

Science, Engineering, and Technology (SET)

Programming in the Context of
4-H Youth Development



4-H SET

Science, Engineering & Technology

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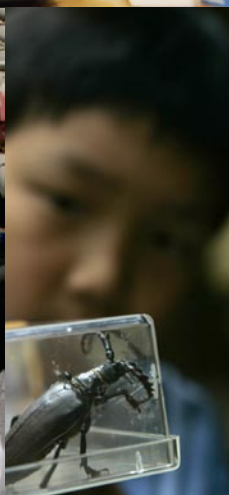
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Science, Engineering, and Technology (SET) Programming in the Context of 4-H Youth Development

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Clearly, 4-H is at a turning point in its history with an extraordinary opportunity to reaffirm its legacy as a leader in hands-on non-formal science, engineering, and technology education. Since the 4-H Youth Development Program began in 1902, 4-H youth have been engaged in demonstration projects that bring innovation and understanding of land-grant college and university research to local communities. Understanding and appreciating the role of science, engineering, and technology is even more critical as the needs of our society and its workforce change. Now, more than ever, we must ensure that our nation's youth develop the necessary competencies and abilities for the United States to remain competitive in the 21st century. (4-H SET: A Strategic Framework for Progress, May 2007.)

Background

This paper was commissioned by the national 4-H SET Leadership Team in October 2006 to identify an established set of nationally recognized standards in Science, Engineering, and Technology (SET) that 4-H could align with — and to identify a set of life-skill outcomes (SET abilities) that could be addressed with reasonable certainty within the context of 4-H youth development. The report is intended for use by the National 4-H SET Leadership Team members and

Extension professionals in supporting the work of state and county 4-H staff and volunteers and to serve as a framework for the design, implementation, and evaluation of 4-H SET programs and curriculum materials. This paper was submitted for blind peer review in April 2007 (conducted by Suzanne Le Menestrel, Ph.D., National Program Leader, Youth Development Research, National 4-H Headquarters, CSREES, USDA) and approved for publication in May 2007.

Introduction

Although the concept of scientific literacy was characterized in the 1950s, it remains a universal, timeless goal for science education. In an ideal world, an individual's progress toward scientific literacy continues throughout life, beginning with informal discovery, nurtured with non-formal experiences, and enriched by formal education. The American Association for the Advancement of Science document *Science for All Americans* describes a scientifically literate person as one who is aware that science, engineering, and technology are human enterprises and who applies scientific content and abilities in meaningful ways. (AAAS, 1990.)

This report provides much in regards to nationally accepted Science, Engineering, and Technology (SET) content and abilities. Existing state and national SET standards have been written with K-12 classrooms in mind, which rely upon formal delivery methods and content mastery. In addition to classrooms, educators within informal settings like science museums have embraced these national standards with a strong emphasis on science inquiry and content. However, SET programming cannot exist solely on the merits of its content — behavioral considerations must be addressed as part of the total learning experience for the student. With this in mind, one must ask the question: “How can one characterize the kind of SET programming that is ideally suited to the non-formal delivery methods used by 4-H?” To address this question, 4-H should rely upon its greatest strength, that is, non-formal experientially based delivery methods that address science abilities and content in a hands-on way under the guidance of a trained (scientifically able) 4-H learning facilitator.

The Evolution of SET Standards

This research into national science standards concentrated on a series of reports that began with *Project 2061* and the significant documents that followed as a result. In 1989 the American Association for the Advancement of Science (AAAS) released a landmark report, *Science for All Americans*, followed by *Benchmarks for Science Literacy: Project 2061* in 1993. Like the *National Science Standards (NSES)* that followed, *Project 2061* attempted to define the science content that students should know by the time they graduate from high school. *Project 2061* did not offer standards for assessment, instruction, professional development, or systems, but subsequent publications from AAAS/*Project 2061* have offered guidance on these issues (1997b, 1998, 2001a, 2001b). These research reports have become the basis for current national science standards. They continue to influence the direction of science education reform. Most states have used these documents as the basis for developing their own state science standards. (Hollweg and Hill, 2003.)

