connections. The eight learning units cover the following technical areas: information and communication technology, agriculture and related biotechnologies, manufacturing technology, energy and power technology, medical technology, construction technology, transportation technology, and entertainment and recreation technology. The goal of the ProBase curriculum is to provide an engineering and technical base for high school students who plan to continue their education in technical or engineering programs at the community college or university level.
Overview of Project

The ProBase Curriculum was developed using a “backward” design process derived from Wiggins and McTighe’s *Understanding by Design* (1998), as shown in Figure 2. (This approach to curriculum development is explored in more detail in the Backward Design section on pages 15-32.) The knowledge base and the end results of the curriculum were identified prior to the generation of the curriculum materials. First, enduring understandings were derived from the core concepts identified in *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000-2004). Standards for Technological Literacy (STL) lists 20 standards and supporting benchmarks for technology education to enable the facilitation of technological literacy in K-12 students. (The standards-based approach to curriculum development is discussed on pages 33-48.)

**Figure 2: The “Backward Design” process**
In order to identify the enduring understandings, a “core concepts filter” (see Figure 3) was used to filter down to the essential domain-specific content worth teaching. The enduring understandings consist of those concepts recognized as being important enough to know well into adulthood, often misunderstood concepts, concepts central to the study of technology, and finally those concepts that are engaging to students. Essential questions were then derived from the enduring understandings to better focus each of the learning units. Additionally, core bridge competencies were established in conjunction with a consortium of community colleges. The bridge competencies identified the technical base needed for incoming college students and informed the development of the enduring understandings.
The knowledge base of the ProBase Curriculum is comprised of three components: (a) the Standards for Technological Literacy (from which the enduring understandings were derived); (b) domain-specific content; and (c) the bridge competencies. As illustrated by Figure 4 below, this provided a strong base for the development of a challenging and authentic set of curriculum.

![Diagram](Link)  
**Figure 4:** The ProBase knowledge base

Using this strong knowledge base, the curriculum specifications were determined. The ProBase curriculum was then developed utilizing a selected panel of experts from across the United States. The ProBase curriculum team hosted several writers’ symposia, where technology education teachers and content experts were asked to develop and refine sections of the curriculum. The curriculum was subject to a series of pilot and field tests at diverse secondary school sites located in a range of geographic areas, from Florida to Oregon. The field tests were conducted by teachers and students in real classrooms and labs across a broad spectrum of population and school demographics (e.g., rural,
urban, suburban, racial, ethnic, socio-economic) programs, and ability levels. With regular instructor debriefing sessions, on-site visits, student debriefings, telephone conversations, e-mail correspondence, and surveys, the curriculum was refined and greatly improved over the two-year testing process.

The curriculum is designed to use a modified-constructivist approach, encouraging students to focus on and design solutions to problems, with minimal constraints (constructivism is explored on pages 49-66). Group work is encouraged to develop cooperative learning skills in brainstorming, designing solutions to the problems, and to meet the bridge competencies. (Cooperative learning is discussed on pages 95-112.) While the Student Guide provides students with problem-based learning experiences (problem-based learning is examined further on pages 67-78), the Instructor Guide provides the instructor with teaching techniques, laboratory set-up procedures, material lists, planning calendars, assessment guides and rubrics, as well as a host of other materials designed to assist the instructor in delivering the curriculum.

The field tests were conducted by teachers and students in real classrooms and labs across a broad spectrum of population and school demographics, programs, and ability levels.
Overview of The ProBase Format

Each nine-week learning unit begins with a Preliminary Challenge that introduces the students to the content of the learning unit. The Preliminary Challenge also serves to prepare students for the Primary Challenge. (Refer to Table 1 below for an illustration of the format of each ProBase learning unit.) For example, in the Medical Technologies unit, students construct a simulated heart using a pump and tubing. The Medical Technologies unit provides an analysis of how medical technologies are used to increase the quality and length of human life, including the tools and devices used to repair and replace organs, prevent disease, and rehabilitate the human body. The unit also explores how the increased use of medical technology carries potential consequences, which require public debate.

---

<table>
<thead>
<tr>
<th>Primary Challenge Driven</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preliminary Challenge</strong></td>
</tr>
<tr>
<td><strong>Introduction to Primary Challenge</strong></td>
</tr>
<tr>
<td><strong>Learning Cycles</strong></td>
</tr>
<tr>
<td><strong>Completion of Primary Challenge</strong></td>
</tr>
</tbody>
</table>

*Table 1: Format of each ProBase unit*
Students are introduced to the Primary Challenge immediately after completing the Preliminary Challenge. The Primary Challenge is a robust design problem that is supported in the subsequent learning cycles. Students are provided approximately two weeks at the end of the unit to complete the challenge. The Primary Challenge is designed to be robust and challenging. In some cases, students may think they are difficult to complete. However, the learning cycles provide the necessary learning experiences for the students to gain the appropriate skills to be able to adequately complete the challenge. The Manufacturing Technologies unit, for example, examines the advances that maintain manufacturing efficiency, along with the effects of manufacturing on the standard of living. The unit also explores the process of changing raw materials into more desirable products and the effects of manufacturing on human consumption. These concepts are encompassed in a dynamic Primary Challenge providing students the opportunity to research, design, and create a functional vending machine.

Each learning cycle is comprised of four phases including an Exploration, Reflection, Engagement, and Expansion, as explained in Table 2. In addition, each learning cycle ends with a connection to the Primary Challenge, titled

<table>
<thead>
<tr>
<th>The Four-Phase Learning Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
</tr>
<tr>
<td>Reflection</td>
</tr>
<tr>
<td>Engagement</td>
</tr>
<tr>
<td>Expansion</td>
</tr>
</tbody>
</table>

Table 2: Explanation of the four phases in each ProBase learning cycle
“Preparing for the Challenge.” For example, Learning Cycle One in the Transportation Unit explores appropriate technology. The Primary Challenge in the Transportation Unit asks students to design and construct a transportation device that is capable of transporting set amounts of water and one passenger over varying distances. Each team is to design the transportation device for an assigned “client nation.”

The organization has provided a list of potential “client nations” for you to help:

<table>
<thead>
<tr>
<th>Ethiopia</th>
<th>Ecuador</th>
<th>Haiti</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>Lebanon</td>
<td>Mali</td>
<td>Nicaragua</td>
</tr>
</tbody>
</table>

*Figure 5: “Client nations” list from the Primary Challenge in the Transportation Unit*

During the Exploration of Learning Cycle One, students are asked to complete a profile sheet for their assigned nation. They are asked additional questions about their assigned nation during the Reflection phase. The Engagement phase engages students in the construction of a small-scale, appropriate technology device using pedal power. Finally, students have the option to complete one of three Expansion activities that explore the hand-crank radio, non-traditional bicycles, and wind energy. In “Preparing for the Challenge,” students are asked to gather all of the information they have collected about their client nation and determine what other information is needed to construct an appropriate solution to the challenge.
Overview of Guide: Theory to Practice

During the remainder of this guide, specific theoretical components and issues directly connected to the ProBase curriculum are discussed. During this discussion, ProBase’s approach to these issues is explained and tips and techniques for effective implementation are provided. The topics explored include:

- Standards-Based Curriculum
- Backward Design
- Constructivism
- Problem-Based Learning
- Engineering Concepts
- Cooperative Learning
- Assessment

This guide provides the background knowledge and servers as a resource tool for ProBase instructors, professional development providers, and teacher educators. This guide serves to fulfill the need to prepare instructors for the ProBase way of teaching.

It will be helpful to define some terminology and explain some of the interdisciplinary connections made in the ProBase curriculum between technology, engineering, mathematics, and science before each topic is explored in more detail. First, technology can be defined as the study of our human-created and -controlled world and universe. Technology education is the school subject which teaches how we, as humans, create the technological (non-natural) world around us (Dugger, 1994). The Accreditation Board for Engineering and Technology defines engineering on their website as “the profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.” According to the National Research Council, science is a study of our natural world and universe. The American Association for the Advancement of Science defines mathematics as the study of all conceivable abstract patterns and relationships.
Because of its interdisciplinary nature, teachers will be provided with specific tips and techniques to feel comfortable teaching the ProBase curriculum. It is important to note that teachers are not expected to be experts in each of these disciplines. Following a constructivist approach, the learning process is student-centered, not teacher-driven. Students are encouraged to find the answers to their own questions, and to not rely heavily on the teacher. However, teachers need to be provided with tools to be adequately prepared to facilitate hands-on, problem-based activities; that is the goal of this guide. As Loucks-Horsley (1998) argued, appropriate curriculum implementation strategies should have the teacher’s time devoted to learning the content necessary to teach the new curriculum and conduct the activities, so that students can best learn the new material and so that teachers can incorporate the new curriculum into long-term instruction.

References


Professional Development Guide
Backward Design
Backward Design

The ProBase curriculum was developed using a “Backward Design” approach to curriculum development, informed by the work of Grant Wiggins and Jay McTighe, in *Understanding by Design* (1998). The core of this approach includes “start[ing] with the end—the desired results (goals or standards)—and then deriv[ing] the curriculum from the evidence of learning (performances) called for by the standards and the teaching needed to equip students to perform” (Wiggins & McTighe, 1998, p. 8). The ProBase curriculum was developed from a set of “enduring understandings” that were derived from Standards for Technological Literacy (STL) and Bridge Competencies (this is discussed further in the next section). This section describes the backward design approach to curriculum design and instruction and further details the development of the ProBase curriculum.

**Backward Design Approach**

Instead of beginning with textbooks, lessons, or activities to develop classroom curriculum, Wiggins and McTighe argue that teachers and curriculum designers need to start with the desired results of the learning experience. In other words, the goals or standards and the evidence of learning should be the beginning of curriculum planning. This appears “backward” to some because the natural inclination of most teachers and curriculum designers is to identify favored lessons or “cool” activities and then build instruction around them. With the backward design approach, the end result of the learning experience is first identified, not the activity. As indicated by Figure 6 (adapted from Wiggins and McTighe, 1998, p. 9), the desired results are identified, the acceptable evidence determined, and then the instruction and learning experiences are planned and implemented.

*Figure 6: Backward Design Process*
Enduring Understandings

Teachers need to first identify what students should know at the completion of a lesson or activity. In order to do that, they should establish goals, review content standards, and determine their expectations for student learning. Wiggins and McTighe offered three “filters” for determining the appropriate results of a learning experience: (1) concepts worth being familiar with, (2) concepts important to know or do, and (3) “enduring” concepts. Enduring concepts or enduring understandings refer to the big ideas that students should know and be able to retain over the long term. The term “enduring understandings” refers to “the big ideas, the important understandings that we want students to ‘get inside of’ and retain after they’ve forgotten many of the details” (Wiggins & McTighe, 1998, p. 10). The “enduring understanding filters” offered by Wiggins and McTighe contain the following questions.

1. Is the concept something important to know as an adult?
2. Does it reside at the heart of the discipline?
3. Does it require uncoverage of abstract and often misunderstood ideas?
4. Does it offer potential for engaging students?
ProBase’s Enduring Understandings

Consistent with the Understanding by Design model, ProBase began by distilling nine enduring understandings from the technology education standards by using a “core concepts filter” (see Figure 7). The content from STL were screened through a similar set of filters. Before becoming an enduring understanding in the ProBase curriculum, each concept had to filter through four questions:

1. Is the concept important enough to know into adulthood?
2. Is the concept often misunderstood?
3. Is the concept central to Technology Education?
4. Does the concept offer potential for engaging students?

Figure 7: Core concepts filter
Teaching for Understanding

An important goal of the backward design approach is to teach for understanding. Teaching for understanding requires that the student’s view of knowledge and coming-to-know is made “more sophisticated by revealing the problems, controversies, and assumptions that lie behind much given and seemingly unproblematic knowledge” (Wiggins and McTighe, 1998, p. 26). Wiggins and McTighe described this process as “uncoverage.” Instead of covering a variety of topics and content, students should uncover the meaning and context of the knowledge under inquiry.

Because of the focus on uncoverage, teaching for understanding (and clarifying misunderstandings) is anchored in questions. Questions enable students to rethink understandings through learning experiences that focus on inquiry and performance. According to Wiggins and McTighe, students “need concrete and meaningful experiences, problems, applications, and shifts of perspective to enable an important question to arise” (p. 33). Essential questions are developed to help guide the learning experiences.

Essential Questions

Simple introductory questions are needed to structure the design of lessons and to serve as lead-ins to the overarching unit and essential questions. The guidelines for entry-point questions involve four criteria:

1. Framed for maximum simplicity
2. Worded in student-friendly language
3. Provoke discussion and questions
4. Point toward the larger essential and unit questions.
Essential questions are then used to target the key concepts and core ideas of the discipline. These questions further structure the design of the lessons and learning experiences. For a list of what essential questions do, see the box below.

**Essential Questions:**

- **Go to the heart of a discipline:** important and controversial problems and topics
- **Recur naturally throughout one’s learning and in the field:** same important questions are asked and re-asked
- **Raise other important questions:** they open up a subject, its complexities, and its puzzles

**ProBase’s Essential Questions**

Upon passing through the enduring understandings filter, each enduring understanding was then further “unpacked” to be meaningful for learning and instruction. All enduring understandings were therefore further clarified through the use of essential questions that a successful student would be able to answer upon completing the unit of study. For example, if a student had recently completed a lesson that covered Enduring Understanding 1 (that technological progression is driven by a number of factors, including individual creativity, product and systems innovation, and human wants and needs); that student should be able to answer the following essential question: what social, cultural, and political pressures lead to the need or want for new technologies? Three to four of these enduring understandings along with the associated essential questions are delivered in each of the eight learning units through complex problems using a constructivist approach to learning and teaching.

A complete list of the enduring understandings and related essential questions are provided in the front section of the Instructor’s Guide of each learning unit. In addition, the enduring understandings are provided in the appendix of this guide.
The second stage of the backward design approach is determining what counts as acceptable evidence of understanding. In order to determine acceptable evidence of understanding, understanding itself must be defined. According to Wiggins and McTighe, there are six facets of understanding: explanation, interpretation, application, perspective, empathy, and self-knowledge. These six facets of understanding are explained in more detail below.

**The Six Facets of Understanding**

When we truly understand, we:

- **Can explain:** Understanding is not mere knowledge of facts but knowledge of why and how. Students should be able to explain an answer with the justification for how the answer was determined.

- **Can interpret:** Making sense of the information presented through stories or facts involves translation and interpretation. Learning cannot be exclusively the memorization and recitation of what someone else says is the meaning of something.

- **Can apply:** As Wiggins and McTighe stated, to “understand is to be able to use knowledge” (p. 51). Application of knowledge is a context-dependent activity. To apply knowledge in educational contexts, there needs to be an emphasis on performance-based learning where work focuses on and culminates in more authentic tasks.

- **Have perspective:** Understanding often requires the ability to see things form a dispassionate and disinterested perspective. Perspective allows students to be “alert to what is taken for granted, assumed, overlooked, or
glossed over in an inquiry or theory” (p. 53). Coursework should encourage students to ask and answer: What is it? What is assumed? What follows?

- **Can empathize:** The ability to walk in another’s shoes is an important aspect of understanding. According to Wiggins and McTighe, students have to learn “how to open-mindedly embrace ideas, experiences, and texts that might seem strange, off-putting, or just difficult to access if they are to understand them and their connection to what is more familiar” (p. 56).

- **Have self-knowledge:** Understanding the world requires that students first understand themselves. Self-knowledge demands that we question our own understandings in order to transform and advance them.
Evidence of Understanding

Assessment strategies should be explored and developed prior to the development of the activities and lessons. This ensures that understanding is given priority and it also helps us to avoid teaching trivia and memorization. These concepts “go beyond discrete facts or skills to focus on larger concepts, principles, or processes” (Wiggins and McTighe, p. 10). **Students are typically more engaged when encountering big ideas in ways that connect to their interests.** The backward design approach forces educators to think about what will qualify as evidence of student learning to prevent the mere coverage of course content. Students will have to delve deeper into the big ideas and show evidence of learning. Teachers should use a variety of assessment methods in order to collect this “evidence.” After having identified the desired results and acceptable evidence, appropriate learning experiences can be developed.

Assessment in ProBase

The ProBase curriculum established a variety of assessments prior to the development of the learning experiences. (Assessment is explored further in another section of this guide on pages 113-122.) Different assessment strategies are used so that student performance is monitored and feedback can be provided throughout the learning experience. Performance tasks (hands-on activities, group projects, and Primary Challenge solutions) allow students to demonstrate their competence in performing an activity. These activities also allow students to demonstrate different facets of understanding such as application, empathy, and interpretation. As displayed in Table 3, the different assessment opportunities offered in the ProBase curriculum target different facets of understanding. Presentations and Inventor’s Logbook entries, for example, can be assessed throughout each learning unit to gauge student understanding through explanation, interpretation, and self-knowledge.
<table>
<thead>
<tr>
<th>Assessment Opportunity</th>
<th>Where in Unit</th>
<th>Activity</th>
<th>Type of Assessment</th>
<th>Facet of Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-on activities</td>
<td>Most learning cycles</td>
<td>Performance-based</td>
<td>Authentic and Formative</td>
<td>Application</td>
</tr>
<tr>
<td>Group projects</td>
<td>Most learning cycles</td>
<td>Performance-based and communication-based</td>
<td>Authentic, Formative, and Peer</td>
<td>Application and Empathy</td>
</tr>
<tr>
<td>Presentations</td>
<td>Many learning cycles</td>
<td>Communication-based</td>
<td>Formative, Summative, and Peer</td>
<td>Explanation, Interpretation, and Application</td>
</tr>
<tr>
<td>Inventor’s Logbook entries</td>
<td>During the Reflection phase of each learning cycle</td>
<td>Communication-based</td>
<td>Formative, Peer, and Self</td>
<td>Self-knowledge, Explanation, and Interpretation</td>
</tr>
<tr>
<td>Primary Challenge</td>
<td>End of each Learning Unit</td>
<td>Performance-based and communication-based</td>
<td>Authentic, Formative, Summative, and Peer</td>
<td>Application, Interpretation, and Empathy</td>
</tr>
<tr>
<td>Comprehensive Examination</td>
<td>End of each Learning Unit</td>
<td>Written</td>
<td>Summative</td>
<td>Explanation and Interpretation</td>
</tr>
</tbody>
</table>

*Table 3: ProBase opportunities for assessment*
Wiggins and McTighe use the acronym WHERE to explain the organization of learning experiences (explained below). They argue that curriculum should be user-friendly through the design of thought-provoking and engaging learning experiences (p. 115-116).

- **Where are we headed?** The goals of the learning experiences should be articulated and made clear to the students, including the performance obligations and criteria for assessment. The meaning and purpose of the learning experiences should be translated to the students at this time as well. Students should clearly see the purpose of each assignment and have a sense of the overall plan of the unit.

- **Hook the student through engaging and provocative entry points.** The learning experiences should be purposely designed to engage students through thought-provoking experiences, challenges, and problems. Student engagement must be explicitly designed into the learning experiences.

- **Explore and enable/equip.** The learning experiences should provide multiple opportunities for students to explore the big ideas and essential questions that have framed the unit. The goal of the curriculum should be to make those abstract big ideas accessible, real, and important to the students.

- **Reflect and rethink.** To help facilitate deeper levels of understanding, learning experiences should require students to reflect upon the activities they completed and rethink their previous understanding. Students should be provided with multiple opportunities to revisit the big ideas and essential questions that are guiding the unit. In particular, rethinking ideas allows students to shift their perspective and relate the new understanding to dissimilar experiences.