The importance of *Project 2061* and subsequent reports as each relate to 4-H SET is three-fold. First, these reports outline the standards used in science (which includes technology and engineering considerations) for teaching and learning and curriculum development.

Second, *Project 2061* emphasizes the interconnected nature of science, engineering, and technology. Technology is recognized as one of the standards within the *National Science Education Standards*. Engineering is recognized, most directly in *Project 2061*, as a problem solving and design process, within several science strands. Third, and

very important, is the changing treatment of abilities within the discipline of teaching and learning science. With *Project 2061* the emphasis shifted from separating science knowledge and science abilities to integrating all aspects of the science experience. This shift continues to gain momentum and receive attention in the current science education literature. (*Taking Science to School*, 2003.) Integration of “learning by doing” fits the 4-H experiential model. Current recognition and

Science for All Americans, an initiative of the American Association for the Advancement of Science (AAAS), was established to reform K-12 education in natural and social science, mathematics, and technology. *Science for All Americans* outlines what all students should know and be able to do by the time they leave high school. *Project 2061*, which followed SFAA, addressed goals for progress, principles for curriculum design, and professional development plans to enable the curriculum

. . . Research indicates that documents using *Project 2061* as a base incorporate technology as an integral set of science understandings and abilities. Engineering is recognized as a problem-solving and design process that translates to abilities within several science content areas. *Taking Science to School*, 2007.

placement of science abilities within science teaching and learning receives attention in this report so that 4-H SET will stay current with best practices as it moves ahead developing SET curriculum and program models.

Following the landmark *Project 2061* initiative, a progression of studies and research reports by the National Research Council and the National Academies have been made available (Figure 1). While this is not an exhaustive review, this report does attempt to chronicle the preeminent developments that have occurred in science education reform.

Currently accepted national science education standards and best practices began with *Science for All Americans* (SFAA), 1989.

to succeed. Each successive publication is built upon the earlier foundation and is meant to be used in planning reform.

Benchmarks for Science Literacy: Project 2061

Benchmarks for Science Literacy: Project 2061 was published to provide educators with a powerful tool for curriculum design at the state and local levels. *Project 2061* is a set of specific science literacy goals that can be organized in a variety of ways. It concentrates on the common core of learning that contributes to the science literacy of all students. A statement of what all students should know and be able to do in science is divided into

Figure 1. Chronology of Science Education Reform Research.

1989	<i>Science for All Americans</i> (SFAA). American Association for the Advancement of Science.
1993	<i>Benchmarks for Science Literacy: Project 2061</i> . American Association for the Advancement of Science.
1996	<i>National Science Education Standards</i> (NSES). National Research Council.
1998	<i>National Educational Technology Standards</i> (NETS). International Society for Technology in Education.
2000	<i>Inquiry and the National Science Standards</i> . National Research Council.
2000, 2002	<i>Standards for Technological Literacy</i> (STL). International Technology Education Association.
2004	<i>Excellence in Environmental Education — Guidelines for Learning</i> . North American Association for Environmental Education.
2007	<i>Taking Science to School — Learning and Teaching Science in Grades K-8</i> . National Research Council, National Academy of Sciences, National Academy of Engineering, and the Institutes of Medicine.

12 Benchmarks. The interconnectedness of science, engineering, and technology in this report is shown in the following abbreviated outline.

1. The Nature of Science — Scientific World View; Scientific Inquiry; Scientific Enterprise.
2. Nature of Math — Patterns and Relationships; Mathematics, Science, and Technology; and Mathematical Inquiry.
3. Nature of Technology — Technology and Science; Design and Systems; Issues in Technology.
4. The Physical Setting — The Universe; The Earth; Processes That Shape the Earth; Structure of Matter; Energy Transformation; Motion; Forces of Nature.
5. The Living Environment — Diversity of Life; Heredity; Cells; Interdependence of Life; Flow of Matter and Energy; Evolution of Life.
6. The Human Organism — Human Identity; Human Development; Basic Functions; Learning; Physical Health; Mental Health.
7. Human Society — Cultural Effects on Behavior; Group Behavior; Social Change; Social Trade-Offs; Political and Economic Systems; Social Conflict; Global Interdependence.
8. The Designed World — Agriculture; Materials and Manufacturing; Energy Sources and Use; Communication; Information Processing; Health Technology; Engineering Solutions.
9. The Mathematical World — Numbers; Symbolic Relationships; Shapes; Uncertainty; Reasoning.
10. Historical Perspectives — Displacing the Earth from the Center of the Universe; Uniting the Heavens and Earth; Relating Matter and Energy and Time and Space; Extending Time; Moving the Continents; Understanding Fire; Splitting the Atom; Explaining the Diversity of Life; Discovering Germs; Harnessing Power.
11. Common Themes — Systems; Models; Constancy and Change; Scale.
12. Habits of Mind — Values and Attitudes; Computation and Estimation; Manipulation and Observation; Communication Skills; Critical Response Skills.

National Science Education Standards

In 1996 the *National Science Education Standards* (NSES), led by the National Research Council, were written to shape the way K-12 science is taught on a national basis. The organization of seven Science Content Standards highlights significant points that are relevant to this study.

1. Science as Inquiry — Inquiry is a step beyond “science as a process,” in which students learn skills, such as observation, inference, and experimentation. The new vision includes the processes of science and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science.

2. Physical Science — Subject matter that focuses on science facts, concepts, principles, theories, and models in physical science.
3. Life Science — Subject matter that focuses on science facts, concepts, principles, theories, and models in life science.
4. Earth and Space Science — Subject matter that focuses on science facts, concepts, principles, theories, and models in earth and space science.
5. Science and Technology — Establishes connections between the natural and designed worlds and provides students with opportunities to develop decision-making abilities. They are not standards for engineering and technology education; rather, standards that emphasize the process of design and fundamental understandings about the enterprise of science and its link to engineering and technology. Fundamental abilities and concepts that underlie this standard include:
 - Identify a problem.
 - State a problem.
 - Design a solution.
 - Implement a solution.
 - Evaluate the solution.
 - Communicate a problem, design, and solution.
6. Science in Personal and Social Perspectives — Help students develop decision-making skills.

7. History and Nature of Science — Reflect science as ongoing and changing.

Inquiry and the National Science Standards

Inquiry and the National Science Standards is a National Academy of Sciences report that addresses the role of scientific inquiry in the context of national science standards. In this report, an equal emphasis is placed on connections between learning science, learning to do science, and learning about science. It is important to mention here that this emphasis and treatment of inquiry skills continue as research in science education progresses.

Briefly and to illustrate the impact and outreach of *Project 2061*, it is interesting to note that *Excellence in Environmental Education — Guidelines for Learning*, 2004, which was published by the North American Association for Environmental Education, was based upon two founding documents in the field: Belgrade Charter (UNESCO-UNLEP, 1976) and Tbilisi Declaration (UNESCO, 1978) and adopted by a United Nations conference. This document established four strands within topics of environmental science education. The strands focus on experiential learning and show the interdependence of content knowledge and science abilities as well as many topics found in the *Project 2061* initiatives such as systems, environmental issues, and personal responsibility.

Strand 1: Questioning, Analysis, and Interpretation Skills

Strand 2: Knowledge of Environmental Processes and Systems

“Scientific inquiry and experimentation should not be taught or tested as separate, stand-alone skills. Rather, opportunities for inquiry and experimentation should arise within a well-planned curriculum in the domains of science.”
Massachusetts Frameworks, 2001.

Strand 3: Skill for Understanding and Addressing Environmental Issues

Strand 4: Personal and Civic Responsibility

Taking Science to School: Learning and Teaching Science in Grades K-8

Taking Science to School: Learning and Teaching Science in Grades K-8 is the latest research in science education reform, published in 2007 by the National Research Council and the National Academy of Sciences. This publication suggests a change in the focus of science education from science content and abilities to focusing on the learner — what it means to be proficient in science. It is a comprehensive framework for science education that challenges thinking beyond the dichotomy between content and process in science.