- **Exhibit and evaluate.** Within a performance-based curriculum, students should be provided with multiple opportunities to exhibit their understandings. In addition, teachers should evaluate that understanding at multiple points to help check misunderstandings and guide a deeper level of understanding.
The WHERE in ProBase

The ProBase curriculum follows the WHERE approach to its organization of the learning units and learning cycles (as shown in Table 4). Each unit is organized around a large, complex problem called the Primary Challenge. After a “hook” activity, called the Preliminary Challenge, students are introduced to the Primary Challenge and made aware of their performance obligations. The learning cycles are designed to equip and enable students to solve the Primary Challenge at the completion of the learning unit. The Inventor’s Logbook provides students the opportunity to reflect on activities just completed and connect their learning to the Primary Challenge. In addition, the logbook entries, along with the activities during the Learning Cycles, allow students to exhibit understanding and teachers to evaluate their performances.
## The WHERE in ProBase

<table>
<thead>
<tr>
<th>WHERE</th>
<th>The ProBase Approach</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where are we headed?</td>
<td>Introduction to the <em>Primary Challenge</em></td>
<td>Introduced toward the beginning of the learning experience (directly after the <em>Preliminary Challenge</em>); describes the challenge, the performance obligations, and criteria for assessment.</td>
</tr>
<tr>
<td>Hook the students</td>
<td>The <em>Preliminary Challenge</em></td>
<td>Sparks student interest with a 3-5 day activity.</td>
</tr>
<tr>
<td>Explore and enable/equip</td>
<td>Learning Cycles</td>
<td>Constructs knowledge and skills to enable students to complete the <em>Primary Challenge</em>. Asks essential questions; delivers core concepts equipping students.</td>
</tr>
<tr>
<td>Reflect and rethink</td>
<td>Inventor’s Logbook</td>
<td>Throughout every learning cycle students are asked to reflect on the completed activities and apply their newly gained knowledge to the <em>Primary Challenge</em>.</td>
</tr>
<tr>
<td>Exhibit and evaluate</td>
<td>Learning Cycles and the Completion of <em>Primary Challenge</em></td>
<td>Each learning cycle provides multiple opportunities for students to exhibit understanding and for teachers to evaluate their performance, culminating in the completion of the <em>Primary Challenge</em>.</td>
</tr>
</tbody>
</table>

*Table 4:* ProBase’s approach to WHERE
The Information and Communication Technologies unit provides a good example of how ProBase utilized the WHERE approach in the design of learning experiences. The Information and Communication Technologies unit examines how technology facilitates the gathering, manipulation, storage, and transmission of data and how this data can be used to create useful products. The unit also explores how communication systems can solve technological problems. These concepts are encompassed in a dynamic Primary Challenge providing students the opportunity to research, design, and create a functional security system for a locker. The supporting learning cycles cover concepts ranging from electromagnetism to conversion and modulation. Students also explore and use electronic communication devices, conversion units, and digital control units to solve different design problems throughout the unit. Table 5 on the next page details how the WHERE approach is reflected in the Information and Communication Technologies unit.
### The WHERE Model in the Information and Communication Technologies Unit

<table>
<thead>
<tr>
<th>WHERE</th>
<th>Unit Components</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where are we headed?</td>
<td>Introduction to the <em>Primary Challenge</em></td>
<td>The challenge is described. Performance criteria is explained, including: • A working system that meets the constraints • A diagram of how the system functions • A 5- to 10-minute presentation • A marketing plan • A comparison of the system to others</td>
</tr>
<tr>
<td>Hook the students</td>
<td>The <em>Preliminary Challenge</em></td>
<td>Students explore different communication technologies including: semaphore, Braille, Morse code, the international alphabet, Navajo Windtalkers, logos, encryption, sound guidance, and databases.</td>
</tr>
<tr>
<td>Explore and enable/ equip</td>
<td>Learning Cycles</td>
<td>Four learning cycles provide multiple activities and opportunities to explore information and communication technologies including: constructing a telegraph, making an AM radio, programming a 7-segment display, and exploring electronic input/output devices.</td>
</tr>
<tr>
<td>Reflect and rethink</td>
<td>Inventor’s Logbook</td>
<td>An example from Learning Cycle 1 asks students to reflect on the telegraph activity and draw a diagram using the communication model to show the process their message went through from sender to receiver.</td>
</tr>
<tr>
<td>Exhibit and evaluate</td>
<td>Learning Cycles and the Completion of <em>Primary Challenge</em></td>
<td>For example, at the end of Learning Cycle 3 students are asked to connect what they have learned to prepare for the <em>Primary Challenge</em>. They are asked to start designing their alarm system and compile their marketing plan. Space is provided for the students to do so, allowing teachers to evaluate their understanding before actual construction work begins on their locker alarm systems.</td>
</tr>
</tbody>
</table>

*Table 5: WHERE in the Information and Communication Technologies unit.*
Tips and Techniques

As Wiggins and McTighe pointed out, teaching “for understanding is not the same thing as teaching for skill or recall of facts” (p. 159). Teaching for understanding deemphasizes instruction and places more emphasis on asking probing questions. In addition, teachers must be vigilant about checking for understanding and be prepared to remedy misconceptions or confusion. Students should realize that “understanding means that they must figure things out, not simply wait for and write down teacher explanations” (p. 161). Understanding itself is more broadly conceived in a Backward Design approach to curriculum implementation. The six facets of understanding described earlier (explanation, interpretation, application, perspective, empathy, and self-knowledge) should result from the learning experiences. Students should be provided the opportunity to acquire these facets of understanding. Below are some tips and techniques to help teachers facilitate these facets of understanding in their students.

Asking Questions

Categories of Questions

- **Convergent Questions**—require students to recall and integrate or analyze information for determining one expected correct answer

- **Divergent Questions**—call for opinions, hypotheses, or evaluations where many possible correct responses may be given

- **Mental Operation Questions**
  - *Factual Questions*—test the student’s recall of information
  - *Empirical Questions*—require integration or analysis of information for a single, correct predictable answer
  - *Productive Questions*—do not have a single, correct, predictable answer
  - *Evaluation Questions*—require a value be placed or some kind of judgment made
Essential questions and Inventor's Logbook questions are provided throughout the ProBase learning units. Additional questions from both the students and teachers should be encouraged and explored. Questions help promote engagement from the students and lead to the uncoverage of the big ideas that are worth understanding. According to Wiggins and McTighe, the “challenge is to map out the most natural and engaging flow of such questions and (delayed) answers” (p. 142). Teachers do not and cannot know all of the answers, and should not be the primary source of information. Students should be encouraged to venture out and find the answers to the questions they generate on their own or as an entire class.

Types of Questions

- **Focusing Questions**—direct student attention
- **Prompting Questions**—a rewording of the original question after an inaccurate response
- **Probing Questions**—used to elicit clarification, develop critical awareness, or refocus

Moore (2005) even calls the ability to question a “sophisticated art” (p. 237). He argues that questions should be at the appropriate level, of the appropriate type, and they must be worded properly in order to generate a response from students. For more specific information about types of questions and questioning techniques see the boxes on this page (adapted from Moore, 2005, pp. 237-249).

Questioning Techniques

- **Redirecting**—asks students to respond to a question in light of a previous response from another student
- **Wait-Time**—teachers should wait to respond or ask another question so that students have time to think and ponder their responses
- **Halting Time**—when presenting complex material, the teacher should halt what he/she is saying and give students time to think
- **Reinforcement**—pattern of positive reaction
Teaching for Understanding Techniques

- Engage students in inquiry and inventive work as soon as possible when understanding seems evident to guide and focus the learning.

- Save lectures for “half-time” and “post-game” analysis, to help students better comprehend the learning experiences they just completed.

- Raise more questions and answer fewer of them.

- Ask naïve or simple questions so that students are able to explain and interpret meaning by coming up with answers.

- Raise complex questions that have many plausible answers to push students into considering multiple perspectives and giving empathetic responses.

- Coach students to conduct effective final performances.

- Encourage students to find knowledge on their own.

- Assess understanding periodically, not just at the end of a lesson or unit (Wiggins and McTighe, p. 164-165).

It is strongly suggested that ProBase teachers obtain and read a copy of Wiggins and McTighe’s Understanding by Design for a more thorough explanation of the backward design approach to curriculum design. This section was intended to provide an overview of backward design and more importantly demonstrate how the ProBase curriculum utilized this approach. Built into the ProBase curriculum is an approach to teaching that will be described further in the constructivism, problem-based learning, and collaborative learning sections of this guide.

References


Professional Development Guide
Standards-Based Curriculum
Standards-Based Curriculum

The integration of technology education standards into the classroom is one of the primary goals of the ProBase Curriculum. The ProBase Curriculum is based upon Standards for Technological Literacy (STL), which lists twenty standards and supporting benchmarks for technology education. These standards detail “the technological facts, concepts, and capabilities” (Reeve, 2002, p. 33) that students should acquire through their educational experiences. As described in the introduction and the backward design section, the knowledge base of the ProBase Curriculum is comprised of three components: (a) Standards for Technological Literacy (from which the enduring understandings were derived); (b) domain-specific content (stemming from STL), and; (c) the bridge competencies. As illustrated in Figure 9, this knowledge base reflects how the ProBase curriculum is standards-based, not standards-reflected. By relying on STL to provide the enduring understandings and content, the standards are able to be delivered more easily to students. With STL at the core of the curriculum, instructors can be assured that the standards are being implemented in their classrooms through the delivery of the core concepts of the field.

Figure 9: The ProBase knowledge base.
Standards

Standards mean different things to different people. In some schools, standards describe general expectations for student knowledge, while in other schools standards describe very specific performance requirements. National and state standards documents typically provide direction for instructors and administrators and help to inform curriculum decisions. Standards, however, are not curriculum. According to Bybee (2000), the “power of standards lie in their capacity to change fundamental components of the educational system, which include curriculum programs, instructional practices, and educational policies designed to implement and sustain the changes implied by the standards” (p. 26). In other words, standards have the capacity to alter the curriculum, the way it is delivered to students, and the rules that govern educational delivery.
Standards for Technological Literacy

In technology education, the standards are called *Standards for Technological Literacy (STL)*. STL is driven by the collective desire to improve K-12 curriculum to achieve technological literacy. Technological literacy is “the ability to use, manage, understand, and assess technology” (ITEA, 2000, p. 9). The standards provide technology educators with a structure and framework for curriculum development, the aim of which is technological literacy.

**STL-Based Curriculum:**

- Focuses on students and their learning.
- Reflects exemplary practices for teaching and learning.
- Incorporates best practices to stimulate student interest and confidence in technological studies, develop technological literacy, and enhance student achievement.
- Emphasizes design and problem-solving activities.
- Provides multi-sensory experiences based on technological knowledge, processes, and contexts.
- Enables students to create design plans, engage in design and problem-solving processes, and systematically evaluate the effectiveness of designs and solutions to practical problems.
- Contributes to standards attainment through planned student experiences.
- Develops technological literacy through organized and sequenced experiences.
- Integrates math, science, and other subjects to broaden students’ understanding of technology.
- Promotes careers in professional and technical fields (Valesey, 2002, p. 6).
Technological Literacy

STL promotes the development of technological literacy. Technologically literate individuals are able to make informed decisions about the technology they use. They also have the “capacity to design, develop, control, use, and assess technological systems and processes” (Shackelford, Brown, & Warner, 2004, p. 7). The three components of technological literacy defined by ITEA in Technology for All Americans (1996) are: (a) the ability to use, (b) the ability to manage, and (c) the ability to understand technology (explained below). Most importantly, technologically literate individuals understand that technology is the “result of combining ingenuity and resources to meet human needs and wants” (ITEA, 1996, p. 11).

Technological literacy means:

- **The ability to use technology:** involves the successful operation of the key systems of the time. This includes knowing the components of existing macro-systems, or human adaptive systems, and how the systems behave.
- **The ability to manage technology:** involves ensuring that all technological activities are efficient and appropriate.
- **The ability to understand technology:** involves more than facts and information, but also the ability to synthesize the information into new insights.
Technologically literate individuals:

- Are capable problem solvers
- View technological issues from different points of view and contexts.
- Acknowledge that the solution to one problem often creates other issues and problems.
- Understand that solutions often involve trade-offs.
- Appreciate the interrelationships of technology, society, and the environment.
- Have the ability to use concepts from science, math, social studies, and the humanities as tools for understanding and managing technological systems.
- Use a strong systems-oriented approach to solving technological problems.
- Can identify appropriate solutions, and forecast the results of implementing the solutions.
- Consider the impact of, and determine which is, the most appropriate course of action.
- Understand the major technological concepts behind the current issues.
- Incorporate various characteristics from engineers, designers, technicians, artists, etc.
- Understand and appreciate the importance of fundamental technological developments.
- Have the ability to use decision-making tools in all aspects of their lives.
- Understand that technology is the result of human activity (adapted from ITEA, 1996, p. 11).
As Weber (2005) has observed, technology education instructors must advocate a holistic approach to STL so that students are able to develop technological literacy. One method of developing technological literacy is to explore “the concepts and theories that are at the very core of the study of technology” (Shackelford, Brown, & Warner, 2004, p. 7). Concepts and theories help to clarify the underlying principles and systems behind different technologies. This approach “enables students to make connections, recognize patterns in technological development, and use technology appropriately” (Shackelford, Brown, & Warner, 2004, p. 7). Concepts and systems can be viewed as the building blocks that help students to develop their understanding of technology.

According to Technology for All Americans, there are a number of concepts central and unique to the study of technology. These concepts serve to underscore the underlying principles and systems of technology. A list of these concepts are provided below.

**Technological Concepts:**

- Technology results from human ingenuity.
- Technological activities require resources.
- People have created technological systems to satisfy basic needs and wants.
- Technological activities have both positive and negative impacts on individuals, society, and the environment.
- Technology provides opportunities and triggers requirements for careers.
- The current state of technological sophistication is the result of the contributions of diverse cultures.
- Complex technological systems develop from simpler technological systems.
- The rate of technological change is accelerating (adapted from ITEA, 1996, p. 30).
Curriculum Alignment

A popular approach to delivering the standards has been through curriculum alignment. Curriculum alignment is achieved when the curriculum covers the topics included in the standards. However, topic coverage does not ensure achievement of the standards by the students. As O’Shea (2005) pointed out, the process of developing curriculum and creating educational experiences that achieve the standards is not an easy task. The complex nature of standards, frameworks, and related standards documents often makes the process of identifying appropriate learning expectations a challenging experience. In developing standards-based curriculum, the “identifiable inputs and outputs of a system can be seen and described, but the process that gives rise to the outputs is the least understood part of the system” (O’Shea, 2005, p. 19). Simply covering the topics that appear in the standards during a lesson or unit does not assure anyone that the standard has been achieved or understood by the student. Thus, while relying on curriculum alignment as a standards integration tool is a faster approach, it is ultimately less effective, when compared to developing a standards-based curriculum that addresses standards from the ground up. Every attempt has been made to make ProBase standards-based rather than standards-aligned.

Standards-Based Curriculum

As Wiggins and McTighe (1998) stated in *Understanding by Design* (their approach to curriculum development is explored in the next section of this guide), “standards provide a framework to help us identify teaching and learning priorities and guide our design of curriculum and assessments” (pp. 7-8). The goal of standards-based curriculum is not to dictate the learning of the standards, but to provide a range of experiences and activities that target different learning styles so that students are able to meet the standards. Standards provide the broad strokes of the end results of learning. As promoted by Wiggins and McTighe’s “backward design” curriculum development model, the standards inform the desired end results of the learning experiences, which then are used to plan the learning experiences. In other words, the standards are used to develop the curriculum.
Standards-Based vs. Standards-Reflected

Not all curriculum is standards-based, even when the authors say it is! Figure 10 shows the difference between standards-based and standards-reflected curriculum. According to ITEA’s *Planning Learning* (2005), high-quality curriculum should be standards-based, not standards-reflected. Similar to curriculum alignment, standards-reflected curriculum means that the teacher or curriculum developer links the standards to existing curriculum. The standards are an afterthought, not the driving force for the curriculum. The ultimate goal of standards-based curriculum is that “what students know, are able to do, and ultimately understand is based on the technological literacy standards” (ITEA, 2005, p. 10).

Figure 10: Standards-Based vs. Standards-Reflected
The standards-based approach to curriculum development can be viewed as a system with inputs, processes, outputs, and feedback. Hider (2005) described a process approach to curriculum development. The input consists of the guiding principles of the curriculum based on the standards. The processes are comprised of the approaches, methods, and guidelines used to develop the curriculum. The output is the actual curriculum. The feedback is provided by reviewers and consumers. Figure 11 shows the systems approach to curriculum development (adapted from Hider, 2005, p. 30).

**Figure 11:** Systems approach to curriculum development

### Standards are important because they:

- Detail the facts, concepts, and capabilities that students should acquire through their educational experiences.
- Outline what students should know, be able to do, and ultimately understand.
- Provide the framework for developing educational experiences.
- Provide alternatives to meeting the needs of students who require additional instruction.
ProBase and $STL$

The ProBase curriculum is standards-based, not standards-reflected as indicated in Figure 12. Enduring understandings were derived from $STL$, prior to the development of the curriculum. The ProBase curriculum delivers the standards in a teachable way because in order for standards to have an impact on learning, instructors must be able to teach them. According to Gandalt & Vranek (2001), one of the most difficult challenges in delivering standards in the classroom is providing teachers with the training, tools, and support they need to help students gain the knowledge outlined in the standards. In fact, given the applied nature of technology education and the tendency of technology teachers to concentrate on activities, one major challenge is to shift the focus to important concepts and ideas that are to be delivered. This is why standards are so important. Standards identify and help to place the focus on concepts. The ProBase curriculum, along with this guide, provides teachers with the necessary tools to deliver the technology education standards.

---

The ProBase curriculum delivers the standards in a teachable way because in order for standards to have an impact on learning, instructors must be able to teach them.

---

**Figure 12:** ProBase curriculum development process
As discussed in the backward design section, *enduring understandings* were derived from the core concepts identified in *STL*. In order to distill *enduring understandings* from *STL*, a “core concepts filter” (as shown in Figure 3 on page 7) was used to filter down to the essential domain-specific content worth teaching. The enduring understandings consist of those concepts recognized as being important enough to know into adulthood, often misunderstood concepts, concepts central to the study of technology, and finally those concepts that are engaging to students. This resulted in nine ProBase enduring understandings (see below).

---

**ProBase Enduring Understandings**

*Students will understand:*

1. That technological progression is driven by a number of factors, including individual creativity, product and systems innovations, and human wants and needs.

2. That technological development for the solution of a problem in one context can spin-off for use in a variety of often unrelated applications.

3. That technological change can be positive and/or negative, and can have intended and/or unforeseen social, cultural, environmental, and political consequences.

4. How technological systems work, the components of those systems, and how they fit into the larger technological, economic, and social systems.

5. The compelling and controversial issues associated with the acquisition, development, use, and disposal of resources.

6. That the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.

7. That technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.

8. How technological assessment is used to determine the benefits, limitations, and risks associated with existing and proposed technologies.

9. How to utilize a variety of simple and complex technologies.
Examples of a Standards-Based Learning Unit

The ProBase Energy and Power Technologies unit is used to illustrate how each ProBase unit is standards-based. The Energy and Power Technologies unit examines the relationship between energy and power technologies and how modern systems impact cultures, societies, and the environment. The unit also explores how energy and power systems can be made more efficient and how they may be utilized in problem solving. These concepts are encompassed in a dynamic Primary Challenge providing students the opportunity to research, design, and create a functional hydro-electric power source. The supporting learning cycles cover topics ranging from the ethical, environmental, social, and political influences to the laws of conservation. Students also explore and build basic electronics and mechanical devices to solve different design problems throughout the unit.

The Energy and Power Technologies unit focuses on four of the nine ProBase enduring understandings. In addition, eight ProBase essential questions are explored in this unit. As discussed previously in this section, the enduring understandings were derived from STL. An examination of one of the learning cycles in the Energy and Power Technologies unit can explore this point further.

Energy and Power Technologies Learning Cycle 1 provides an introduction and overview of the historical and present-day sources and forms of energy and power. In addition, this learning cycle examines the manner in which power is generated and the ethical, environmental, social, and political influences behind the choices we make locally, regionally, and globally. During this learning cycle, students create a timeline of a specific energy source, assessing the energy source based on specific criteria, and then they develop a presentation. Students also build a simple generator in this learning cycle to understand the basic concepts of electricity generation. Learning Cycle 1 delivers three ProBase enduring understandings and three ProBase essential questions. The enduring understandings are derived from Standards 4, 7, and 16.
Energy and Power Technologies Overview

Up to this point, we have been discussing the Project ProBase Learning Units in general terms. The following points will be specific to Energy and Power Technologies.

Enduring Understandings and Essential Questions

The Energy and Power Technologies Learning Unit focuses on four of the nine enduring understandings. As they complete Energy and Power Technologies students will understand:

3. That technological change can be positive and/or negative and can have intended and/or unforeseen social, cultural, environmental, and political consequences.

4. How technological systems work, the components of those systems, and how they fit into the larger technological, economic, and social systems.