This research addresses the following questions:

1. How is science learned, and are there critical stages in children’s science development of scientific concepts?
2. How should science be taught in K-8 classrooms?

3. What research is needed to increase understanding about how students learn science?

(It is important to note that equal emphasis is placed on how students learn and how teachers teach. Though it is often overlooked in the attempt to identify Science Standards, much emphasis was placed on professional development within the *1996 National Science Education Standards* as well.)

The four strands identified in the new research document now incorporate content and abilities into the whole discipline of how learners understand and practice science. Students who are proficient in science:

1. Know, use, and interpret scientific explanations of the natural world.
2. Generate and evaluate scientific evidence and explanations.
3. Understand the nature and development of scientific knowledge.
4. Participate productively in scientific practices and discourse.

As happened with the *Project 2061/NSES* series, it will take time for any new research to influence curriculum materials, classroom

activities, and professional development practices. However, as this research develops into working documents for practitioners, core ideas soon to be known as *science anchors* will emerge. (*Taking Science to School*, 2007.) These core science anchors will be used to manage instruction and direct professional societies, textbook companies, professional development providers, and youth development organizations like 4-H to work from a set of core key ideas. The report findings will give 4-H and all those who focus on teaching and learning the opportunity to address scientific literacy from the role of the learner and the learning facilitator.

Technology Outcomes Within National Science Standards

To consider technology in the context of science education, it is necessary to establish the rationale for its use and purpose. The literature provides two distinct approaches to technology in education. One approach (educational technology) addresses the use of technology to enhance the teaching and learning process across the curriculum, dealing primarily with information and communication. The other approach (technology literacy) addresses technology from the aspect of design, problem solving, fabrication, operations, testing, troubleshooting, modeling, and maintaining equipment and systems.

The 1998 National Educational Technology Standards (NETS), sponsored by the **International Society for Technology in Education (ISTE)**, places emphasis on the use of technology as a tool to enhance the teaching and learning process, dealing primarily with

information and communication, including the use of media, multimedia hardware and software information, telecommunications, web environments, communication, data processing, and using technological resources for solving problems, locating, evaluating, and collecting information. The NETS Project defines standards for students by integrating curriculum technology, technology support assessment, and evaluation of technology use. Teachers can use these standards as guidelines for planning technology-based activities in all curricular areas in which students achieve success in learning, communication, and life skills. The document describes what the student should know about technology and be able to do with technology.

In 2002, the *Standards for Technology Literacy* (STL) were developed to align technology and design process standards with *Project 2061* and the National Science Education Standards. This scholarly work established a set of 20 technological standards and articulated a vision for a technologically literate citizenry. STL identifies content knowledge, abilities, and application to the real world. The standards in STL were built around a cognitive base as well as a doing/activity base. Technology literacy includes but is not limited to design, model making, problem solving, controls, optimization and trade-offs, inventions, and many other human topics dealing with human innovation. The International Technology Education Association (ITEA), one of the sponsoring organizations, is a professional association for technology education teachers who teach “technology education.”

Based on the interconnectedness of science and technology as noted in our review of science reform literature (see Figure 1), technology literacy is considered to be a

tool of science and as such is recognized in the National Science Education Standards. Technology is characterized in these standards both as the “knowing” and the “doing” part of technology — emphasizing fundamental understandings about the enterprise of technology and its links with science and the process of design and problem solving.

Engineering Outcomes Within National Science Standards

Engineering has been and continues to be recognized as a problem-solving and design process within science and technology. Derived from the word *ingenuity*, the process of engineering requires students to solve problems and design solutions using science, math, and technology as their tools.