6. That the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.

9. How to utilize a variety of simple and complex technologies.

The essential questions addressed in each learning cycle will be correlated to the learning cycle objectives.
Tips and Techniques

The Student Guides of each unit list only the objectives at the beginning of each learning cycle for the students to review and understand. The Instructor Guides, however, detail the enduring understandings, essential questions, and objectives for each unit. It is recommended that these be explained to the students and returned to often throughout the delivery of the learning unit. This will help ensure that the students comprehend the purpose and value of working on the activities and completing the assignments. Keep in mind that while the ProBase curriculum does not point out every instance where a standard is addressed inside the curriculum, the curriculum was designed from the ground up using STL. Ultimately the standards help to identify and maintain a focus on concepts and big ideas that students need to know rather than merely completing activities for their own sake.

References


Constructivist Approach

The ProBase curriculum uses a modified constructivist approach. A constructivist approach is grounded in the belief that knowledge is best acquired when students construct their own knowledge. Each ProBase Learning Unit is designed around a large, complex problem called the Primary Challenge. Students are provided with the core concepts and skills in the learning cycles to solve the Primary Challenge. Students are guided through the process through cooperative, problem-based learning experiences to support their learning, allowing them to construct their own understanding of the most important (core) concepts. The Instructor’s Guide provides instructors with the necessary information to facilitate and guide students using constructivist activities (in this way, the ProBase curriculum utilizes a modified-constructivist approach). This section describes the theory behind constructivism and constructivist teaching and learning. In addition, tips and techniques are provided in order to aid the implementation of constructivist learning through the ProBase curriculum.

Constructivism

Constructivism is not a teaching model. Rather, it is a theory of learning based primarily upon Jean Piaget’s work. Piaget believed that what we call knowledge does not represent independent reality. Knowledge is the incorporation of new information into the individual’s existing knowledge base (Fosnot, 1996). In other words, what constitutes as knowledge is specific to each person. Each person uses previous experiences and knowledge to make meaning from new information (Larochelle, et. al. 1998). Constructivists argue that new knowledge can only be learned or constructed by an individual using prior knowledge.
Constructivism is presented in a variety of ways in the literature; however, two categories are relevant for educational purposes: cognitive and social constructivism. **Cognitive constructivism** is based on Piaget's beliefs. This view encompasses the belief that learners actively restructure or rearrange knowledge in highly individualized ways. **Social constructivism**, however, sees learning as primarily a product of the individual's culture and surroundings. Lev Vygotsky originated the social constructivist view of learning. Social constructivism focuses largely on the context or surrounding environment of learning, while cognitive constructivism focuses primarily on an individual's process of learning (Windschitl, 2002).

**social & cognitive CONSTRUCTIVISM**

Cognitive and social perspectives of constructivism can aid teachers as they design learning activities and conceptualize their role as facilitators of instruction. Both perspectives emphasize the active nature of learning. In this view of learning, meaning is derived only when learners actively engage in the learning process by putting forth the effort to construct new knowledge (Palmer, 2005). Proponents of constructivism believe that the traditional teacher-dominated classroom is inadequate for successful, meaningful, life-long learning.

---

**Cognitive constructivism**—theory of learning stating that knowledge is restructured in highly individualized ways.

**Social constructivism**—theory of learning that stating that knowledge is a product of an individual's culture and surroundings.

**Proponents of constructivism believe that the traditional teacher-dominated classroom is inadequate for successful, meaningful, life-long learning.**
John Dewey’s beliefs about education can be linked to the constructivist approach to teaching. Dewey believed that learning emerged from the child, not the instructor. He argued that quality teaching should take into account how students best learn, particularly the context or environment that induces student learning (Matthews, 2003). Educational experiences should be social, connected to previous experiences, embedded in meaningful activities, and related to students’ understandings of the world. These beliefs are echoed in the constructivist literature. Instead of the traditional “mimetic” or memorization approach, constructivist teaching practices are designed to be meaningful to students, allowing students to construct their own understanding using their prior experiences and knowledge.

Constructivism Learning & Teaching

The basic premise behind utilizing a constructivist approach to teaching is that learners acquire knowledge by constructing it for themselves. Learning involves the active creation and modification of knowledge, not the passive absorption of information. This approach enables learners to construct links between new ideas and what they already know. For example, students who understand selective breeding for a dominant trait in crops are able to construct links to understanding cloning and genetic modification of crops (discussed further in ProBase Agriculture and Related Biotechnologies, Learning Cycle 1).

Teachers use the constructivist approach to encourage independent thinking, allowing students to direct the learning experience. Teachers often have students manipulate raw materials or data in laboratory settings or consult primary sources rather than textbooks (Brooks & Brooks, 1993). Constructivism focuses on thinking processes rather than on the quantity of information that can be memorized or recited. Content is important in a constructivist classroom; however students “uncover, discover, and reflect on content and their conceptions of such through inquiry, investigation, research, and analysis in the context of a problem, critical question, issue, or theme” (Marlowe & Page, 2005, p. 8).
Learning in constructivist terms is:
- The process and result of questioning, interpreting, and analyzing information.
- Integrating current experiences with past experiences.
- Using information to develop, build, and alter meaning and understanding.

Implementation Issues

According to Windschitl (2002), implementing the constructivist approach has been difficult for many instructors, resulting in fragmented teaching strategies. Many of the major challenges faced by instructors include:

- translating the philosophy of constructivism into a basis for instruction;
- reorienting the classroom to a constructivist culture; and,
- struggling with the outside forces that tend to challenge the constructivist teaching approach.

Windschitl (2002) argued that “pseudo-principles” have emerged resulting in a distortion of the concept of constructivist teaching, preventing a sound implementation in the classroom. Among these “pseudo-principles” are:

- the belief that there can be no direct instruction;
- constructivism is the same as discovery learning;
- students must be physically or socially active to learn;
- all ideas by students are equally legitimate; and,
- that there are no rigorous assessment strategies associated with constructivist teaching.
According to Windschitl, these assumptions misrepresent the constructivist approach to teaching. The ProBase curriculum uses a modified constructivist approach to learning because of these challenges. The Student Guide is designed to be meaningful for students, allowing them the opportunity to construct knowledge from their previous experiences and knowledge. The Instructor Guide is more prescribed so instructors can effectively facilitate this type of approach. See Table 1 on page 10 for how ProBase approaches different constructivist teaching principles.

The constructivist approach to teaching is grounded in psychology and social science research, providing the basis for this type of approach to teaching and learning. Constructivist curriculum is centered on student learning and the focus of instructors is on meaningful understanding. This approach provides sound pedagogy so that instructors avoid relying on activities for their own sake. Constructivism has largely been embraced by the K-12 science, social studies, and mathematics education communities as a foundation for teaching. For example, it has largely been accepted by the science community that students learn about science by using “their existing knowledge, beliefs, interests, and goals to interpret any new information, and this may result in their ideas becoming modified or revised” (Palmer, 2005, p. 1854).

In order to better understand a general constructivist approach to teaching, the following commonalities are outlined below.

**Common Components of Constructivist Classrooms:**

1. **Learner-centered:** Instruction is focused on what the learners bring to the classroom in terms of prior knowledge, intellectual strategies, culture, etc. The instructor uses these experiences to aid students in understanding new ideas.
2. **Interest-level:** New understanding is developed more easily when students are interested and engaged in learning. Targeting students’ prior knowledge and areas of interest increases the likelihood that students will actively explore their existing understandings and transform them.

3. **Real-life context:** The context of learning is deemed to be extremely important for student interest and deeper understanding.

4. **Collaboration:** Interaction with others in the development and exploration of new ideas is an important aspect of constructing meaning. By explaining, defending, discussing, and assessing their own ideas and challenging, questioning, and comprehending others’ ideas, students develop a deeper understanding of the concept or issue at hand.

5. **Active learning:** Students should actively engage in their own learning in order to construct new meaning. Visible learning actions include writing, discussing and searching for information. Less visible learning actions include reading, listening, monitoring, reflecting, considering, evaluating, and checking information.

6. **Time:** For broad and deeper understanding to occur students need time to digest the new information.

7. **Feedback:** In order for students to better reflect on the relationship between existing knowledge and new information, feedback is necessary. Feedback, in the form of performance-based observations, provides students with opportunities to revise their thinking, encounter differing points of view, and develop a coherent rationalization for their new understanding.

8. **Support:** Instructors primarily offer students support in the learning process. Support can come in the form of providing cues, identifying critical errors, providing feedback, and demonstrating how tasks can be completed (Sherman & Kurshan, 2005).
A Note on Assessment

Assessment within the constructivist learning process is viewed as a tool to aid the learner, not just an accountability device or as a teacher effectiveness measure (assessment is discussed further in another section of this guide). “Errors” are perceived as a result of learners’ conceptions and not to be minimized or avoided. Instead of emphasizing “rightness” or “wrongness,” assessment within constructivist pedagogy takes the form of nonjudgmental feedback. Assessment through teaching, participating in student/teacher interactions, observing student/student interactions, and watching students work with ideas and materials is valued as a reflection of student learning more than tests and external assessments. Assessments focus both on the processes and products of learning. Therefore the assessment methods must be rich and interpretive. These methods may include clinical interviews, observations, student journals, peer reviews, research reports, the building of physical models, and performances in the forms of inquiries, plays, debates, dances, or artistic renderings. These artifacts or performances require well-designed, flexible rubrics for evaluation that stress the process of learning. Many of these assessment methods are utilized in the ProBase curriculum and are explored in detail in the assessment section of this guide.

Constructivist Teaching Models

With the popularity of the constructivist teaching approach, numerous constructivist teaching models have emerged. In the appendix, there is a summary of a small selection of some of those models.

The ProBase Approach to Constructivism

As Wiggins and McTighe (1998) pointed out, “instructional methods and techniques follow from the specific types of learning needed to achieve the desired results (evidence of understanding) in the unit or course” (p. 163). Within the ProBase curriculum, a modified-constructivist approach follows from the cooperative, problem-based approach to learning embedded in the curriculum. Table 6 outlines the guiding principles of constructivist teaching and the implementation of these principles within the ProBase context.
### Table 6: Constructivist teaching principles and ProBase

<table>
<thead>
<tr>
<th>Guiding Principles of Constructivist Teaching</th>
<th>ProBase Implementation of these Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encourage and accept student autonomy and initiative.</td>
<td>Students are encouraged to complete the <em>Primary Challenge</em> with as little guidance as possible.</td>
</tr>
<tr>
<td>Use raw data and primary sources, along with manipulative, interactive, and physical materials.</td>
<td>The ProBase curriculum relies on hands-on activities that use manipulative, interactive, and physical materials.</td>
</tr>
<tr>
<td>Allow student responses to drive lessons, shift instructional strategies, and alter content.</td>
<td>The Reflection portion allows students to respond to the activities and can be starting-off points for redirection.</td>
</tr>
<tr>
<td>Encourage students to engage in dialogue, both with teacher and with one another.</td>
<td>Discussion is integrated into most of the learning cycles and is encouraged throughout the learning unit.</td>
</tr>
<tr>
<td>Encourage student inquiry by asking thoughtful, open-ended questions and encourage students to ask questions of each other.</td>
<td>The Instructor Guide contains probing questions, along with the Reflection questions provided in the Student Guide. Spontaneous questions are encouraged.</td>
</tr>
</tbody>
</table>

The Student Guides were designed to promote active learning, with students being encouraged to construct their own knowledge during the *Preliminary* and *Primary Challenges*, as well as in the supporting Learning Cycles. For this reason, minimal instruction and guidelines are provided in the Student Guides to encourage students to ask questions and seek their own answers, which is consistent with the constructivist approach to learning. The ProBase Instructor Guides, however, are designed to equip the instructors with the knowledge needed to facilitate the successful implementation of the learning experiences. The Student Guide pages are inset in the Instructor Guide and tips, techniques, and other useful information is provided in the margins. The differences between these two guides are outlined in Table 7 according to the section of the ProBase learning unit.
<table>
<thead>
<tr>
<th>Section</th>
<th>Student Guide</th>
<th>Instructor Guide</th>
</tr>
</thead>
</table>
| Front Section | -Key concepts and learning unit goal outlined  
-ProBase Learning Cycle format explained  
-ProBase design model explained | -Learning unit overview and related ProBase teaching and learning style information discussed  
-Learning unit concept map  
-Materials and equipment list  
-ProBase design model explained  
-Unit calendar |
| Preliminary and Primary Challenge | -Scenario described  
-Key terms defined  
-Material list outlined  
-Performance requirements listed  
-Rubric provided | -Purpose of activity explained  
-Key concepts outlined  
-Learning unit goal provided  
-Facility requirements described  
-Suggested daily outline provided  
-Equipment and materials listed by number of students/groups  
-Preparation for activity explained  
-Instructor resources listed  
-Teaching tips included throughout  
-Rubric provided |
| Learning Cycles | -Scenario described  
-Objectives listed  
-Key terms defined  
-Material list outlined  
-Constraints/requirements listed  
-Performance requirements listed  
-Rubric provided | -Purpose of learning cycle explained  
-Objectives and essential questions provided  
-Learning cycle concept map provided  
-Facility requirements described  
-Suggested daily outline provided  
-Equipment and materials listed by number of students/groups  
-Estimated number of class periods provided  
-Preparation for activity explained  
-Teaching tips included throughout  
-Rubric provided |
| Inventor’s Logbook/Reflection Phase | -Questions asked and space provided for answers | -Questions listed and plausible answers provided |

*Table 7: The modified-constructivist approach in ProBase*
The Instructor Guide

After an extensive pilot and field testing process, where the ProBase curriculum was delivered in high school labs and classrooms by high school teachers across the country, the Instructor Guides were expanded based on teacher feedback and input. The Instructor Guides are designed to ensure that the instructors are supplied with the necessary information to feel comfortable incorporating the curriculum within their classrooms. For example, the front section supplies instructors with detailed information to help prepare them for the rest of the unit. In each unit, instructors are provided with details about the purpose of the learning unit with the “Learning Unit Overview.” In addition, a brief discussion about constructivist-based teaching and learning is provided, along with other detailed information about the ProBase approach to teaching and learning.

Information specific to each unit is also included in the front matter. Using the Agriculture and Related Biotechnologies unit as an example, the different resources provided in the Instructor Guide are described below. The Agriculture and Related Biotechnologies unit examines how agricultural technologies provide increased crop yields and allow adaptation to changing environments, enabling the growth of plants and animals for various uses. The unit also provides an analysis of the various uses of biotechnology and the ethical considerations of those uses. These concepts are encompassed in a dynamic Primary Challenge providing students the opportunity to research, design, and create a functional method for propagating new plants. The supporting learning cycles cover topics including government regulation, genetic modification, and soil salinity. Students also explore and use micro-propagation techniques, control logic, sensors, and microprocessors to solve different design problems throughout the unit.
Included in every ProBase Instructor Guide is a **concept map** depicting the core concepts being delivered in that particular unit by learning cycle. It is recommended that the teacher place the poster-size version of this map (available on the CD) somewhere in the classroom and then discuss it with the students. This will help them understand the “road map” of the learning experience, as well as help anchor each activity within the core concepts. The *Agriculture and Related Biotechnologies* learning unit concept map is shown below.

**Figure 14:** Concept Map found in the *Agriculture and Related Biotechnologies* Instructor Guide
Another important tool to aid instructors is the **materials and equipment lists** (shown below) that detail all of the materials and equipment necessary to complete the unit. The list provides the quantity, the learning cycle the item is used in, and any notes and recommendations discovered during the field testing of the unit. Within the notes and recommendations category, suggested sources and part numbers are often supplied for the more unusual materials. The ProBase curriculum was designed to keep the costs as low as possible, so many of the materials can be purchased at local super stores or home repair centers.

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Item</th>
<th>Learning Cycle</th>
<th>Notes and Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Camera</td>
<td>Primary</td>
<td>Suggested source: science department or Carolina, # 71-1309</td>
</tr>
<tr>
<td>7</td>
<td>Scalpels</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Tweezer forceps</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Cds photocells</td>
<td>Primary, LC 2</td>
<td>Suggested source: Radio Shack®, part # 276-1657</td>
</tr>
<tr>
<td>7</td>
<td>Basic Stamp serial programming cables</td>
<td>Primary, LC 2</td>
<td>Suggested source: Parallax®, Inc. (<a href="http://www.parallax.com">www.parallax.com</a>), part # 800-00003</td>
</tr>
<tr>
<td>7</td>
<td>Basic Stamp HomeWork Boards™</td>
<td>Primary, LC 2</td>
<td>Suggested source: Parallax, Inc. (<a href="http://www.parallax.com">www.parallax.com</a>), part # 28158</td>
</tr>
<tr>
<td>1</td>
<td>Glass stirring rod</td>
<td>Preliminary, LC 3</td>
<td>Suggested material for building enclosed environments</td>
</tr>
<tr>
<td>1</td>
<td>Measuring instrument or cylinder to measure 20 mL, 30 mL, 95 mL, 100 mL, and 180 mL</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Measuring instrument to measure 5 and 20 grams</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Strainer</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Thin wires (one end bent into a loop)</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Microscope slides</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Microscopes or as many as possible</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Blender</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Knife</td>
<td>Preliminary</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 15:** Learning Unit Equipment list found in the *Agriculture and Related Biotechnologies* Instructor Guide
In addition to the concept map and materials and equipment list, a **unit calendar** is provided in the front matter of each Instructor Guide. The *Agriculture and Related Biotechnologies* unit calendar is shown below. The calendar was based on a semester-long schedule, outlining nine weeks of five-day 50-minute periods. (For block scheduling, instructors will need to adjust the calendar appropriately.) The days on the calendar are blocked according to learning cycle and learning phase (*Exploration*, *Engagement*, and *Reflection*). At least two weeks (ten days) are entirely devoted to working on the *Primary Challenge* throughout and at the end of the learning unit.

**Agriculture and Related Biotechnologies Unit Calendar**

<table>
<thead>
<tr>
<th>Week</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Course Introduction Preliminary Challenge</td>
<td>Preliminary Challenge</td>
<td>Intro to Primary Challenge; Enduring Understandings</td>
<td>Learning Cycle 1 - Exploration I</td>
<td>Learning Cycle 1 - Exploration I Reflection I</td>
</tr>
<tr>
<td>2</td>
<td>Learning Cycle 1 - Exploration II</td>
<td>Learning Cycle 1 - Exploration II Reflection II</td>
<td>Learning Cycle 1 - Exploration I Engagement</td>
<td>Learning Cycle 1 - Exploration I Engagement</td>
<td>Preparing for the Challenge</td>
</tr>
<tr>
<td>3</td>
<td>Learning Cycle 2 - Exploration I</td>
<td>Learning Cycle 2 - Exploration I Reflection I</td>
<td>Learning Cycle 2 - Exploration II</td>
<td>Learning Cycle 2 - Exploration II Reflection II</td>
<td>Learning Cycle 2 - Engagement</td>
</tr>
<tr>
<td>4</td>
<td>Learning Cycle 2 - Engagement</td>
<td>Learning Cycle 2 - Engagement</td>
<td>Learning Cycle 2 - Engagement</td>
<td>Learning Cycle 2 - Engagement</td>
<td>Preparing for the Challenge</td>
</tr>
<tr>
<td>5</td>
<td>Learning Cycle 3 - Exploration</td>
<td>Learning Cycle 3 - Exploration</td>
<td>Learning Cycle 3 - Exploration</td>
<td>Learning Cycle 3 - Reflection</td>
<td>Learning Cycle 3 - Engagement</td>
</tr>
<tr>
<td>6</td>
<td>Learning Cycle 3 - Engagement</td>
<td>Preparing for the Challenge</td>
<td>Learning Cycle 4 - Exploration</td>
<td>Learning Cycle 4 - Exploration</td>
<td>Learning Cycle 4 - Exploration</td>
</tr>
<tr>
<td>7</td>
<td>Learning Cycle 4 - Reflection</td>
<td>Learning Cycle 4 - Engagement</td>
<td>Learning Cycle 4 - Engagement</td>
<td>Learning Cycle 4 - Engagement</td>
<td>Preparing for the Primary Challenge</td>
</tr>
<tr>
<td>8</td>
<td>Preparing for the Primary Challenge</td>
<td>Preparing for the Primary Challenge</td>
<td>Preparing for the Primary Challenge</td>
<td>Preparing for the Primary Challenge</td>
<td>Preparing for the Primary Challenge</td>
</tr>
<tr>
<td>9</td>
<td>Preparing for the Primary Challenge</td>
<td>Preparing for the Primary Challenge</td>
<td>Preparing for the Primary Challenge</td>
<td>Presentations of the Primary Challenge</td>
<td>Presentations of the Primary Challenge</td>
</tr>
</tbody>
</table>

*Figure 16:* Unit Calendar found in the *Agriculture and Related Biotechnologies* Instructor Guide
Merely meant as a guide, the calendar can help instructors plan and prepare for the entire learning unit. During the learning experience, instructors may find that students need to spend more or less time on a particular learning cycle than is provided in the calendar. It is strongly recommended that instructors monitor student learning and spend as much time as necessary for students to develop the six facets of understanding discussed in the backward design section of this guide. The goal of the ProBase curriculum is that students understand the core concepts of technology education, not rush through the activities to fit into a prescribed calendar.

In addition, teaching tips are scattered throughout the learning cycles to provide additional information to help the ProBase learning experience proceed more smoothly. Teaching tips are often suggestions concerning the introduction of learning material or the delivery of an activity. An example of a teaching tip is shown here from the Agriculture and Related Biotechnologies unit.

**Teaching Tips**

At this time, students should start a photo laboratory journal in which they keep records concerning the propagation method used, information about the type of plant, and pictorial and written observations of the progress of the cutting. Students can then document the reasons for success or failure and compare their findings with the technique used in the next learning cycle, micro-propagation. Use of the camera should be monitored closely.

*Figure 17: Teaching Tip found in the Agriculture and Related Biotechnologies Instructor Guide*
Tips and Techniques

With the intention of providing as much assistance as possible to the instructor while keeping the learning experience as constructivist in nature as possible for the student, a large amount of the Instructor Guide is devoted to tips and techniques for successful implementation. Table 8 provides some additional general tips and techniques for successfully implementing a constructivist approach through describing the student and instructor role in this type of learning environment.

<table>
<thead>
<tr>
<th>Instructors should:</th>
<th>Students should:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actively elicit students’ ideas and experiences.</td>
<td>Actively engage in complex, meaningful, problem-based activities.</td>
</tr>
<tr>
<td>Provide resources and tools to support student engagement in tasks.</td>
<td>Work collaboratively and engage in task-oriented discussions.</td>
</tr>
<tr>
<td>Encourage student discussion, writing, drawings, etc. to make thinking processes explicit.</td>
<td>Apply knowledge to diverse and authentic contexts through explaining ideas, interpreting texts, and constructing arguments.</td>
</tr>
<tr>
<td>Encourage student reflection and autonomous thinking.</td>
<td>Avoid focusing exclusively on the acquisition of “right answers,” but explore other avenues of thought.</td>
</tr>
<tr>
<td>Employ a variety of assessment strategies and provide consistent feedback on the process, as well as the products, of student thinking.</td>
<td>Elaborate and reflect on new understanding.</td>
</tr>
</tbody>
</table>

*Table 8: Instructor and student roles in constructivist learning*
In other words, instructors should assume the role of facilitator/co-learner and students should assume the role of learner/constructor of knowledge during the learning experience. Teachers can employ a range of facilitative strategies to support student learning and understanding. One important strategy that teachers can employ is modeling, where the teacher thinks aloud or acts out how to approach a problem. Other strategies include coaching, guiding, and advising, which include providing prompts, probes, or suggestions. In addition, instructors can provide students with heuristics or conceptual structures for learners to use in approaching problems.

A crucial component of constructivist learning is centering the teaching around large, complex problems. Thus, the ProBase curriculum, in addition to using a modified-constructivist approach, draws on problem-based learning theory and core engineering concepts to provide authentic and meaningful learning experiences for students. The next two sections are devoted to problem-based learning and engineering concepts within the ProBase learning context.

References


Problem-Based Learning Approach

The ProBase curriculum utilizes the problem-based learning approach to teaching. Each ProBase learning unit is centered on a large, complex problem called the Primary Challenge. To solve the Primary Challenge, students construct needed knowledge and experience through a series of learning cycle activities and lessons. Throughout the learning cycles students also encounter problems that they are asked to solve. This problem centered approach to learning allows students to develop the skills necessary to become self-directed problem solvers. This section presents a brief overview of problem-based learning theory and provides some tips and techniques for implementing this approach using the ProBase curriculum.

Problem-Based Learning

Problem-based learning was popularized by Barrows and Tamblyn (1980) in its application to medical school students. They researched the reasoning abilities of medical school students and concluded that problem scenarios were the best approach to student engagement and learning (Savin-Baden & Major, 2004). Problem-based learning is a term that can be applied to many approaches to learning generally centered on problem-solving. Problem-based learning is defined as “a method of learning in which the learners first encounter a problem followed by a systematic, student-centered enquiry process” (Schwartz, Mennin, & Webb, 2001, p. 1). Typically students are presented with a loosely structured, real-world problem. Working in small groups, they are challenged with deriving a solution(s) or resolution(s) to the problem. The role of the teacher shifts from being the focus of the learning experience to becoming the facilitator.

Problem-based learning emerged largely in response to the growing dissatisfaction with the traditional teacher-centered approach to education. According to Savin-Baden and Major (2004), problem-based curriculum is organized around problems rather than focusing on disciplines, which tend to dominate the traditional approach. Classroom activities also tend to be quite different. Problem-based learning classrooms feature the use of teams, small groups, tutorial instruction, and active learning, with an emphasis on cognitive skills.
The traditional approach typically includes whole-class lecture and passive note-taking. Another major difference is that the outcomes facilitated by problem-based learning tend to be on a more advanced conceptual plane, including learning key concepts embedded in an engaging context, the development of skills, and the development of life-long learning skills.

Within problem-based learning, students proactively develop self-directed learning skills as they determine how to solve real world problems. To do this, they must make decisions about the types of resources to use, how to acquire and use new information to implement solutions, and how to evaluate results. Students work independently and interdependently, determine multiple solutions, and test their viability. The emphasis shifts away from memorizing facts to engaging important concepts. Also, students are encouraged to come up with multiple solutions, rather than just one correct answer. According to Lambros (2004), this approach to learning positively enhances students’ comprehension, social skill development, content retention, and motivation.

Due to the variety of problem-centered learning theories (described on the next page) that have emerged, Boud (1985) outlined eight characteristics that distinguish the problem-based learning approach. These characteristics are listed below.

**Problem-Based Learning Characteristics**

1. An acknowledgment of the base of experience of learners.
2. An emphasis on students taking responsibility for their own learning.
3. A crossing of boundaries between disciplines.
5. A focus on the process rather than the products of knowledge acquisition.
6. A change in the teacher’s role from that of lecturer to that of facilitator.
7. A change in focus from teacher’s assessment of outcomes of learning to student self-assessment and peer assessment.
8. A focus on communication and interpersonal skills so that students understand that in order to relate their knowledge, they require skills to communicate with others, skills that go beyond their area of technical expertise (in Savin-Baden & Major, 2004, p. 4).
Although problem-based learning has been considered a broad approach to learning, with endless ways to implement, many have distinguished problem-based learning from other approaches to learning. Although some see these differences as relatively minor, Table 9 provides an overview of the different problem-centered learning theories. Project-based learning, for example, has been argued by some to be one in the same as problem-based learning, while others view them as two different approaches. Despite the minor differences between these approaches, all center on problem-solving as the key to learning. Although there are elements of all of these approaches in the ProBase curriculum, the problem-based approach of the ProBase curriculum most closely aligns with the description of problem-based learning (PBL).

<table>
<thead>
<tr>
<th>Method</th>
<th>Organization of knowledge</th>
<th>Forms of knowledge</th>
<th>Role of student</th>
<th>Role of teacher</th>
<th>Type of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem-based learning</td>
<td>Open-ended situations and problems</td>
<td>Contingent and constructed</td>
<td>Active participants and inquirers</td>
<td>Enabler of learning opportunities</td>
<td>Team and individual learning</td>
</tr>
<tr>
<td>Project-based learning</td>
<td>Teacher-set, structured tasks</td>
<td>Performative and practical</td>
<td>Completes project</td>
<td>Task setter and project supervisor</td>
<td>Problem solving and problem management</td>
</tr>
<tr>
<td>Problem-solving learning</td>
<td>Step-by-step logical problem-solving through knowledge provided by the teacher</td>
<td>Propositional and practical</td>
<td>Solves problems</td>
<td>A guide to the right knowledge and solution</td>
<td>Finding solutions to given problems</td>
</tr>
<tr>
<td>Action learning</td>
<td>Group-led discussion and reflection</td>
<td>Personal and performative</td>
<td>Sets goals and advises self and others</td>
<td>Facilitator of reflection and action</td>
<td>Achievement of individual goals</td>
</tr>
</tbody>
</table>

*Table 9: Problem-centered learning theories (adapted from Savin-Baden & Major, 2004, p. 7)*
Problem-Based Learning (PBL)

Curriculum design is central to effectively implementing problem-based learning. This is because curriculum “impinges upon teachers’ and students’ roles and responsibilities, and the ways in which learning and knowledge are perceived” (Savin-Baden, 2003, p. 16). Problem-based curriculum should be designed with the problem as the core element. Problem-based curriculum tends to be constructivist in nature, which prods students to make their own decisions about what knowledge is needed to solve the problem at hand. As described in the previous section of this guide, the ProBase curriculum is based on authentic problems and uses a constructivist approach to teaching.

According to Savin-Baden and Major, there are two basic models of problem-based learning curriculum design: (1) the pure model and (2) the hybrid model. The pure model of curriculum design is entirely problem-based, where students meet in small teams and do not receive lectures, tutorials, or other traditional instruction. The hybrid model incorporates resource sessions, such as lectures and tutorials to support student learning. The ProBase curriculum approaches problem-based learning using the hybrid model. Student learning is supported through content knowledge provided in the text. In addition, teachers are provided with the necessary information to implement the learning activities.
Implementing Problem-Based Learning

Teachers should begin the problem-based learning experience by starting students with a problem scenario that is “fun, humorous, and non-technical, in which they do not feel threatened” (Savin-Baden & Major, 2003, p. 68). This is very important, since most research suggests that students learn best when they are actively engaged. Early engagement is also important because it helps to sustain student interest when problems become increasingly challenging. After students have been introduced to the problem-based learning approach, more challenging and technical problems are introduced. As students work on a problem, they identify concepts that need to be understood in order to formulate a solution. One word of caution; it is important that the emphasis extend beyond just solving a problem. Problems should be viewed as tools to cause students to learn concepts as well as to understand the processes needed to find a solution (Evensen & Hmelo, 2000). It is not enough to engage the students with a challenging problem—the assignment must lead to an important learning goal. A general framework for implementing problem-based learning is provided in Table 10 below by indicating the steps of the process and the actions that occur within each step.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction of the Problem</td>
<td>Teacher describes problem scenario.</td>
</tr>
<tr>
<td>Inquiry Process</td>
<td>What do we know?</td>
</tr>
<tr>
<td></td>
<td>What do we need to know?</td>
</tr>
<tr>
<td></td>
<td>How can we find it out?</td>
</tr>
<tr>
<td>Series of lists</td>
<td>Facts list</td>
</tr>
<tr>
<td></td>
<td>Need-to-know list</td>
</tr>
<tr>
<td></td>
<td>Learning issues list</td>
</tr>
<tr>
<td>Plan of Action</td>
<td>Possible solutions explored.</td>
</tr>
<tr>
<td>Proceed to Solution</td>
<td>Groups work together to determine how to proceed.</td>
</tr>
<tr>
<td>Reflection</td>
<td>Process and content learned is discussed.</td>
</tr>
</tbody>
</table>

*Table 10: Problem-based learning framework*
The Problem

While it appears obvious, the primary element of problem-based learning is problems. There are three dimensions to most problems that should be considered when developing or selecting a problem to be introduced to students:

1. The context – the physical context of the problem and the implied task
2. The content – such as the disciplinary areas that can provide insight
3. The schema or deep structure – the underlying principle of the problem

A guide to choosing/presenting problems:
- Start with a problem about which students will have some knowledge.
- Use problems that will gain students’ interests.
- Problems should be puzzling, mysterious, or in some way dramatic.
- Problems should be varied by using different media.
- As much as possible use authentic problems.

In addition to the dimensions of a problem, there are different types of problems that target different types of knowledge. As shown in Table 11, different types of problems require different types of knowledge so they can be solved. The table also provides examples of questions derived from the different ProBase learning units that help solve a particular type of problem.

<table>
<thead>
<tr>
<th>Types of Problems</th>
<th>Explanation problem</th>
<th>Fact-finding problem</th>
<th>Strategy problem</th>
<th>Moral dilemma problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of Knowledge</td>
<td>Explanatory knowledge</td>
<td>Descriptive knowledge</td>
<td>Procedural knowledge</td>
<td>Personal knowledge</td>
</tr>
<tr>
<td>Example of Question</td>
<td>Why do architects use different types of scales?</td>
<td>What would a transit look like?</td>
<td>How does a designer use the design loop?</td>
<td>What is an appropriate solution?</td>
</tr>
</tbody>
</table>

*Table 11: Problem types, types of knowledge, and example questions (adapted from Savin-Baden & Major, 2004, p. 67)*
ProBase and Problem-Based Learning

Each ProBase learning unit begins with the Preliminary Challenge, which serves to introduce the content of the learning unit and engage students with a fun, hands-on activity. The Preliminary Challenge also introduces students to the problem-based approach of the ProBase curriculum and prepares students for the Primary Challenge. The Primary Challenge is a large, complex problem that drives the entire learning unit. The Primary Challenge is introduced to the students at the beginning of the learning unit. Students work through several learning cycles in order to construct the necessary skills and knowledge to solve the Primary Challenge at the end of the learning unit. The learning cycles are also centered on problems that students must solve in order to proceed through the learning unit. The eight Primary Challenges in the ProBase learning units are listed below.

In the ProBase learning units, students research, design, and create a:

- Scaled-model of a planned unit development: Construction.
- Hydro-electric power source: Energy and Power.
- Musical instrument: Entertainment and Recreation.
- Security system for a locker: Information and Communication.
- Vending machine: Manufacturing.
- Therapeutic solution to congestive heart failure: Medical.
- Water transportation system: Transportation.

The general problem-based learning framework described earlier is embedded within the ProBase learning unit. As shown in Table 12 using the Transportation Technologies learning unit, the Preliminary Challenge introduces the problem-based approach, followed by the introduction to the Primary Challenge. Students are then guided through the inquiry process through the learning cycles. At the end of each learning cycle students return to the Primary Challenge to apply what they have learned in that learning cycle to their solution. Students are asked questions about different aspects of the challenge to help guide them to an appropriate solution. At the end of the learning unit students construct their solutions to the Primary Challenge. In teams they decide how to best proceed by first determining what they know and what else they need to find out.
**ProBase Approach to Problem-Based Learning**

<table>
<thead>
<tr>
<th>Problem-Based Learning Framework</th>
<th>Learning Unit Section</th>
<th>Transportation Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to the Problem-Based Approach</td>
<td>The Preliminary Challenge</td>
<td>Students research different modes of transportation and create a display according to a set of criteria.</td>
</tr>
<tr>
<td>Introduction of the Problem</td>
<td>Introduction to Primary Challenge</td>
<td>Students research, design, and create a functional water transportation system for a specified country that can travel a predetermined course and deliver cargo.</td>
</tr>
</tbody>
</table>
| Inquiry Process | Learning Cycles | *Engagement activities:*
*Learning Cycle 1:* Create a pedal powered device.
*Learning Cycle 2:* Construct a transit.
*Learning Cycle 3:* Design a CO\textsubscript{2} vehicle.
*Learning Cycle 4:* Create a full-size carriage system.
*Learning Cycle 5:* Construct a vehicle to pull with the greatest possible force. |
| Series of Lists | Preparing for the Challenge (at the end of each learning cycle) | Teams are asked questions such as: What other information do you need to know about your assigned nation to complete the Primary Challenge? How will your team determine the distance that your vehicle must travel? |
| Plan of Action; Proceed to Solution | Completion of Primary Challenge | Teams work on their solutions by reflecting on the requirements of the Primary Challenge and identifying what questions they now have answers to, and what questions have yet to be answered. |
| Reflection | Reflection phase throughout each learning cycle | Students are asked questions at the end of most activities to reflect on what they have just completed and to apply the knowledge they have gained to the Primary Challenge. |

*Table 12:* The ProBase approach to problem-based learning
Tips and Techniques

The role of the teacher within the ProBase learning experience is different from the more traditional approach to teaching. Due to the constructivist nature of problem-based learning, teachers are encouraged to limit their interventions into the learning process. Throughout the learning experience, students should be encouraged to seek answers to their questions and resolve team conflicts on their own. The teacher serves as the facilitator of the learning experience, providing feedback and stimulating discussions. Since the focus is on student learning rather than the achievement of a specific task for testing purposes, the teacher serves to aid the students in the process of learning by assuming the role of guide and often as co-learner. A list of facilitation techniques (Savin-Baden & Major, p. 97) are provided below.

Facilitation Techniques

1. Acknowledge and use prior experience.
2. Recognize that being a facilitator means also being a learner.
3. Ensure that the team’s concerns are heard. Be an active listener.
4. Be responsive to team concerns. Act quickly and flexibly in order to effectively respond to issues that arise.
5. Appreciate shared risks and benefits of team learning.

Being a facilitator (or guide) is often a new role for many teachers. Some teachers feel that it is their role to be the expert, to provide clear, direct, and easily understood answers. Many students see it this way as well. Becoming a facilitator requires a different set of skills. The teacher must fill the role of planner, evaluator, and resource person in order to help guide students through the learning unit. This approach to teaching often requires more supervision than lecture-based instruction. In addition to supervising the learning experience, the teacher also promotes critical reflection by asking questions throughout the process. Reflection questions are provided throughout each learning cycle; however, teachers are encouraged to generate other questions to stimulate
the students’ thinking. Another important role of the teacher is to evaluate students’ learning to ensure that students understand the key concepts. Assessment is discussed in another section of this guide; however, it should be noted here that assessment in a problem-based context tends to be less formal than in traditional classrooms. In problem-based environments, assessment blends in with instruction and is designed to gauge students’ comprehension, check on understanding, and provide a context within which students can explain key definitions or concepts in their own words. Keep in mind that self-assessment is an important part of the process as well. A great deal can be learned by conducting a self-assessment after completing a problem-based learning activity.

Providing feedback is another critical aspect of facilitation. Feedback is not only provided through commenting on the product of the group’s work, but also by providing comments about the team’s process and progress, the inter-relationship of the students, and overall group dynamics. Feedback should be clear, positive, and specific. In addition to providing feedback, the facilitator must also be able to stimulate discussions as a critical aspect of student comprehension and reflection. There are numerous strategies to help teachers facilitate discussions, some of which are outlined below.

**Discussion Strategies**

1. Ask open-ended and reflective questions.
2. Support and value student responses to create an atmosphere of trust and openness.
4. Turn direct questions asked of the teacher back to the students.
5. Suggest alternative ideas when a team comes to a standstill or chooses an inappropriate track.
6. Monitor progress through discussions.
7. Reflect back on activities that have been completed.

*Keep in mind that self-assessment is an important part of the process as well. A great deal can be learned by conducting a self-assessment after completing a problem-based learning activity.*
The student’s role in the problem-based learning process is to be an active, motivated problem-solver. Just as teachers may not be familiar with the facilitator role, students may also not be familiar with their role. Thus, students may need to be coached into assuming this role. As opposed to the traditional, lecture-based approach where students are the passive recipients of information, within the problem-based learning approach students are the active constructors of their own knowledge. Students need to be motivated to fully engage in this process. The Preliminary Challenge is designed to “hook” student interest into that particular area of technology with a fun, one- or two-day activity. In addition, the Preliminary Challenge introduces students to the problem-based learning approach of the ProBase curriculum. In addition, (as discussed above) the selection of the problem is crucial to ensure that students are engaged and excited about solving the problem. The Primary Challenge and learning cycle problems were drawn from real-life contexts. Using an engineering design approach to problem solving, the ProBase curriculum is designed to engage students with authentic, hands-on problems. The engineering focus of ProBase is discussed in the next section of this guide.

References


Professional Development Guide
Engineering Concepts
Engineering Concepts

The ProBase curriculum infuses engineering concepts throughout many of the learning unit activities. The primary infusion of engineering into the curriculum is accomplished through the use of the engineering design process. Engineering design can be used as a tool to help guide thinking in the technical classroom. The concept of design is at the core of engineering, encompassing the process by which “nature is to be manipulated and artifacts are to be created and made to function” (2061 Panel Report, 1989). The engineering design process is a logical and effective procedure with widespread applicability. In the ProBase curriculum, a technological design loop model is used to convey the engineering design process. The ProBase curriculum relies on the teacher’s understanding of the theory behind the design process and provides an example in the beginning of each guide for students. Many activities throughout, either directly or indirectly, reference or infer a connection to the technological design loop.