Although there are no nationally recognized Engineering Standards for K-12 education to date, engineering from a standards-based approach is receiving attention from current instructors of math, science, and technology. Realizing the importance of engineering outcomes for developing a new generation of engineers, many professional organizations and university engineering faculty have worked to create engineering curriculum modules applicable for K-12. Relevant and rigorous engineering education modules have been designed to fit a variety of science and math and technology standards.

Based on the interconnectedness of science and engineering and technology as noted in our review of science reform literature (see Figure 1), the process of engineering design is considered to be the application of scientific knowledge to solve problems and design

solutions. More specifically, the *Massachusetts Science and Technology/Engineering Curriculum Framework* outlines the steps in the Engineering Design Process as follows:

- Step 1 — Identify the Need or Problem.
- Step 2 — Research the Need or Problem.
- Step 3 — Develop Possible Solutions.
- Step 4 — Select the Best Possible Solutions.
- Step 5 — Construct a Prototype.
- Step 6 — Test and Evaluate the Solution.
- Step 7 — Communicate the Solution.
- Step 8 — Redesign.

Contained in the National Science Education standards are two content standards specific to the practice of engineering: Content Standard A — Science as Inquiry and Content Standard E — Science and Technology. Engineering is characterized as a problem-solving and design process that translates directly to abilities within these two content standards. A connection between science standards and the engineering design process is also acknowledged within *Benchmarks*. *Benchmarks* characterizes engineering in Chapter 3 — The Nature of Technology, Chapter 8 — The Designed World, and Chapter 10 — Habits of Mind in this way:

Scientists investigate the natural world and learn scientific knowledge; engineers create the designed world resulting in technologies. Technologists apply the research, analysis, and designs of their colleagues, the scientist and the engineer. Technologists also supervise technicians who are involved in fabricating, operating, testing, troubleshooting, and maintaining equipment and systems.

Scientific Abilities Within National Science Standards

Ways of thinking and doing science, technology, and engineering are oftentimes referred to as learner abilities. *Science for All Americans* was written to clarify what students should “know” and “be able to do.” Prior to *Project 2061*, learner abilities were identified as separate but equal in importance to the understanding of content. Even in 4-H, learner abilities were addressed for the sake of changing behavior. As noted by well-known behaviorists Pfeiffer and Jones in their Experiential Learning model embraced by 4-H in the late 1980s: **“Learning can be defined as a relatively stable change in behavior and that’s the usual purpose of training.”** (Pfeiffer and Jones, 1985.) Throughout the mid-1990s, this philosophy led to the core belief that achieving the desired behavioral change was far more important than achieving a level of proficiency with the content.

Beginning with *Project 2061* in 1993, emphasis shifted from separating knowledge and abilities into distinct learning modules to integrating behavioral expectations into the learning of content. Even expectations for learning shifted from **“mastery of content and abilities”** to **“becoming proficient in content and competent in abilities.”** Such a shift in thinking has allowed non-formal organizations like to 4-H to move beyond a strict behaviorist interpretation of how learning should take place — through behavior modification and training — by embracing the work of cognitive theorists.

Ideally, learners engaged in science content use abilities such as inferring, hypothesizing, measuring, estimating, and experimenting

to bring meaning to their world. These types of behaviors, together with the knowledge, scientific values, and intellectual habits they produce, define the nature of science education outlined in *Benchmarks for Science Literacy*, 1992. Unfortunately, learners are too often burdened with activities that fail to properly facilitate the development of SET abilities in meaningful and significant ways. Curriculum designers tend to focus their attention on the content of their units, equating “teaching” with “covering the content” and giving much less thought to the abilities that students develop over time.

Fortunately, there is an increasing body of research supporting the notion that learners learn best when actively engaged, physically, mentally, and emotionally, within non-formal learning settings. According to Rogers (2004), non-formal learning is that point along the Informal/Formal learning continuum where one arrives at a purposeful and assisted learning situation, (see Figure 2). It’s that point just beyond self-discovery where learning takes place from daily experiences and exposure to the environment — to a more purposeful and assisted learning environment where the presence of a learning facilitator provides focus, support, and feedback to the learner’s topic of interest. However, it stops short of formal learning where one’s autonomy for learning is surrendered to an instructor who controls the content, the environment for learning, and the desired learning outcomes.