STL and Engineering

As discussed in the standards-based section of this guide, with the development of and infusion of Standards for Technological Literacy (STL) (2000) into technology education classrooms, technological literacy has been targeted as a primary learning objective. The National Academy of Engineering and the National Research Council (2002), in a joint report, pointed to three interdependent dimensions of technological literacy: knowledge, ways of thinking and acting, and capabilities. Many educators have proposed engineering as an avenue to bring about these dimensions of technological literacy. Dearing and Daugherty (2004), for example, concluded that there is a consensus between engineering and technology education in the areas of problem-solving, communication, working within constraints and parameters, brainstorming, appropriate technology, and the impacts of technological growth.

As revealed in Table 13 on the next page, technology and engineering share many concepts, methods, and processes. Primarily, both disciplines “treat solving practical problems as their philosophical nucleus” (Dugger, 1994, p. 7). Actually, engineering can be considered a more refined area of study within the broader discipline of technology.
With the many parallels, many educators have begun to focus on particular engineering concepts. Partnerships with engineering have been established to help integrate engineering into K-12 education. For example, the National Center for Engineering and Technology Education (NCETE) is a National Science Foundation center for learning and teaching. NCETE is the only center addressing engineering and technology education. The ultimate goal of NCETE is to infuse engineering design, problem solving, and analytical skills into technology education in order to increase the quality, quantity, and diversity of engineering and technology educators. For more information visit: www.ncete.org.

Table 13: Shared technology and engineering concepts (table adapted from Dugger, 1994, p. 8)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involved with our human created and controlled world.</td>
<td>Involved with utilizing the materials and forces of nature for the benefit of human-kind.</td>
</tr>
<tr>
<td>Concerned with “how to.”</td>
<td>Concerned with “how to.”</td>
</tr>
<tr>
<td>More directly involved.</td>
<td>Very specifically involved.</td>
</tr>
<tr>
<td>Guided by trial and error or skilled approaches derived from the concrete.</td>
<td>Guided by a more theoretical study with specific solutions recommended.</td>
</tr>
<tr>
<td>Concerned about the solution of problems and knowledge to that solution.</td>
<td>Concerned about the solution of problems and knowledge to that solution.</td>
</tr>
<tr>
<td>Used in combination with such words as: application, instrumental principles, tools, response to perceived needs, effectiveness, doing, invention, innovation, empirical laws, engineering, design, etc.</td>
<td>Used in combination with such words as: practicality, vision, ingenuity, research, design, systems, analysis, application, technology, invention, innovation, etc.</td>
</tr>
<tr>
<td>Its success or failure is usually determined by social acceptance and success in the marketplace.</td>
<td>Its success or failure is usually determined by social acceptance and success in the marketplace.</td>
</tr>
<tr>
<td>Action oriented and requires intervention.</td>
<td>Action oriented and requires intervention.</td>
</tr>
<tr>
<td>Systems oriented.</td>
<td>Systems oriented.</td>
</tr>
<tr>
<td>Dependent on engineering, mathematics, and science.</td>
<td>Dependent on technology, mathematics, and science.</td>
</tr>
</tbody>
</table>
The greatest focus on the integration of engineering into K-12 has been through problem-solving (particularly engineering design) as a way to solve technological problems. According to STL (2000-2002), engineering design is as “fundamental to technology as inquiry is to science and reading is to language arts” (p. 90). Lewis (2005) stated that engineering design is “the single most important content area set forth in the standards, because it is a concept that situates the subject more completely within the domain of engineering” (p. 37). As Dugger (1994) pointed out, “the primary essence of technology and engineering is synthesis or design in nature—with the objective being the combining of separate elements into a whole” (p. 20).

In addition to being standards-based, engineering design serves other purposes in the technology education classroom. Wicklein (2006), for example, articulated five reasons in support of incorporating engineering design into technology education. Engineering design:

1. Is more understood and valued than technology education by the general populace.
2. Elevates the field of technology education to higher academic and technological levels.
3. Provides a solid framework to design and organize curriculum.
4. Provides an ideal platform for integrating mathematics, science, and technology.
5. Provides a focused curriculum that can lead to multiple career pathways for students.

In addition to the reasons listed above, Burghardt and Hacker (2004) argued that design activities have great potential to:

- Engage children as active participants in the learning process.
- Integrate learning from language, the arts, mathematics, and science.
- Encourage pluralistic thinking, avoiding a right/wrong dichotomy and suggesting instead that multiple solutions are possible.
- Provide children an opportunity to reflect upon, revise, and extend their internal models of the world.
- Encourage children to put themselves in the minds of others as they think about how their designs will be understood and used (p. 6).
Engineering Design

Engineering design is a form of problem-solving, “where there is the require-
ment that, in addition to solving the problem, the solution be creative” (Middleton, 2005, p. 65). The purpose of engineering design is to “take a speci-
fication of a set of needs (an idea for a new, novel or revised process or product,
and a set of statements of performances and constraints) and transform it
into full instructions for manufacturing a product and/or implementing a
process” (Eder, 1994, p. 135). Designing involves a coordinated interaction
between a group of designers and the object being designed. The engineering
design process typically involves frequent, repeated sub-processes of problem-
solving. As ProBase’s enduring understanding number seven states, “techno-
logical design is a systematic process used to initiate and refine ideas, solve
problems, and maintain products and systems.” The general cycle of problem-
solving during the design process typically follows a variation of the steps
outlined below.

Engineering Design Steps
1. Define the problem.
2. Search for, generate, and develop ideas for possible solutions.
3. Evaluate and decide among the possible solution ideas.
4. Communicate solution ideas to clients, manufacturers, etc.

The Technological Design Loop

The engineering design process model (in the ProBase curriculum, the tech-
nological design loop; see Figure 18 on the next page) is a circular model that
portrays the necessary iterations and multiple refinements that are often
needed to develop a design solution. The engineering design process model
is a useful tool to help introduce and facilitate engineering design in the class-
room. The model is provided in the front matter of the Student and Instructor
Guides of each ProBase learning unit, along with an explanation and introd 

As ProBase’s enduring understanding number seven states, “technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.”
the thinking processes that designers follow while developing solutions to problems. The “loop” aspect of the engineering design process portrays the importance of feedback so that solutions are continually evaluated to ensure they meet the specified requirements of the design.

In the ProBase curriculum, the technological design loop begins with the clarification of the problem, so that it is understood well enough to allow for the creation of a complete solution. The design parameters are established and outlined during this step in the process. Typical parameters include the availability of resources, the technical expertise needed, and the amount of money available. Once the problem is clarified, brainstorming possible solution ideas begins. The solution that best meets the parameters is selected, refined, and fully developed during the next phase of the design loop. A model or prototype is then created of the potential solution and then tested during the next steps of the design loop. If refinements are necessary (and they almost always are), they are made so that the solution is refined and can be implemented. After the problem is believed to be solved, the solution is communicated. If other problems or feedback concerning the solution arise, the loop starts over again.

![Diagram of ProBase's Technological Design Loop](image-url)
Design Constraints/Criteria

The search for and evaluation of design ideas are typically determined to be appropriate according to a certain set of constraints or criteria. These often include:

- Functionality
- Quality
- Safety
- Ergonomics
- Aesthetics
- Environmental considerations
- Economics
- Anthropometrics
- Efficiency
- Marketability

**Functionality** is concerned with how the product or solution fulfills its intended purpose. **Quality** is how well the product or solution meets certain minimum standards. Safety issues include complying with codes and regulations that provide safe use and operation by the user. **Ergonomics** is how the product is designed so that the user can operate it with ease and maximum efficiency. **Aesthetics** is the appeal of the product based on the selection of materials, processes, finish, color, or shape. **Environmental considerations** must be considered so that it does not adversely affect the environment. **Economics** are important in design because the product must be produced to keep the cost low without sacrificing safety (Gomez, 2000). **Anthropometrics** are the standards and requirements that allow the product to fit the human spectrum or condition. **Efficiency** is concerned with having the design accomplish a purpose or function with minimal use of resources. Finally, **marketability** is the likelihood that someone will purchase the product once it is commercialized.

Attempting to meet all of these design criteria is almost always impossible, which introduces the concept of trade-offs. **Trade-offs occur in the engineering design process when one design requirement is deemed more important than another or when one benefit is ignored in favor of another regarded as more desirable.**
desirable. Trade-offs can occur in the selection of materials. One material may be the most desired because of its high quality; however, the waste from the production line may be harmful to the environment. A trade-off in quality for an environment-friendly material is made. ProBase’s enduring understanding number six conveys the importance of this concept, stating that students will understand that the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.

Two other important engineering concepts can be integrated into the classroom through engineering design problems: (1) predictive analysis and (2) optimization. Engineers apply mathematical and scientific principles to solve problems prior to the selection of a design solution. The introduction of these tools into the analytical stage of the design process represents an indispensable part of engineering design (Harris & Jacobs, 1995). “The process of thinking before acting” is critical if designing is to be a predictive rather than a trial-and-error process (Hayes, 1989, p. 58). Design optimization extends beyond simply producing a design that adheres to a defined set of constraints. The purpose of optimization is to achieve the “best” design relative to a set of prioritized criteria. These include maximizing factors such as productivity, strength, reliability, longevity, efficiency, and utilization. Engineers must make many technological and managerial decisions during the design process in order to produce a best design. The ultimate goal of all such decisions is to minimize undesirable effects, while maximizing desirable effects, producing a “better, more efficient, less expensive solution that is in harmony with the laws of man and nature” (Ertas & Jones, 1993, p. 229).

Teaching Design

The challenge of incorporating engineering design into the classroom is that it requires a different approach to teaching than the traditional lecture-based approach or the traditional industrial arts approach. In the lecture-based approach, the instructor’s role is to be the primary source of disseminating content. In the traditional industrial arts approach, instructors primarily provide lessons on machine and tool operation, allowing students to learn manual skills. With these approaches, the teacher is the expert and the student passively receives information. According to Warner (2003) the “teaching of design needs to involve much more than instruction on the manipulative skills of using tools or making drawings, more than instruction on the intellectual knowledge of how a task can be done” (p. 7). Teaching design “must involve
teaching students how to actively use both their minds and their hands in order to be creative, inventive problem solvers” (Warner, p. 7).

Infusing engineering design into the classroom means that instructors need to facilitate the hands-on, minds-on application of practical and conceptual knowledge and creativity in their students. Engineering design or problem-solving is a complex activity requiring higher-order thinking, “facilitated not primarily by abstract thought but by visual mental imagery and the manipulation of concrete materials” (Middleton, 2005, p. 66). Teachers should be able to explain some of the processes and strategies of how to design to assist students’ engineering design problem-solving and creative thinking.

The creativity of engineering design should be explicitly related to students. Scott, Lonengran, and Mumford (2005) pointed out that when engineering design is taught as a creative process, multiple ways to solve a design problem are encouraged. Perhaps Burghardt and Hacker (2004) summed up the approach to teaching design best with: “pedagogically solid design projects involve authentic, hands-on tasks; use familiar and easy-to-work materials; possess clearly defined outcomes that allow for multiple solutions; promote student-centered, collaborative work and higher order thinking; allow for multiple design iterations to improve the product; and have clear links to a limited number of science and engineering concepts” (p. 6).

**Approaches to Teaching Design**

The studio experience of design has been targeted as an avenue for teaching design. The studio experience includes the process of critiquing and reinforcing new ideas into a more definitive solution. Kaufman (2005) outlined the three primary steps of the studio experience approach to teaching design:

1. Understanding—research and discovery
2. Action—actual artifacts are created through design
3. Evaluation—critique and plan for the next design iteration (p. 11)

Understanding in the context of the studio design experience encompasses the things that designers do before and during the design process to be able to develop ideas and solutions. Action occurs during the studio design experience once an idea is ready to be developed and created into a sketch or three-dimensional model. Evaluation during the studio design experience enables the designer to review how much has been accomplished and establish what still needs to be completed.
Another approach to incorporating engineering design into the classroom (and one that ProBase utilizes) is problem-based learning (PBL). PBL as an approach to teaching and learning provides educators with the “opportunity to use constructivist pedagogical practice to engage students in their own learning” (Burghardt & Hacker, p. 6), so they are constructing meaning in an authentic context. PBL and constructivist pedagogy are both explored in separate sections of this guide.

**Introducing Engineering Design**

Garmire (2003) argued that two important aspects of using the engineering design process in classrooms should be introduced to students. First, that all engineering design is a compromise. There is never enough time or money, especially in the confines of a classroom and school schedule, to implement a perfect design. Students (and teachers) must become comfortable with compromise and at making trade-offs. Second, engineering design involves and often hinges on teamwork. Teamwork or group work is discussed in the cooperative learning section of this guide, but its importance should be related to the engineering design process as well. Engineering design is almost never done by one person alone. Coordinating teamwork is an important aspect of infusing engineering design into the classroom.

In addition to these two elements of the engineering design process, the element of trial-and-error should also be related to students. Although the engineering design process involves more than finding a solution to a problem, in that it requires finding a preferred means of achieving the desired solution, the importance of trial-and-error should not be ignored. Failures are common, and often lead to better conceived engineering design solutions. Students should be made aware that the “process” of design is often as important as the “end result.” The teacher’s role during the engineering design process is very active as the facilitator and guide. For the most part, teachers should monitor the process and progress of the students, helping them to explore the intended learning objectives and reassuring them or redirecting them as needed. Teachers are not expected to know all of the answers. Students are responsible for determining what they need to know and for locating that information.
The engineering design process is referred to and used throughout the ProBase learning units. For example, the Manufacturing Technologies unit devotes an entire learning cycle to the engineering design process. The Manufacturing Technologies unit examines the advances that maintain manufacturing efficiency, along with the effects of manufacturing on the standard of living of various peoples. The unit also explores the process of changing raw materials into more desirable products and the effects of manufacturing on human consumption. These concepts are encompassed in a dynamic Primary Challenge providing students the opportunity to research, design, and create a functional vending machine. The supporting learning cycles cover topics and activities ranging from the external factors affecting product design and quality to the use of design models and principles. Students also explore and use microprocessors, “position-able” motors, sensors, and relays to solve different design problems throughout the unit.

Learning Cycle 3 in the Manufacturing Technologies unit is titled “Looping Through Design.” This learning cycle introduces students to the engineering design process and describes the technological design loop. In the Exploration phase students are asked to generate a list of questions that would guide their decision-making process when purchasing a flashlight. Using a worksheet, they must analyze different flashlights according to the criteria they generated. Along with other tasks in the Reflection phase, students are asked to categorize their questions according to the following principles of engineering design: function, efficiency, aesthetics, ergonomics, and anthropometrics. In the Engagement phase of Learning Cycle 3, students focus on the engineering design principles that guide the development of manufacturing facilities. Given a disassembled flashlight, in teams, students are asked to design and implement an assembly line process. Throughout this learning cycle, students are asked to refer to the technological design loop and consider the general engineering design principles. This helps students to develop engineering design thinking skills, which will aid them in the design of their Primary Challenge solution.
Tips and Techniques

As discussed earlier in this section, teaching engineering design is challenging. Following a constructivist, problem-based approach, the ProBase curriculum utilizes a student-centered approach that calls for the instructor to facilitate the learning process. The constructivism and problem-based learning sections of this guide provide some tips and techniques for facilitating this type of approach. In addition, the box below provides a list of elements that are also important for the infusion of engineering design into the classroom (Eder, 1994). These elements require that instructors become familiar with the basic principles of engineering design so that they can help guide students through the process by recommending different strategies.

Engineering design teachers should:

- Present knowledge about the principles and the object to be designed.
- Help students in how they logically approach the design process.
- Help students to develop adequate judgment and reasoning skills.
- Help students to develop free expression and acceptance of ideas within the constraints of the recognized problem.
- Encourage the recognition and ownership of the existence of a problem.
- Encourage communication abilities through oral and written reports.
- Encourage students to identify constraints and think about trade-offs between design constraints.
- Encourage students to identify optimal solutions.
- Use math and science principles to design solutions.

It is recommended that teachers place a poster (provided with the ProBase curriculum) of the technological design loop in their classroom for students to refer to when designing. In addition, the technological design loop is introduced to students in the front matter of each ProBase learning unit. Students should spend time reading this introduction so they are familiar with this process before beginning work on the learning unit activities. In the Instructor Guide of each unit, there are simple activities that are recommended to help instructors introduce the engineering design process to students. For example, students can use the technological design loop to design a cover for a book or CD or use the model to design a paper airplane. These short activities serve as a way to introduce the engineering design process and to help students begin to use the technological design loop.
Once students have a grasp of the engineering design process and how to use the technological design loop, they should be encouraged to use it throughout the learning unit. The engineering design process is especially important for completing the **Primary Challenges** in the ProBase curriculum. The technological design loop not only provides an aid to students working on their solutions to engineering design problems, but also helps teachers in evaluating student designs. In addition, the assessment rubrics provided at the end of each learning cycle and for the **Primary Challenge** solutions aid teachers in the evaluation of student designs. Figure 19 is the rubric provided in the **Manufacturing Technologies** unit to aid in the assessment of the **Primary Challenge**. Assessment is discussed in more detail in another section of this guide.

As discussed earlier, engineering design is typically a group effort. Most of the ProBase activities, especially the design-centered activities, use a team-based approach. Students must work in teams to arrive at an acceptable solution to a given problem. In the next section of this guide cooperative learning will be discussed, as well as tips and techniques for facilitating team-based work.

---

### Primary Challenge Rubric

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Point Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Challenge Product</td>
<td>Completed product is fully functional and addresses all criteria, parameters, and equipment specifications set forth in the Primary Challenge.</td>
<td>40</td>
</tr>
<tr>
<td>Primary Challenge Product</td>
<td>Completed product is functional and meets most criteria, parameters, and equipment specifications set forth in the Primary Challenge.</td>
<td>30</td>
</tr>
<tr>
<td>Primary Challenge Product</td>
<td>Completed product represents a serious attempt to solve the primary challenge, but does not address many of the stated requirements, criteria, or specifications.</td>
<td>15</td>
</tr>
<tr>
<td>Primary Challenge Product</td>
<td>Product is not complete or does not function well and does not meet stated criteria, parameters, or specifications.</td>
<td>10</td>
</tr>
</tbody>
</table>

**Drawings, Diagrams & Sketches**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Point Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear evidence of a comprehensive understanding and development effort, and for people successfully tested the solution.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Clear evidence of a comprehensive understanding of all requirements, criteria, or specifications, uses proper format, and was completed electronically.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Drawings, diagrams, or sketches do not demonstrate understanding of all requirements, criteria, or specifications.</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Research & Development**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Point Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and development was conducted while solving the Primary Challenge, but documentation was marginal.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Research and development was conducted while solving the Primary Challenge, but documentation was not clearly documented.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Research and development techniques were used while attempting to solve the Primary Challenge.</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Documentation**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Point Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team responded to most questions and/or maintained topical records, logs, and other notations of activities while completing the Primary Challenge.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Team responded to most questions and/or maintained topical records, logs, and other notations of activities while completing the Primary Challenge.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Team responded to most questions and/or maintained topical records, logs, and other notations of activities while completing the Primary Challenge.</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Presentation**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Point Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation demonstrates an understanding of major concepts, addresses most presentation requirements, and conforms to time limits constraints.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Presentation does not demonstrate a group of the major concepts delivered, does not conform to stated presentation guidelines and/or time limits.</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Total Points**

---

*Figure 19: Primary Challenge Rubric from Manufacturing Technologies Unit*
References


Constructing Cooperative Learning

Collaborative or cooperative learning is a team-based approach that introduces students to real world experiences in the classroom. In the context of the ProBase curriculum, team-based learning helps develop the necessary collaborative and social skills to succeed in college and a variety of careers. With the belief that learning is embedded in and enabled by social interaction, teamwork is the focus of most of the activities within the curriculum. Successful teamwork requires negotiation, mediation, and cooperation and also provides opportunities for students to compare and contrast their ideas with others, expanding their knowledge base. Another important aspect of learning enabled by teamwork is the process of personal reflection. Teamwork encourages verbalization of that reflection. Teamwork, however, is not as simple as just putting students into groups and asking them to complete a task. Students must be prepared for the experience with appropriate tools. To facilitate, monitor, and assess cooperative learning in the classroom, teachers need the group process skills to structure teams that will have the greatest chance of success. This section provides the theory behind cooperative learning and provides some tips and suggestions for the facilitation of this type of learning using the ProBase curriculum.