The challenge for 4-H is to identify an appropriate set of Science, Engineering, and Technology (SET) abilities for emphasis within the context of non-formal youth development. Our review of the literature found no definitive collection of nationally recognized SET Abilities. There are as many different

Figure 2. Roger's Learning Continuum.

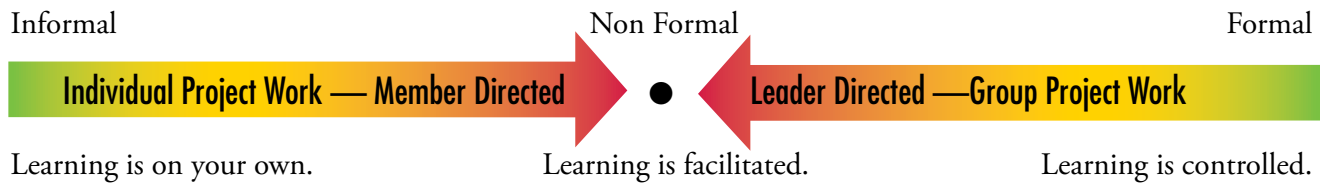


Figure 2 originates from the work of Allan Rogers, (2004) Looking Again at Non-Formal and Informal Education, The Encyclopedia of Informal Education, http://www.infed.org/biblio/non_formal_paradigm.htm. The figure has been adapted to provide a context for the types of member-directed and leader-directed SET programming available through 4-H. In this figure, emphasis is placed on moving learners closer to the non-formal center of the continuum with appropriate curriculum materials, properly trained learning facilitators, real-world learning environments, and authentic learning activities.

reports on this topic as there are identified abilities. Perhaps the most meaningful place to begin is to characterize these abilities from an experiential perspective.

In December 1987, David Kolb presented a paper at the National Science Foundation Conference on Contributions in Informative Science in which he theorized that all science activities fall under eight categories of abilities — exploration, focusing, grounding, structuring, investigation, verification, recording, and communication (Figure 3). The “knowledge base abilities” derived from Bloom’s *Taxonomy of the Cognitive Domain* are found under Kolb’s headings of Exploration and Focusing. The remaining cognitive abilities, often called “higher order thinking skills,” are found under the headings of Grounding, Structuring, Investigation, Verification, Recording, and Communication.

Science educators have attempted to expand upon Kolb's thinking by examining the most basic abilities necessary for the learning of science and the application of these abilities beyond the classroom. Beginning with the National Science Teachers Association's publication, *The Content Core* (1993) identified science as observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models, hypothesizing, and predicting. This was followed by *Science Guidelines for Non-Formal Education* (Carlson and Maxa, 1997), where researchers described the process of science as observing, communicating, comparing, measuring, ordering, categorizing, relating, inferring, and applying.

This perspective continues to gain momentum and receive affirmation in today's literature.

Taking Science to School: Learning and Teaching

Figure 3. Kolb's Model with Inquiry Process Components and Science Ability Categories.

Experiential Education	Concrete Experience (Experience)		Reflective Observation (Reflect)		Abstract Conceptualization (Generalize)		Active Experimentation (Apply)	
Scientific Inquiry Process Domains	Problem Finding		Question Asking		Answer Seeking		Portrayal of Knowledge	
Science Ability Categories	Exploration	Focusing	Grounding	Structuring	Investigation	Verification	Recording	Communication

Science in Grades K-8 (2007) emphasizes that doing science entails much more than reciting facts or being able to design experiments. It suggests that the next generation of science curricula should be centered on a few core ideas (science anchors) that are intertwined with behavioral outcomes. Learners should take part in a variety of learning experiences that address content and abilities. Those experiences should include conducting investigations; sharing ideas with peers; talking and writing in specialized ways; and using mechanical, mathematical, and computer-based models. Science should be a process of using evidence to build explanatory theories and models, and then checking how well the evidence supports them.

To establish the most relevant behaviors (SET abilities) in the context of non-formal youth development, we have identified 30 of the most recurring abilities cited in

today's scientific literature. (See Appendix A.) Furthermore, we have used Kolb's research to align these abilities with various Science Ability Categories linked to his experiential model. From Figure 4, one can quickly identify the types of abilities to emphasize during selected experiences along an experiential path. It is important to note that abilities within a particular category are not exclusive to that domain. On the contrary, targeting abilities based solely on their assigned location in this model becomes less important as learners acquire knowledge and begin to function at multiple levels along an experiential path.

4-H SET From An Experiential Perspective

In its simplest form, experiential learning is based on the needs and interests of the learner, utilizes non-formal learning methods, matches

Figure 4. Kolb's Model with Inquiry Process Domains, Ability Categories, and Compilation of Science Abilities.									
Kolb	Experiential Education	Concrete Experience (Experiences)		Reflective Observation (Reflect)		Abstract Conceptualization (Generalize)		Active Experimentation (Apply)	
	Scientific Inquiry Process Domains	Problem Finding		Question Asking		Answer Seeking		Portrayal of Knowledge	
	Science Ability Categories	Exploration	Focusing	Grounding	Structuring	Investigation	Verification	Recording	Communication
Horton, Gogolski, and Warkentien	Science Abilities (to be practiced as well as to facilitate learning)	Observe	Categorize/ Order/ Classify Organize	Infer Question Predict Hypothesize Evaluate	State a Problem Plan an Investigation Use Tools Develop Solutions Design Solutions Problem Solve	Measure Draw/ Design Build/ Construct Collect Data Invent/ Implement Solutions Test Research a Problem	Interpret/ Analyze/ Reason Troubleshoot Redesign Optimize Collaborate	Compare Model/ Graph/ Use Numbers Summarize/ Relate	Demonstrate/ Communicate to Others

learner interests with adult facilitators, and provides experiences that are organized along a path of experience, reflection, generalization, and application (Horton and Hutchinson, 1999). To truly define a curriculum as experiential, there must be some evidence that experiential processing takes place. According to Joplin (1995), experience alone is not experiential education. Rather, true experiential education is characterized by overt and systematic interventions by the learning facilitator along an experiential path. Joplin identifies these overt interventions as follows.

Focus — Includes presenting the task and isolating the attention of the learner for concentration. A proper focusing stage is specific enough to orient the learner but not so specific as to rule out independent discovery.

Support and Feedback — Exists throughout the learning experience and includes maintaining close proximity to the learner to facilitate questioning and clarify instructions. Adequate support enables the learner to continue to try. Adequate feedback will ensure that the learner has the necessary information to move forward.

Debriefing — Here learning is recognized, articulated, celebrated, and assessed. It is the opportunity to ensure that the learner's previous actions do not go unquestioned, unrealized, or unorganized. This intervention includes facilitating decisions about what needs to be done next or how things could have been done differently.

Figure 5 illustrates Joplin's facilitation construct in the context of Kolb's experiential learning model. As Joplin explains, the approach to which the defining elements (content and abilities) of a learning experience are facilitated using this model is up to the discretion of the curriculum designer. Most importantly, the process should complement the sequence of learning events rather than intrude as some repetitious prescription for learning. A second important point made by Joplin is that experientially based instruction materials should overtly communicate the role of the learning facilitator — like beacons strategically placed along the experiential path that illuminate the type of intervention necessary. If anything, the facilitator training should focus on modeling proper behavior — focus, support, feedback, debrief — rather than on controlling the learner's experience.