Team-Based Learning

Team-based learning is based on the constructivist rationale of learning (explored in another section of this manual). Students understand a concept best if they have applied it and store it in their own mental warehouse. This process is extremely difficult when done individually. Discussion and collaboration with small groups or teams of peers makes this process of understanding much easier for the learner (Stein & Hard, 2000). Especially when working on a problem that does not have a clear solution, a team “can be ‘smarter’ than any single individual member” (Cohen, 1994, p. 13). Team members contribute ideas that stimulate other members so that the team is able to create new understandings of the problem, leading to a better-conceived solution.
There are two general approaches to team-based learning: (a) collaborative learning and (b) cooperative learning. According to Bruffee (1999), these two approaches are essentially versions of the same thing. Both are educational approaches to learning that emphasize social interaction as the basis for constructing knowledge. Both approaches were developed as a way to encourage interdependence among learners. In some respects “collaborative learning in colleges and universities complements and supplements cooperative learning that children may have experienced in primary school” (Bruffee, p. 87). Collaborative learning picks up where cooperative learning leaves off. Cooperative learning stresses making education more efficient and effective by having students work together. Collaborative learning stresses the acquisition of conceptual learning through social integration.

The major differences between collaborative and cooperative learning center on their implementation. A major goal of cooperative learning is to hold students formally accountable for their own learning within the team. Collaborative learning’s goal is to attempt to shift the control or authority from the teacher to the student teams, challenging the traditional hierarchical nature of most classrooms. The major difference between the two approaches is the issue of accountability. Whereas cooperative learning attempts to accomplish individual accountability, collaborative learning encourages self-governance by the student teams with little attention paid to individual accountability. This lack of individual accountability makes collaborative learning a “hard-sell” in schools heavily dependant upon individual grades and grade point averages. Thus, whereas proponents of cooperative learning advocate assigning roles within each team (such as coordinator, facilitator, time-keeper), advocates of collaborative learning advise that only a recorder be assigned. Teachers seldom intervene in working teams in collaborative learning and disagreements are encouraged because different points of view facilitate problem solving.
Despite the differences between the two approaches to team-based learning, both stress the importance of collaboration. Research suggests that there are many benefits to student collaboration including that it:

- improves academic performance among high and low achievement students;
- increases self-esteem and social relations,
- socializes students; and,
- mediates between students’ individual experience and the intellectual tasks of the course provide opportunities for shared reflection.

Thus, not surprisingly “participation in teams has been found to increase student satisfaction and promote retention” (Stein & Hard, 2000, p. 3).

**ProBase and Cooperative Learning**

The ProBase curriculum draws largely from the cooperative approach to teaching and learning. There are numerous types of cooperative learning discussed in the research, including formal cooperative learning, informal cooperative learning, cooperative base teams, and cooperative structures. Formal cooperative learning is the approach used in the ProBase curriculum. Formal cooperative learning occurs when students work together, for as little as one class up to several weeks, to achieve shared learning goals and complete specific tasks and assignments. In formal cooperative learning teams, teachers do the following:

1. Specify the objectives.
2. Make decisions prior to the start of the lesson including: size of teams, roles, materials needed, etc.
3. Explain the task by clearly defining the assignment.
4. Teach the required concepts and strategies for completing the assignment.
5. Monitor students’ learning and working in teams to provide assistance or intervention.
6. Evaluate students’ learning (Sharan, 1994).
Each of these steps is accounted for in the ProBase curriculum. The following will help supplement the curriculum by outlining how ProBase approaches cooperative learning and by offering tips and techniques for implementing the steps listed above. Some of the tips and techniques are merely suggestions and will depend on the teacher's comfort level and experience working with teams.

**ProBase and Cooperative Learning**

There are five basic features that are essential for successful cooperative learning experiences: (1) interdependence, (2) individual accountability, (3) face-to-face interaction, (4) social skill development, and (5) team processing. (Johnson & Johnson, 1994; Stein & Hard, 2000). Evidence of these features enables teachers to determine the success of team-based exercises.

<table>
<thead>
<tr>
<th>Basic Features of Cooperative Learning:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interdependence among team members.</td>
</tr>
<tr>
<td>2. Accountability of individual students.</td>
</tr>
<tr>
<td>3. Frequent face-to-face interaction.</td>
</tr>
<tr>
<td>4. Development of social skills needed for collaboration.</td>
</tr>
<tr>
<td>5. Critical analysis of team processes.</td>
</tr>
</tbody>
</table>

*Interdependence* among team members is promoted by stressing that the success of the individual depends on the success of the team. Teachers must design, structure, and sequence activities so that interdependence is required for successful completion. For example, procedural guidelines can require consensus for the final product and the procedures by which it is produced. In addition, by assigning roles, a division of labor is outlined that requires students to work together to achieve a solution (discussed further below). Students may be required to share resources, encouraging them to work more closely together. Also, students can be rewarded both on their own performance as well as the success of the team.
The issue of *accountability* is an important aspect of cooperative learning. A variety of assessments, administered throughout the learning experience, are crucial to ensure individual accountability (assessment is described in the next section of this manual). Some of the forms of evaluation should occur toward the beginning of the learning experience to influence subsequent performance. Reflection is also a crucial component of accountability throughout the learning experience. Students should be encouraged to reflect on assessment and use its outcomes to improve their performance. Teachers can set aside time for this type of reflection and suggest how it might be interpreted and used as guidelines for action. It is also critically important to allow the cooperative team the opportunity to evaluate the performance and contribution of each member of the team. This concept is discussed in more detail under team processing below.

*Face-to-face interaction* seems an obvious component of cooperative learning; however, students often divide tasks and then work alone to complete them. This interferes with the goal of collaboration. Teachers can provide time to ensure that students collaborate on most aspects of the activity with a suitable level of supervision and encouragement. In addition, the classroom can be arranged in such a way that collaboration is encouraged, through techniques such as arranging the room to promote face-to-face interaction.

There are certain *social skills* that can (and should be) developed in order to effectively learn in a cooperative environment. These skills should be identified by the teacher early in the experience and then modeled by the teacher throughout. For example, active listening and articulation of differences are important skills in cooperative learning. Some of these skills can be represented in the roles that may be assigned to team members, such as recorder, facilitator, and trouble-shooter.

Finally, *team processing* or reflective discussion is a crucial component to ensure learning in the cooperative experience. Teams should regularly be prompted to review their performance and make plans to improve coordination. Teachers should provide the time and guidance necessary for teams to effectively process the cooperative learning experience. Questions can be posed for the teams to address and certain procedures can be outlined for the reflective discussion. The results of team processing should be discussed by the class as a whole so that all students learn from each team’s experiences.
Cooperative Classroom Environment

An important aspect of implementing team-based learning experiences is establishing a climate that supports this type of learning. Prior to beginning any activity, teachers should make decisions about the composition of the teams. The task, goal, and objectives of the activity should also be clearly articulated to the students. For students who are inexperienced in collaboration, a series of smaller, modestly challenging tasks can give students the chance to discover the value, interest, and ability to work effectively in teams.

Teachers should strive to create an environment where students can explore different ideas within their teams and the entire class to realize their capability. By paying close attention to students’ interpretations, particularly to puzzlement, confusion, and differences of opinion, teachers establish the notion that ideas are complicated and are worthy of time and consideration. Through cooperative learning, students realize that ideas can be worked out in a group context, drawing on others’ experience and knowledge. Teachers essentially “become an engineer who structures and facilitates group learning efforts rather than a worker who simply pours knowledge into pupils at a work station” (Johnson, Johnson, & Holubec, 1994, p. v.).

Listed below are some general suggestions for forming and interacting with teams (adapted from Adams & Hamm, 1990). Implementation issues such as the structuring of teams, assigning roles, arranging the classroom, facilitating teams, and assessment strategies are described in more detail below.

Team-Based Instruction Suggestions

- Accept a higher working noise level in the classroom.
- Experiment with different team patterns and sizes.
- Give students general rules for teamwork.
- Promote involvement by all students.
- Avoid interruptions of teams that appear to be working well.
- Intervene in teams that appear to be struggling beyond the ability to function.
Structuring Teams

Teachers should think through how they assign the teams because the group composition can greatly affect the dynamics and function of the team. Teams should be balanced for academic talent, extroversion and introversion characteristics, and the avoidance of cliques within the team. Students should be encouraged to help each other throughout the learning process, serving as academic, linguistic, or other intellectual resources for one another. An important skill that is instilled through teamwork is the ability to request assistance and the duty to provide it. Students should learn how to justify and support their ideas and be able to explain how, rather than do or solve another’s problem.

There is no ideal team size. The right size depends on the lesson’s objectives, students’ ages, experience working in teams, the available curriculum materials and equipment, and the time limits for the lesson. Teams larger than five often present problems for participation and interaction. The basic rule of thumb is the smaller the team the better. As the team size increases, team members and the teacher/facilitator must be more skillful in order to function effectively. Also, larger teams tend to require more resources and the level of direct student interaction and involvement decreases. Smaller teams have the advantage of making it easier to identify and address group dynamics problems.

Stein and Hard (2000) outlined four distinct stages in the evolution of teams: (1) forming, (2) storming, (3) norming, and (4) performing. They argue that the formation of teams is a developmental process. Both teachers and students should be aware of this process so that conflict and tension are recognized as signs of progress, not necessarily of failure.

Stage One: Forming

During this stage, students can be anxious and may be guarded in how they participate within the team. Teachers should help members get to know one another, establish trust, and clarify goals. Teams should be prompted to discuss the goals of the activity, establish the tasks that need to be accomplished, set ground rules, agree on the roles (if assigned) for individual members, and plan tasks for future meetings during this stage. An agenda with procedures
for operation can be developed to help accomplish the goals during this stage. Teachers can also provide suggestions for ground rules and team roles to help teams start the process more smoothly. In addition, teachers should ask questions to verify progress, draw out quieter team members, and probe students’ understandings of the task.

**Stage Two: Storming**
Disagreements and conflicts develop, even in successful teams. This stage often occurs when hostility between team members develops, cliques form, team members are challenged or criticized, and disputes about leadership occur. While these kinds of dynamics are typical, natural occurrences during the team building process, it is important that teachers learn how to actively manage group dynamics. Teachers can help teams evolve past this stage by discussing conflict and suggesting strategies for resolving disagreements. Team members should be encouraged to articulate their differences in a constructive manner and active listening should be modeled and encouraged. If intervention is necessary, teachers should sit in with teams and solicit participation from all of the members, asking them to articulate the problems and reevaluate the goals and tasks for accomplishing the activity. Teachers should also make specific suggestions to improve the team’s efficiency.

**Stage Three: Norming**
During this stage, team members begin to work more efficiently and effectively together to the point that teams become nearly self-sufficient. Teachers must balance and coordinate the individual contributions of each team member with a focus on the final product for evaluation and assessment purposes.

**Stage Four: Performing**
Teams function as integrated units during this stage. Team members become committed to each other’s success and are willing to help and advise one another. Teachers serve mainly as a resource for teams, providing ideas and logistical support. Reflection opportunities should be provided during this stage. This stage marks the successful implementation of cooperative learning.
Assigning Roles

The issue of assigning roles to students within their teams is debated by proponents of collaborative and cooperative learning. Collaborative learning proponents argue that assigning roles often restricts team members into one particular role throughout the task. Effective teams should evolve and establish roles for members as they progress through the learning experience. However, cooperative learning proponents suggest that assigning roles to students enables the teams to function more efficiently earlier in the learning experience, creating interdependence. In addition, it enables individual accountability because each student knows what they are responsible for and how they will be assessed by the teacher. Roles can also reduce the chance that some students will not contribute or will dominate the team.

The decision to assign roles is ultimately in the hands of the teacher. When students are new to cooperative learning, it is perhaps appropriate to assign certain roles to team members. Roles prescribe what team members can expect from each other and what each member is obligated to do, removing some of the uncertainty from the process. Whether or not roles are assigned, teachers should assist teams in achieving a healthy balance between division of labor and interdependence. Students should be made aware that they will be assessed on adequately fulfilling individual responsibility toward the ultimate success of the team. If teachers choose to assign roles, listed below are some possible roles and duties that can be assigned to individual team members.

**Roles and Duties:**

- **Facilitator**—organizes the team’s work, makes certain students understand the team’s job, takes the team’s questions and concerns to the teacher
- **Checker**—checks for understanding of the other team members throughout the learning experience, checks for agreement
- **Recorder**—records the team’s responses to questions and decisions, in charge of data collection
- **Trouble-shooter**—looks for and identifies possible problems or “bugs” in proposed solutions
- **Materials Manager**—gathers, distributes, and monitors the team’s use of materials to limit waste
- **Time-keeper**—monitors the team’s use of time to ensure the project is completed by deadline
When assigning roles, teachers should consider the actions that need to occur in the team in order for the task to be completed. This will help to define and then assign students roles. Roles should be rotated, so that students can practice different skills and learn from their classmates’ performance. It is suggested that the role of leader should not be assigned because leaders should be allowed to emerge and this role should be cultivated in all students.

The design and arrangement of classroom space and furniture is another important aspect of cooperative learning. The design of the classroom space affects student and teacher behavior and can facilitate or obstruct student learning. This aspect is especially important in promoting face-to-face interaction. Listed below are some effects of classroom design and some general guidelines for designing a cooperative learning classroom.

**Classroom Design:**

- Communicates the appropriate behavior and expectations of the learning experience.
- Affects student achievement and the actual amount of time students spend on task by affecting students’ visual and auditory focus.
- Affects student participation in instructional activities and patterns of communication.
- Affects opportunities for social contact among students.
- Defines appropriate circulation and interaction patterns in the room and guides students’ work and behaviors (Johnson, Johnson, & Halubec, 1994, p. 30).

**Classroom Design Guidelines:**

- Team members should be close enough to share materials, maintain eye contact, and talk with each other without disrupting other teams.
- Students should be able to see the teacher at the front of the room without twisting in their chairs or being uncomfortable.
- Teams need to be far enough apart so they do not interfere with each other.
- Students need to have easy access to each other, the teacher, and the materials they need for specific learning assignments.
Introducing the Task

At the start of the cooperative learning experience, teachers should clearly specify the objectives of the activity. Also, early in the process the task and goal of the activity should be clearly articulated to the students. Students should understand what they are being asked to do and how they will be able to accomplish the task. When introducing the task, teachers may want to provide a visual structure to portray the task and help students organize the subtasks that need to be completed. Visual organizers are blank illustrations using lines, arrows, boxes, and circles to show concrete relationships between abstract ideas or events. They can help students by guiding their thinking through a spatial format.

Examples of Visual Organizers

- **Web Network**: a wheel that has a main idea, important fact, or conclusion in the center and supporting ideas and information radiating from it.
- **Mind Map**: an expanded web network with four major features: (1) a key idea, (2) sub-ideas, (3) supporting ideas, and (4) connectors that show relationships.
- **Continuum**: ranks or orders steps or ideas of a task or set of tasks.
- **Chain diagram**: records steps in a procedure or stages of a process.
- **Spider diagram**: outlines supporting details for a central idea.
ProBase Teams

Most of the activities in the ProBase curriculum are designed to be completed in teams, typically of three to four students. All of the Primary Challenges are designed to be completed by teams, typically of five to six students. The Construction Technologies unit’s Primary Challenge, for example, has students researching, designing, and creating a scaled-model of a planned unit development. The supporting learning cycles cover topics and activities ranging from drawing and modeling to scale, to determining the necessary elements of a development and use of land options. Most of these activities are designed to be completed with the same Primary Challenge teams so that camaraderie is established and the team’s skill and knowledge level is built together.

Figure 20: Wall Section from Learning Cycle 4 of the Construction Technologies Unit
Monitoring and facilitating several teams at once may be unnatural and chaotic, especially when the teams seem off task, but students will get better at the process and become more organized as they progress. Teachers need to be mindful of guiding the teams through the process by observing the teams closely and providing feedback. Feedback is a nonjudgmental observation that describes a performance or problem. Students should be provided with areas of improvement throughout the learning process to better develop their collaborative skills. Teachers need to be vigilant about monitoring the teams and be prepared to intervene to provide assistance to increase students’ team skills and conceptual learning.

According to Johnson, Johnson, and Holubec (1994), there are four stages of monitoring that teachers should engage in during the cooperative learning experience. The first stage is the preparation stage. Teachers should prepare by identifying what are the appropriate and inappropriate behaviors that should be monitored and develop an observation form to record those behaviors. The next stage of monitoring is to observe the teams and make observations on how they are working together as a team. If necessary, teachers may decide to intervene and provide suggestions on how to improve a team’s task work or teamwork. This is the next stage of monitoring teams. The last stage of monitoring, according to Johnson, Johnson, and Holubec, is to have the students assess the quality of their participation in the teams. This encourages self-monitoring behavior in future cooperative learning experiences. This type of monitoring can occur in a more informal manner. To make more structured observations, teachers can follow the steps listed on the next page.
Although teams should be allowed to make mistakes and find appropriate solutions, there are times when teachers need to intervene to provide assistance to the team. For example, when the team is hopelessly off-task, does not seem to understand the task sufficiently enough to get started, is experiencing extreme interpersonal conflict, or is falling apart because they cannot organize themselves to get any work done, the teacher should step in and help the team get back on track. Provided below are some possible problems that may arise in teams and some proposed solutions.

**To Make Structured Observations:**

1. Decide which skills you will observe.
2. Construct an observation form to record frequencies.
3. Observe each team and record how often each student performs the specified behaviors.
4. Summarize observations in a clear and useful manner and present them to the students/teams as feedback.
5. Help students analyze the observation data and infer how effectively the team is functioning (Johnson, Johnson, & Holubec, 1994).

**Suggestions for Solving Teaming Problems**

*Potential Problem: One Member “Takes Over”*

**Potential Solution**

- Set firm goals and objectives
- Assign tasks to each member
- Assign individual responsibilities

*Potential Problem: Personality Conflicts*

**Potential Solution**

- Select and use a mediator/leader
- Ask members of the team to keep personalities out of meetings
Potential Problem: Lack of Focus

Potential Solution
- Set a timeline and stick to it
- Assign individual tasks and a time for reporting

Potential Problem: Procrastination

Potential Solution
- Set rewards for completed tasks
- Assign early deadlines
- Break tasks into small pieces

Potential Problem: Different Grade Expectations

Potential Solution
- Divide group tasks so that members understand each other's roles
- Ask team members to keep an open mind
- Redefine the project
- Brainstorm a number of potential solutions prior to implementation
- Don’t take the first ideas presented without discussing other potential solutions

Assessment is another crucial component of cooperative learning. There are two primary types of assessments that occur in cooperative learning: (1) self-assessment and (2) team assessment. Self-assessment tools include reflection papers, individual tests, and self-evaluations. Team assessment tools include team papers or presentations, observations, reviews of work, and progress reports. These two types of assessments and the other forms of assessment found within the ProBase curriculum are discussed further in the next section of this manual.
References


Professional Development Guide
Assessment Strategies
Assessment Strategies

The ProBase curriculum incorporates a variety of assessment strategies. This is important so that student performance can be monitored and feedback can be provided throughout the learning experiences offered in the curriculum. As described in the first section of this manual, the ProBase curriculum was designed using a backward design approach developed by Wiggins and McTighe (1998). The backward design approach forces educators to identify major, enduring concepts and to think about what will qualify as evidence of student learning BEFORE lessons are created. This is “backwards” from the teaching and curriculum design often implemented, where the tendency is to BEGIN with activities. A variety of assessment methods should be utilized in order to collect this “evidence.” This section describes the different approaches to assessment and the variety of assessments offered in the ProBase curriculum.

Assessment

Student assessment is a vital part of the instructional process. Assessment involves quantifying, describing, observing, reporting, and giving feedback to gauge student learning and the appropriateness of the curriculum. Quality assessment is based on quality assessment measurement devices and methods. Measurement tools must be properly designed so that the information that is generated will provide an accurate picture of what students actually know, are able to do, and value. More than one type of assessment tool and approach should be used to properly assess student performance. Also, assessment should be both formative (woven throughout the learning process) and summative (occurring at the end of the instructional process) (Moore, 2005; ITEA, 2005). As Wiggins and McTighe (1998) stated, “checks for understanding” should occur throughout the learning process. They argued that “ongoing formative and informal assessment is vital if students are to achieve understanding and avoid misunderstanding” (p. 65).
As shown in Table 14, all quality assessments should meet three general criteria: reliability, validity, and usability. Reliable assessments provide consistent results when used repeatedly. Valid assessments correspond to the content delivered in the course. Usable assessments are easy to use, administer, and score. More specifically, quality assessments should accomplish the following:

- Confirm teachers’ intuitive judgments
- Align to significant tasks
- Serve as an authentic part of the curriculum
- Require little additional time (away from instruction or learning)
- Align with standards
- Provide a platform for student and teacher reflection
- Provide models and criteria for acceptable performances (Squires, 2005)

Ultimately, assessment devices and methods should improve teaching and learning (ITEA, 2005).

<table>
<thead>
<tr>
<th>Quality Assessment Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The measurement device:</strong></td>
</tr>
<tr>
<td>Reliability</td>
</tr>
<tr>
<td>Validity</td>
</tr>
<tr>
<td>Usability</td>
</tr>
</tbody>
</table>

*Table 14: Assessment Checklist*


ProBase Assessment Strategies

The ProBase curriculum provides multiple opportunities for different types of assessment, including **authentic assessment**, **formative assessment**, and **summative assessment**. **Authentic assessment** provides the students with the opportunity to demonstrate their knowledge and abilities in real-world situations. **Formative assessment** occurs throughout the learning process, providing students with feedback that is typically more informal and individualized. **Summative assessment** occurs at the end of the unit and indicates what has been learned or achieved on completion of instruction.

Other important elements of assessment are **self-assessment** and **peer-assessment**, both of which include students in the assessment process. Self-assessment allows for reflection on the learning process and comparisons to be made with the teacher’s assessment. Self-assessment can take the form of checklists of work completed and self-correction or observation. Self-assessments also serve as a chance for the student to gauge how they are doing in the lesson or course without fear or embarrassment. Peer-assessment also allows for reflection and accountability within the group. It should be noted that self- and peer-assessments are sometimes difficult to implement. Many students will resist these approaches, preferring that the assessment process be conducted by teachers. Given the growing importance of project and team-based work as well as the need for workers who are capable of monitoring their own performance, self- and peer-assessment skills are becoming increasingly important. The key points to be made here are that (a) this will not come naturally for students and (b) teachers will need to develop the skills necessary to facilitate this new type of assessment.

Multiple opportunities exist for teachers to assess students and for students to assess themselves throughout the ProBase learning experience, as shown in Table 15 on the next page. Performance tasks (hands-on activities, group projects, *Primary Challenge* solutions) allow students to demonstrate their competence in performing an activity, and should be monitored along their develop-
ment with authentic assessments. Group projects, presentations, and Inventor’s Logbook entries can be assessed throughout each learning unit to gauge student learning. These communication-based activities are opportunities for students to verbalize their knowledge and can be assessed by the teacher and by the students themselves (McLean & Lockwood, 1996). Inventor’s Logbook entries encourage students to actively reflect on their learning and assess how far they have come and what they still need to know in order to complete the Primary Challenge. Presentations can provide rich opportunities for peer-assessment. In addition, these activities enable students to develop and hone their communication skills (both written and oral). Effective communication has been recognized as a crucial skill in the engineering field, along with many other technology fields.

<table>
<thead>
<tr>
<th>Assessment Opportunity</th>
<th>Where in Unit</th>
<th>Activity</th>
<th>Type of Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-on Activities</td>
<td>Most learning cycles</td>
<td>Performance-based</td>
<td>Authentic and Formative</td>
</tr>
<tr>
<td>Group Projects</td>
<td>Most learning cycles</td>
<td>Performance-based and communication-based</td>
<td>Authentic, Formative, and Peer</td>
</tr>
<tr>
<td>Presentations</td>
<td>Many learning cycles</td>
<td>Communication-based</td>
<td>Formative, Summative, and Peer</td>
</tr>
<tr>
<td>Inventor’s Logbook Entries</td>
<td>During the Reflection phase of each learning cycle</td>
<td>Communication-based</td>
<td>Formative, Peer, and Self</td>
</tr>
<tr>
<td>Primary Challenge</td>
<td>End of each Learning Unit</td>
<td>Performance-based and communication-based</td>
<td>Authentic, Formative, Summative, and Peer</td>
</tr>
<tr>
<td>Comprehensive Examination</td>
<td>End of each Learning Unit</td>
<td>Written</td>
<td>Summative</td>
</tr>
</tbody>
</table>

Table 15: ProBase Opportunities for Assessment
Rubrics

At the end of each learning cycle and as a part of the Primary Challenge, an assessment rubric is provided to aid teachers in the assessment of students’ performance. Rubrics define the various levels of performance and the elements required within each level (see Figure 21). This rubric is used to help teachers assess the Primary Challenge solutions for the Entertainment and Recreation Technologies unit. The Entertainment and Recreation Technologies unit explores technological entertainment and recreation systems as well as the social, cultural, and environmental implications of their usage. These concepts are encompassed in a dynamic Primary Challenge providing students the opportunity to research, design, and create a functional musical instrument.

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Challenge Product</td>
<td>Completed product is fully functional and addresses all criteria, parameters, and equipment specifications set forth in the Primary Challenge.</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Completed product is functional and meets most criteria, parameters, and equipment specifications set forth in the Primary Challenge.</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Completed product represents a serious attempt to solve the Primary Challenge, but does not address many of the stated criteria, parameters, or specifications.</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Product is not complete or does not function and does not meet stated criteria, parameters, or specifications.</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawings, Diagrams &amp; Sketches</td>
<td>Drawings, diagrams, or sketches illustrate an understanding of all requirements, criteria or specifications; uses proper format and was completed electronically.</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, specifications, or criteria. Completed using an electronic format.</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, specifications, or criteria. Did not utilize an electronic format (hand drawn).</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Minimal research and development techniques were used while attempting to solve the Primary Challenge. Documentation was incomplete or poorly presented.</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; Development</td>
<td>Clear evidence of a comprehensive research and development effort was provided.</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Research and development was conducted while solving the primary challenge, but documentation was marginal.</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Some research and development techniques were used while attempting to solve the primary challenge, but were not clearly documented.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Minimal research and development techniques were used while attempting to solve the primary challenge. Documentation was marginal.</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documentation</td>
<td>As directed, the team responded to questions and/or maintained comprehensive records, logs, and other notations of activities while completing the Primary Challenge.</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Team responded to questions and/or maintained some records, logs, and other notations of activities while completing the Primary Challenge.</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Team marginally responded to questions and did not maintain records, logs, and other notations of activities while completing the Primary Challenge.</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>Presentation demonstrates a full grasp of the major concepts, addresses all stated presentation requirements, and conforms to time limit constraints.</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Presentation demonstrates significant understanding of major concepts, addresses most presentation requirements, and conforms to time limits.</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Presentation topically addresses some of the concepts delivered in this unit, but does not conform to stated presentation guidelines and/or time limits.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Presentation does not demonstrate a grasp of the major concepts delivered in this unit and/or does not address stated presentation guidelines or time limits.</td>
<td>2</td>
</tr>
</tbody>
</table>

**Figure 21**: Primary Challenge Rubric from Entertainment and Recreation Technologies
In addition to outlining the performance criteria of an activity, rubrics have many advantages for both teachers and students. Rubrics enable teachers to:

- More objectively critique evidence of student learning.
- Generate feedback for improved instruction.
- Monitor student progress by providing benchmarks against which to measure and document progress.
- Grade student performance.

Rubrics also provide distinct advantages for students by:

- Clearly identifying expectations.
- Generating clear feedback.
- Establishing criteria for grading based on objective evidence (ITEA, 2005).

**Comprehensive Examinations**

In addition to rubrics, Inventor’s Logbook entries, and presentations, comprehensive examinations were also designed for the ProBase curriculum. These examinations were developed to assess a broad range of information delivered with each of the ProBase units. These exams include different types of questions: multiple choice, open-ended, problem-solving, true/false, short answer, listing, fill-in-the-blank, and essay. The exams are provided in MS Word format so they can be adapted by the teacher to fit time and content constraints. Answers are provided for the teacher, along with how each question aligns with the curriculum and the standards, as well as the page number where that particular concept was addressed in the curriculum.

The different types of questions allow for broader and more accurate methods of assessment. Many of the different types of questions in the exam fall into the category often referred to as “alternative assessments.” Alternative assessments require students to demonstrate the knowledge being assessed, providing a direct link for an inference concerning what they have learned.
Constructed-response items (open-ended, problem-solving, short-answer) enable students to construct their own answers, which allows a range of correct responses. Essay questions are also included so the teacher can evaluate how well students can analyze and synthesize information, which requires critical thinking, analysis, and synthesis skills.

Below are some issues involved in assessment, particularly the more difficult aspects of assessing group, problem-based work with authentic assessments. It is important to note that assessment should extend beyond results and outcomes to processes. The hands-on activities and the Primary Challenge solutions are important; but just as important are the processes, concepts, and methods used along the way. Students should be assessed according to the qualities described in the rubric and determined by the teacher, not on the final product itself. Failure is often an important aspect of problem-solving. The type of learning that occurs when things do not turn out as planned is an invaluable opportunity for new learning. Failures provide the data and motivation for exploring even better solutions.

Another important form of assessment during problem-based, group work is feedback. Students should be given feedback on their performance throughout the learning process, so they are given an opportunity to improve and are provided with the necessary reinforcement. Teachers will want to maintain detailed records throughout the process on each student as a way to monitor and assess their performance and progress. Feedback can be oral or written, formal or informal. But it should occur multiple times throughout the process and include suggestions for improvement.

Teachers should also be aware of the different ways students can contribute in a group work setting. Students can contribute through probing questions, through facilitating the group’s progress, by recording decisions, etc. If roles are assigned to each group member, students should be assessed accordingly. However, if roles are not assigned, group members may be contributing to
the success of the team in less obvious ways. Teachers must become skilled at recognizing all of the team members’ contributions and provide feedback that recognizes those contributions and areas of improvement.

In summary, Johnson, Johnson, and Holubec (1994) provided five “rules” for assessment within group-based learning environments, which are listed below. Along with the assessments provided in the ProBase curriculum, these rules can help teachers become quality assessors throughout the learning experience.

**Assessment Rules**

1. All assessments should be performed in the context of the teams.
2. Assessment should occur often and throughout the learning experience.
3. Students should be directly involved in their assessment.
4. Use a criterion-referenced system, not a comparison among students for all assessment.
5. Use a wide variety of assessment formats and tools.

**References**


Implementation Issues

This final section of the ProBase Professional Development Guide is devoted to answering some common questions about implementing the ProBase curriculum within the classroom. Topics that are discussed include integrating ProBase into a semester or school year, selecting and sequencing ProBase units, and purchasing materials and equipment. Throughout this section, quotes will be presented from field-test teachers who implemented the curriculum in their classrooms. In addition, the scope of ProBase professional development is outlined.

How do I integrate ProBase curriculum into my semester/year?

Each ProBase unit is designed to be a stand-alone, nine-week learning experience. So, the delivery of all eight units will provide a total of two years (72 weeks) of curriculum. There is no particular sequence of units that should be followed in implementing the curriculum. If a teacher has certain time restrictions and would like to select particular units to integrate into the classroom, there are many options. For example, if a teacher is limited to only one semester to implement the ProBase curriculum, one option could be to select and implement two units (i.e., Information and Communication Technologies and Energy and Power Technologies or Manufacturing Technologies and Transportation Technologies). Another option is to select and implement one unit over an entire semester. Every learning cycle in each ProBase Learning Unit includes Expansion activities that can be used to lengthen and reinforce a variety of learning experiences. Yet another option could be to provide an introduction to engineering and then work through one ProBase unit. For example, as discussed in the engineering section of this guide, the technological design loop overview provided in the introductory section of each Instructor's Guide includes activities designed to introduce students to the engineering design process. This, along with other engineering-infused activities, can provide an introduction to engineering and to one of the ProBase units.

"ProBase is not a one-sided curriculum but a broad base curriculum of technology that gives the true meaning to the words of teaching engineering at the high school level."

--Joe Wagner, Neuqua Valley High School
How do I choose which units to use? Which fit together best?

Again, there is no particular sequence that should be followed in implementing the ProBase curriculum. Each unit was designed to be a stand alone learning experience that delivers on the Standards for Technological Literacy. One option could be to have the students choose an interest area to help determine which unit to select. One field-test teacher had success implementing two different ProBase units at the same time to satisfy the differing interests of her students. Although this was considerably more challenging for the instructor, the students were even more motivated because they were engaged in activities in their interest area.

The International Technology Education Association (ITEA) is marketing and distributing the ProBase curriculum through their Engineering byDesign™ Standards-Based Program Series. ITEA has chosen to package the learning units by 36-week courses, semesters, and by individual learning units. The 36-week course packages include the Advanced Design Applications and the Advanced Technological Applications.

The Advanced Design Applications package includes the following four, nine-week ProBase Learning Units:

- Manufacturing Technologies
- Energy and Power Technologies
- Construction Technologies
- Transportation Technologies

The Advanced Technological Applications package includes the following four, nine-week ProBase Learning Units:

- Information and Communication Technologies
- Medical Technologies
- Agriculture and Related Biotechnologies
- Entertainment and Recreation Technologies
Due to this packaging scheme, a logical semester grouping might look like this:

- **Manufacturing Technologies and Construction Technologies**
- **Energy and Power Technologies and Transportation Technologies**
- **Information and Communication Technologies and Entertainment and Recreation Technologies**
- **Agriculture and Related Biotechnologies and Medical Technologies**

---

**Figure 22: ITEA advertisement for the ProBase curriculum**

---

**Implementation Issues**
Where do I purchase materials and equipment?

As discussed in the constructivism section of this guide, each Instructor’s Guide provides a materials and equipment list (shown below) that lists all of the materials and equipment necessary to complete each unit. In addition to providing the quantity, the list provides the suggested sources and part numbers for the more unusual materials. The ProBase curriculum was designed to keep the costs as low as possible; so many of the materials can be purchased at local super stores or home repair centers.

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Item</th>
<th>Learning Cycle</th>
<th>Notes and Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>250 mL beakers</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6 mL measuring instruments or cylinders</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Blender</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Knife</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Measuring instrument or cylinder to measure 20 mL, 30 mL, 95 mL, 100 mL, and 180 mL</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Measuring instrument to measure 5 and 20 grams</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Microscope slides</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Microscopes or as many as possible</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Strainer</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Thin wires (one end bent into a loop)</td>
<td>Preliminary</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Glass stirring rod</td>
<td>Preliminary, LC 3</td>
<td>Suggested source: science department or Carolina, # 71-1309</td>
</tr>
<tr>
<td>7</td>
<td>Scalpels</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Tweezer forceps</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>CdS photocells</td>
<td>Primary, LC 2</td>
<td>Suggested source: Radio Shack®, part # 276-1657</td>
</tr>
<tr>
<td>7</td>
<td>Basic Stamp serial programming cables</td>
<td>Primary, LC 2</td>
<td>Suggested source: Parallax®, Inc. (<a href="http://www.parallax.com">www.parallax.com</a>), part # 800-00003</td>
</tr>
<tr>
<td>7</td>
<td>BASIC Stamp HomeWork Boards™</td>
<td>Primary, LC 2</td>
<td>Suggested source: Parallax, Inc. (<a href="http://www.parallax.com">www.parallax.com</a>), part # 28158</td>
</tr>
<tr>
<td></td>
<td>Large plastic (storage) box</td>
<td>Primary, LC 2</td>
<td>Suggested material for building enclosed environments</td>
</tr>
</tbody>
</table>

Figure 23: Learning Unit Equipment list found on pg. xvi in the Agriculture and Related Biotechnologies Instructor Guide

“My goal is to motivate students to develop the problem solving skills necessary to solve complex engineering problems. I feel the ProBase curriculum provides such a venue. Students are only given the project requirements and then must define, research, and test in order to complete the final project. Oral and written communication is easily incorporated into the project.”

--William Yucuis, Lyman High School
Where does ProBase fit into what schools/districts require? How do I position ProBase?

School district and state requirements vary from one part of the country to another. As such, teachers must make decisions about how to implement ProBase according to their own school or state requirements. One of the most common issues is the integration of math and science into the technology education classroom. ProBase was designed to incorporate math and science principles into each learning unit. In fact, each Learning Unit in the ProBase curriculum was written in collaboration with expert curriculum consultants from the math and science communities. In some districts and locations, it is possible that math and science credit can be arranged in conjunction with ProBase. Partnerships with a math or science teacher are also highly desirable. Another option that is strongly recommended is to make connections with program faculty at the local community college or university to establish AP credit for ProBase learning experiences.

How can I explain ProBase to my parents/principals/administrators?

This guide hopefully provides you with enough information to be able to articulate the development, theory, and concepts explored in the ProBase curriculum. In addition, a sample letter, provided in the appendix of this guide, can be adapted and sent to parents, principals, or administrators to introduce and explain the curriculum.

“I would recommend ProBase, the standards based curriculum, because of cost and knowing that it was written and tested by teachers in the field, along with professionals from industry.”

—Marsha Brown, St. Charles North High School
How can a community college instructor use ProBase in the classroom?

The ProBase curriculum was designed to be implemented in the upper-level high school grades. However, through the Expansion activities and the integration of more engineering, math, and science concepts into the existing ProBase curriculum, the learning units can be easily adapted and integrated into the community college classroom.

What types of ProBase professional development workshops, programs, and in-service activities can be developed?

There are six different types of professional development programs that can be developed for the ProBase curriculum. These programs are arranged as units that have different purposes, audiences, time-frames, and formats. Below is a brief description of each unit. A more detailed description is provided in a table in the appendix of this guide, titled ProBase Professional Development Units.

ProBase Professional Development Unit 1 includes a one hour presentation designed to expose potential stakeholders (teachers, principals, administrators) to the ProBase curriculum. Unit 2 is focused specifically on potential implementers of the curriculum and can provide professional development credit. This two to four hour workshop’s focus is to explain and demonstrate how the ProBase curriculum uses constructivist, problem-based learning to increase student achievement. Unit 3 is designed for teachers to develop the knowledge, abilities, and understanding necessary to successfully teach ProBase. This unit can last anywhere from two to five days and can provide undergraduate or graduate credit if facilitated at a college or university. Unit 4
is designed for experienced ProBase teachers who are interested in developing the knowledge and abilities that lead to continuous improvement, mastery, and leadership in the ProBase community of learners. Unit 5 is targeted for those individuals interested in developing the knowledge and abilities necessary to become certified ProBase teacher trainers. Finally, Unit 6 is designed to inform participants how to continuously assess, lead, adapt, and inform the ProBase community of learners.

The ProBase Professional Development Units provide a structure for the long-term implementation of the ProBase curriculum. This guide provides the necessary information about the theory, development, and format of the ProBase curriculum to be used in conjunction with these professional development units or to assist individual teachers in the implementation of specific ProBase Learning Units. This guide was developed to supplement the Instructor Guides for each of the ProBase Learning Units to better prepare for the implementation of the curriculum into the classroom. The guide was divided into different sections that focused on the primary elements of the ProBase curriculum: Backward Design, Standards-Based Curriculum, Constructivism, Problem-Based Learning, Engineering Concepts, Cooperative Learning, and Assessment. This final section has discussed some of the most common implementation issues and the professional development efforts associated with the curriculum. Throughout the guide, tips and techniques for successful implementation have been provided. In addition, examples from each of the eight ProBase Learning Units have been used to illustrate the different facets of the curriculum.

As stated, the eight ProBase units can be used independently, in conjunction, or as an entire curriculum package. For ordering information contact the International Technology Education Association’s Center to Advance the Teaching of Technology and Science (CATTS) at (703)860-2100 or www.iteacnect.org. The ProBase curriculum is being offered through their Engineering by Design™ Standards-Based Program Series.
The ProBase Enduring Understandings were derived from the core concepts identified in *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000/2004). The Standards list 20 standards and supporting benchmarks for technology education to enable the facilitation of technological literacy in K-12 students. More specifically the ProBase Enduring Understandings consist of those concepts recognized as being important enough to know, often misunderstood concepts, concepts central to the study of technology, and finally those concepts that are engaging to students. Essential questions were then derived from the enduring understandings to better focus each of the learning units. The enduring understandings and essential questions are listed on the next two pages.
1. that **technological progression** is driven by a number of factors, including individual creativity, product and systems innovation, and human wants and needs.
   a. How are new technologies **developed and marketed**?
   b. What social, cultural, and political **pressures** lead to the need or want for new technologies?
   c. What are the specific **roles of professionals** involved in technological adaptation and change?
   d. What **factors** need to be in place for new technologies to be viable in the national and international marketplace?
   e. What are the fundamental **processes/principles** used to develop new technologies?

2. that **technological development** for the solution of a problem in one context can **spin-off** for use in a variety of often unrelated applications.
   a. How do **technologies migrate** from one context (or location) to another and what are the implications?
   b. What **roles** do the patent, trademark, and copyright laws play in the **dissemination of technological ideas**?
   c. How have technological innovations caused **paradigm shifts** throughout history and what are these major shifts?

3. that **technological change** can be positive and/or negative, and can have intended and/or unforeseen social, cultural, environmental, and political consequences.
   a. What are some of the unforeseen **consequences** of specific technological changes throughout history?
   b. How can a technology cause both good and harm and how do humans prepare for or respond to these **impacts**?

4. how **technological systems** work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
   a. What are the systems and **subsystems** involved in the various contexts of technology?
   b. What are the key elements of the various technological **systems** and what are the **relationships** between these systems?
   c. How do various technological **systems influence** the economy, society, the environment, and culture?

5. that there are compelling and controversial **issues** associated with the acquisition, development, use, and disposal of **resources**.
   a. What kinds of **resources** are required in each of the eight technological contexts?
   b. What is the **relative value** of specific resources used in technological systems?
   c. To what extent have **resource issues** (acquisition, development, use, and disposal) **affected** the direction of technological **development**?
   d. What **resources** are **needed** to solve a specific design problem (people, information, materials, tools, capital, energy, time, technical ability)?
that the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.

a. To what extent have optimal designs been achieved in the eight technological context areas?

b. What are the key factors that cause designers to make decisions about trade-offs, limitations, and constraints when designing new products and systems? (Micro Factors)

c. How can members of the public, politicians, or the state of the economy influence the design of new technological products and systems? (Macro Factors)

d. How can social values and principles guide in the development of solutions to technological problems?

7. that technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.

a. What are the five primary methods through which technological problems are solved and how do they differ (i.e., troubleshooting, research and development, experimentation, invention and innovation, design problem solving)?

b. To what extent can design problems be approached through a series of generic procedures (the design loop)?

c. What design criteria are typically considered when developing new technologies (i.e., marketability, safety, useability, reliability, cost, materials, etc.) and how do these influence the final product/system design?

d. How are decisions made regarding information that should be discarded or ignored?

e. How can the attributes of design and the principles of design aid in the development of quality solutions?

f. How can the establishment of relationships, controlling variables, categorizing techniques, and making inferences aid in the development of new technological designs?

8. how to evaluate the benefits, limitations, and risks associated with existing and proposed technologies.

a. How does a risk/benefit analysis aid the designer in addressing potential harmful effects prior to development?

b. What are some important ethical decisions that should be considered when developing any new technology?

c. Are all product/system designs created for the purpose of adding social value?

d. How are ethical considerations, economic considerations, engineering realities, and political forces balanced during technological innovation?

e. In what ways are technological needs and wants being balanced with long term environmental or social consequences?

9. how to utilize a variety of simple and complex technologies.

a. How are technologies used to control devices and systems?

b. How do technologies communicate with one another and provide information to humans?

c. To what extent are technological systems and devices controlled by people and to what extent are they controlled by other technologies?

d. How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?
As shown in the figure on the next page, the ProBase curriculum was developed using a “backward” design process derived from Wiggins and McTighe (1998). The knowledge base and the end-results of the curriculum were identified prior to the generation of the curriculum materials. The enduring understandings and essential questions were derived from the core concepts identified in the STL. Next, core bridge competencies were established in conjunction with a consortium of community colleges. The bridge competencies identified the technical base needed for incoming college students. The acceptable evidence of learning was established, including the development of assessments and activities. Finally, the ProBase Learning Units were developed and field tested.
Distill Enduring Understandings from *Standards for Technological Literacy*

Establish Essential Questions
Identify Bridge Competencies
Develop Learning Units

<table>
<thead>
<tr>
<th>Identify Desired Results</th>
<th>Determine Acceptable Evidence</th>
<th>Generate Learning Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enduring Understanding</strong></td>
<td>~Primary Challenge ~Summative Assessment ~Learning Cycle Assessment ~Inventor’s Logbook</td>
<td>~Concepts ~Skills ~Bridge Competencies ~Activities</td>
</tr>
<tr>
<td>What will students understand as a result of this Learning Unit?</td>
<td>What evidence will show that students understand? What complex design challenge encompasses all unit questions?</td>
<td>What knowledge and skills are needed to answer the Primary Challenge? What are acceptable solutions to the Primary Challenge?</td>
</tr>
<tr>
<td>2-3 per Learning Unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essential Questions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What questions will focus this Learning unit?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-12 per Learning Unit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The matrix on the next page outlines the enduring understandings targeted by each ProBase Learning Unit. Along the far left column is a list of the nine enduring understandings and along the top row are the Learning Units by title. Within each cell is the specific essential question that the particular Learning Cycle seeks to answer. For example, the *Entertainment and Recreation Learning Unit* meets enduring understandings one, two, three, and nine. The essential questions associated with enduring understanding one: technological progression are B (What are social, cultural, and political pressures lead to the need or want for new technologies?) and E (What are the fundamental processes/principles used to develop new technologies?). These are explored in Learning Cycles one, two, and three.
<table>
<thead>
<tr>
<th>Enduring Understanding</th>
<th>Entertainment &amp; Recreation</th>
<th>Information &amp; Communication</th>
<th>Transportation</th>
<th>Energy &amp; Power</th>
<th>Manufacturing</th>
<th>Medical</th>
<th>Ag &amp; Bio</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological Progression 1</td>
<td>B-LC3 E-LC1 E-LC2</td>
<td>B-LC2 E-LC1</td>
<td>E-LC1</td>
<td></td>
<td>B-LC1 D-LC3 E-LC3</td>
<td></td>
<td></td>
<td>E-LC2</td>
</tr>
<tr>
<td>Technological Spin-offs 2</td>
<td>A-LC4</td>
<td></td>
<td></td>
<td></td>
<td>A-LC1</td>
<td>C-LC1</td>
<td>C-LC1</td>
<td></td>
</tr>
<tr>
<td>Technological Change 3</td>
<td>B-LC3 B-LC4</td>
<td>A-LC1 B-LC1</td>
<td></td>
<td></td>
<td>B-LC4</td>
<td>A-LC3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological Systems 4</td>
<td>A-LC1 A-LC3 B-LC2</td>
<td>A-LC2 B-LC4 A-LC3</td>
<td>B-LC5 B-LC6</td>
<td>B-LC3 B-LC4</td>
<td></td>
<td>A-LC3 A-LC5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issues about Resources 5</td>
<td></td>
<td>B-LC4</td>
<td>A-LC3</td>
<td>B-LC1</td>
<td></td>
<td>B-LC2 C-LC2 A-LC2 D-LC3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constraints &amp; Tradeoffs 6</td>
<td></td>
<td></td>
<td>B-LC4</td>
<td>A-LC3</td>
<td>B-LC1</td>
<td></td>
<td>A-LC3 C-LC1</td>
<td></td>
</tr>
<tr>
<td>Technological Design 7</td>
<td></td>
<td></td>
<td>F-LC5</td>
<td></td>
<td>B-LC3 C-LC1 C-LC2 C-LC3 E-LC2</td>
<td></td>
<td>C-LC2 C-LC3 C-LC4 C-LC5 D-LC5 E-LC1 E-LC3</td>
<td></td>
</tr>
<tr>
<td>Evaluating Risks 8</td>
<td>A-LC1 A-LC3</td>
<td></td>
<td>A-LC1 A-LC3</td>
<td></td>
<td></td>
<td>A-LC2 D-LC2 D-LC3</td>
<td>A-LC1</td>
<td></td>
</tr>
<tr>
<td>Utilizing Technologies 9</td>
<td>A-LC1 B-LC2 D-LC3 D-LC4</td>
<td>A-LC3 A-LC4 B-LC1 B-LC2 B-LC3 B-LC4</td>
<td>B-LC2 B-LC4 B-LC5</td>
<td>B-LC1 C-LC3 D-LC2 A-LC4 A-LC6 B-LC4 D-LC5</td>
<td></td>
<td></td>
<td>D-LC4 A-LC2 C-LC3 D-LC2</td>
<td>D-LC1 D-LC4</td>
</tr>
</tbody>
</table>
As explored in detail in the Constructivism section of this guide, ProBase utilized a constructivist approach to learning and teaching. Due to the fact that there are a plethora of constructivist teaching approaches an outline of a few constructivist models published from the 1990s on are outlined on the next few pages. All of the models are based on the belief that new knowledge is best learned when it is constructed by a student using prior knowledge. Within the ProBase curriculum a modified-constructivist approach follows from the cooperative, problem-based approach to learning embedded in the curriculum. The Student Guides were designed to promote active learning, with students being encouraged to construct their own knowledge throughout each Learning Unit.
Constructivist Models: Late 1990s onward (Palmer, 2005)

**The Banet and Nunez (1997) Model**—teaching sequence centered on surprising activities. Consists of three phases:

1. Initiation—the program is explained, students become motivated, and their ideas are elicited.
2. Restructuring of Ideas—situations that provoke cognitive conflict are used to reveal the inadequacy of students’ ideas and to encourage the formation of new knowledge.
3. Application and Review—ideas are shown to be valid and students review the change in their thinking.

**Conceptual Replacement Approach** (Dekkers and Thijs, 1998)—concept refinement and context expansion. Consisted of the following teaching sequence:

1. Find a shared meaning of the concept in limited contexts.
2. Refine the partial concept and expand the contexts until the meaning is no longer shared…
3. Resolve dissonance: compare and find shared meanings, based on the already established agreements.

**The Hewson (1999) Model**—guidelines for teaching conceptual change. Components included:

1. Ideas—of both students and teachers must be part of the classroom discussion.
2. Metacognition—students express opinions about ideas.
3. Status—some ideas become more acceptable to students and other ideas less acceptable.
4. Justification—the reasons for ideas and status decisions need to be justified.

**Metacognitive Learning Cycle** (Blank, 2000)

1. Concept assessment phase—students reflect on their science ideas and the status of those ideas.
2. Concept exploration phase—students explore phenomena related to the concept.
3. Concept introduction phase—the instructor introduces the main concept in the lesson and the students reflect on any changes in their ideas.
4. Concept application phase—students are presented with other examples of the concept and again consider the status of their ideas.

**Dual-Situated Learning Model** (Blank, 2004) Six stages:

1. Examining attributes of the science concept.
2. Probing students’ misconceptions of the science concept.
3. Analyzing which mental sets students lack.
4. Designing dual-situated learning events.
5. Instructing with dual-situated learning events.
6. Instructing with challenging situated learning event.

**A Motivational Model of Constructivist-informed Teaching** (Palmer, 2005)

1. Selection of concepts that represent appropriate challenge—instructors should select concepts that “represent achievable challenge” (p. 1874) so that students achieve success and are motivated.
2. The use of “dual-purpose” teaching techniques—that not only contribute towards the development of scientifically acceptable conditions, but also have the potential to motivate.
3. A classroom climate that encourages positive motivation beliefs—students should be a choice in task formats and work partners for example.
A detailed description of six professional development programs for the ProBase curriculum is provided on the next two pages. These programs are arranged as units that have different purposes, audiences, time-frames, and formats. Unit 1 includes a one hour presentation designed to expose potential stakeholders to the curriculum. Unit 2 is focused on potential implementers. Unit 3 is designed for teachers to develop the abilities necessary to teach ProBase. Unit 4 is designed for experienced ProBase teachers who are interested in continuous improvement and leadership in the ProBase community of learners. Unit 5 is targeted for those individuals interested in developing the abilities necessary to become certified ProBase teacher trainers. Unit 6 is designed to inform participants how to continuously assess, lead, adapt, and inform the ProBase community of learners.
<table>
<thead>
<tr>
<th>AETL Standards</th>
<th>PD Unit 1</th>
<th>PD Unit 2</th>
<th>PD Unit 3</th>
<th>PD Unit 4</th>
<th>PD Unit 5</th>
<th>PD Unit 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brief introduction to all Standards</td>
<td>PD 1</td>
<td>PD 1</td>
<td>PD 2</td>
<td>PD 2</td>
<td>PD 3</td>
<td>PD 3</td>
</tr>
<tr>
<td>PD 5</td>
<td>PD 2</td>
<td>PD 6</td>
<td>PD 4</td>
<td>PD 5</td>
<td>PD 5</td>
<td></td>
</tr>
<tr>
<td>PD 5</td>
<td>PD 5</td>
<td>PD 5</td>
<td>PD 5</td>
<td>PD 5</td>
<td>PD 5</td>
<td>PD 5</td>
</tr>
</tbody>
</table>

**Enduring Understanding**

Participants will become aware that ProBase leads to increased student achievement.

Participants will understand how ProBase uses constructivism and problem-based learning to increase student achievement.

Participants will develop the knowledge, abilities, and understanding necessary to successfully teach ProBase.

Participants will develop knowledge and abilities that lead to continuous improvement, mastery, and leadership in the ProBase community of learners.

Participants will continuously assess, lead, adapt and inform the ProBase community of learners.

**Essential Questions**

1. **Awareness of the design of the curriculum**
   - Enduring Understanding
   - Constructivist methods
   - Understanding By Design

2. **Awareness of the content/organization of the curriculum**
   - How ProBase functions/
   - the basic set-up
   - Content
   - Organization/Layout of the ProBase units
   - Structure

3. **Awareness of the value of the program**
   - Convincing activities
   - Proof of ProBase success
   - Examples of how to use “Logbooks” properly
   - Design skills

4. **Awareness of necessary facility requirements**

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>PD Unit 1</th>
<th>PD Unit 2</th>
<th>PD Unit 3</th>
<th>PD Unit 4</th>
<th>PD Unit 5</th>
<th>PD Unit 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understanding constructivism</td>
<td>Have video skills of ProBase in action</td>
<td>Knowledge of energy conversion process</td>
<td>Experience with ProBase</td>
<td>Models efficient management techniques</td>
<td>Leads teacher training</td>
<td>1. Efficacy research</td>
</tr>
<tr>
<td>2. Understanding standards and essential questions</td>
<td>Technology Standards</td>
<td>Standard-based instruction</td>
<td>Background in knowledge in tech ed</td>
<td>Project storage</td>
<td>Leads change</td>
<td>2. Reflect on Practice</td>
</tr>
<tr>
<td>3. Understanding Learning Cycles and problem driven instruction</td>
<td>Explain purpose of Expansion activities</td>
<td>Problem solving skills</td>
<td>Design loop</td>
<td>Time</td>
<td>Leads participation of professional learning community</td>
<td>3. Coordinates change</td>
</tr>
<tr>
<td>4. Understanding the need for broad-based assessments</td>
<td>Engineering process</td>
<td>Basic Design</td>
<td>Methodology</td>
<td>Multiculturalism</td>
<td>Leads the planning, organizing, conducting, assessing, and follow-up training</td>
<td>4. Collaborates with others</td>
</tr>
<tr>
<td>5. Understanding necessary facility requirements</td>
<td>“Various” math concepts</td>
<td>Conversions (measurements)</td>
<td>Creative</td>
<td>Cooperative learning</td>
<td>Leads adult learning</td>
<td>5. Commitment to the program</td>
</tr>
<tr>
<td>6. Use management</td>
<td>“Various” math concepts</td>
<td>Creative</td>
<td>Cooperative learning</td>
<td>Minor computer skills</td>
<td>How to deal with problem teachers</td>
<td>6. Communicates a vision</td>
</tr>
<tr>
<td>7. Use Assessment</td>
<td>“Various” math concepts</td>
<td>Creative</td>
<td>Cooperative learning</td>
<td>Minor computer skills</td>
<td>Familiarity with different adult audience</td>
<td>7. Seeks out ideas and opportunities</td>
</tr>
<tr>
<td>8. Use Assessment</td>
<td>“Various” math concepts</td>
<td>Creative</td>
<td>Cooperative learning</td>
<td>Minor computer skills</td>
<td>Adult learning methods</td>
<td></td>
</tr>
</tbody>
</table>

**ProBase Professional Development Guide**
<table>
<thead>
<tr>
<th>Audience</th>
<th>Potential Stakeholders</th>
<th>Potential Implementers</th>
<th>Teacher Implementers</th>
<th>Experienced Teachers/ Potential Trainers</th>
<th>Trainers in Training</th>
<th>Leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1 hour</td>
<td>2-4 hours</td>
<td>2-5 days</td>
<td>Varying formats</td>
<td>4-5 days</td>
<td>N/A (lifetime)</td>
</tr>
<tr>
<td>Format</td>
<td>Presentation</td>
<td>Presentation/ Workshop/ Professional Development credit</td>
<td>Institute, Undergraduate or Graduate Course</td>
<td>Learning Communities (local/virtual), Portfolios, Self-assessments, Graduate course</td>
<td>Institute, Online Component, Graduate Course</td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td>None</td>
<td>None</td>
<td>Certified way</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

Sharp assessment skills
Assess learning
Assessment tools (selection and use)
4. Use facilitate problem-based learning
Ability to lead discussions
Allow for flexibility in logistics
Lots of sample solutions (pictures)
Locate different sources for students to reference
5. Use facilitate equipment
6. Use funding/marketing/promotion/recruiting
Raise funds through business community
Marketing
Recruiting skills

Divergent thinking
Ability to think outside of the box
Comfort with learning with the students
Understand guiding principles (enduring understandings)
3. Models command of resources and extensive knowledge base
Resourceful
Able to access outside resources
Point out the teaching tips
Network with other ProBase teachers
Give resources
How to find resources
Establish a knowledge base
Explain what the program is designed to do
Prior experience with ProBase
Know the details
4. Models marketing/promotion to adults
Be willing to present ProBase to school boards or curriculum councils
Market to community/principal
Incentives
How to promote ProBase to students/parents/administrators
Salesperson/promotions of curriculum
Program marketing to kids

Potential Stakeholders
Potential Implementers
Teacher Implementers
Experienced Teachers/ Potential Trainers
Trainers in Training
Leaders

Appendix
A sample informational letter that can be mailed to parents, administrators, and principals explaining the ProBase curriculum is provided on the next page. This letter can be used to explain the decision to implement this curriculum and to inform parents about the activities that their children will be engaged in. This letter can easily be adapted to meet an individual teacher’s needs. For example, if only select ProBase Learning Units are implemented those units can be briefly explained in the letter. In addition to sending a letter, it is recommended that the curriculum be made available to administrators to review. Also, showcases can be conducted for students to reveal their Primary Challenge solutions. This will allow students to show the results of their hard work and get parents involved.
Dear Mr./Mrs. ______________________,

I would like to take this opportunity to explain the exciting and challenging learning experiences that will be undertaken by the students enrolled in my class. I have chosen to implement the ProBase curriculum in my classroom this year. In particular, I would like to explain what is involved in the ProBase curriculum and the expected student learning outcomes. Ultimately, I believe the decision to incorporate this standards-based, engineering-infused curriculum will help prepare students for college and their future careers.

The National Science Foundation funded ProBase curriculum offers hands-on problem-solving activities and materials designed to deliver core technological and engineering concepts. Students focus on and design solutions to problems. Group work is encouraged to develop cooperative learning skills in brainstorming and designing solutions to the problems. Each ProBase unit centers on a large, robust design problem called the **Primary Challenge**. The learning cycles provide the necessary skills and knowledge to be able to adequately complete the challenge. The *Manufacturing Technologies* unit (or **insert and describe the unit(s) you have selected to implement**), for example, examines the advances that maintain manufacturing efficiency, along with exploring the process of changing raw materials into more desirable products. These concepts are encompassed in a dynamic *Primary Challenge* providing students the opportunity to research, design, and create a functional vending machine.

I am excited about integrating the ProBase curriculum in my classroom. The students and I will be challenged and engaged in the real-world problem-solving experiences presented in the curriculum. If you have any questions, please do not hesitate to contact me. (**Insert your contact information.**) I am looking forward to a great school year.

Sincerely,

Your Name