Figure 5. Experiential Facilitation Model

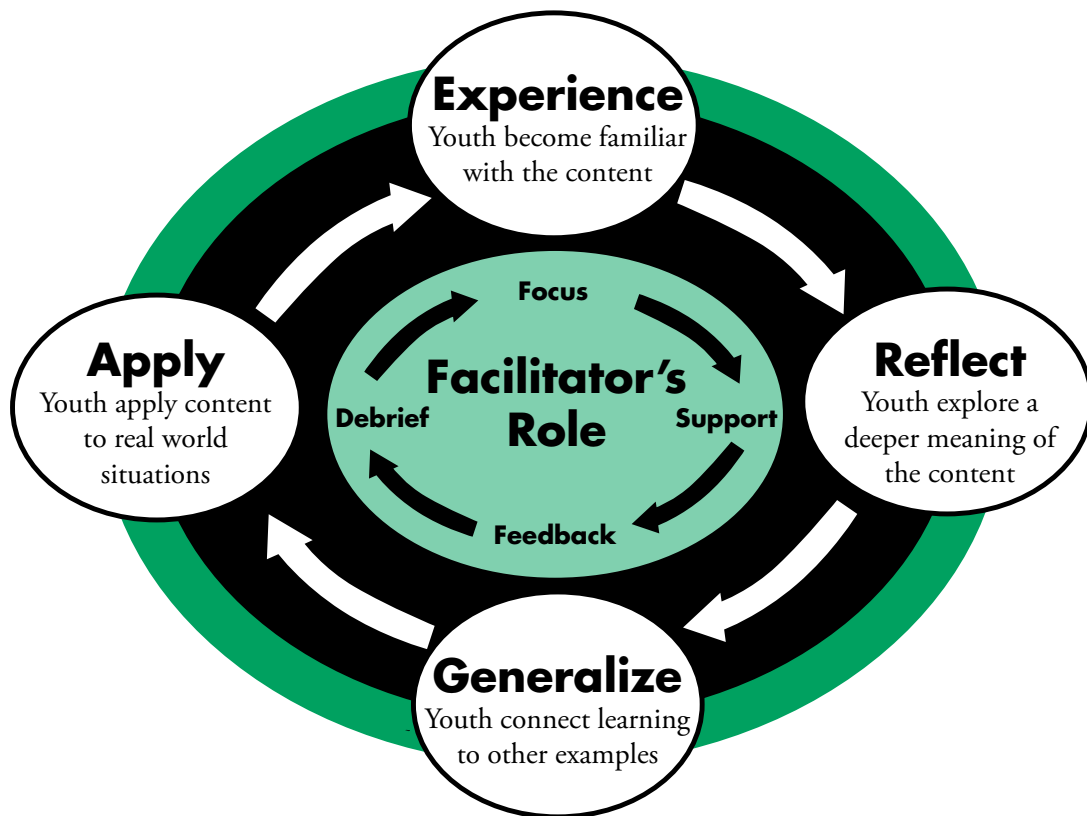


Figure 5 is adapted from the works of David Kolb, (1984), *Experiential Learning: Experience as the Source of Learning and Development*, Englewood Cliffs, New Jersey, Prentice-Hall, Inc., and Laura Joplin (1995), *The Theory of Experiential Education* (pp.22-29), Dubuque, Iowa, Kendall/Hunt Publishing Co. While the authors acknowledge the presence of other prominent experiential models in the literature (like the Pfeiffer and Jones model typically cited in 4-H curriculum materials), the authors view the foundational work of David A. Kolb and his Experiential Learning Model as the best fit for the purposes of this paper.

Essential Elements — SET Curriculum Design

The philosophy of designing experientially based SET curriculum brings into focus the way in which teaching materials are created, especially how information is organized along an experiential path. This organized information is referred to as “curriculum components” and includes:

- Aims, goals and objectives.
- Subject matter.
- Learning experiences.
- Assessment.

The uniqueness of these components, the emphasis placed on them, and the manner in which they are organized comprise what we mean by curriculum design. (McTighe and Wiggins, 1999.) Three overriding principles have been characterized as “essential elements” in the design of effective SET curriculum materials (National Research Council, 2005):

- Engaging Resilient Preconceptions — *addressing a child's initial understanding and preconceptions about science.* Children do not come to the table as blank slates. Rather, each child arrives with informally acquired ideas and experiences that often distort their view of the world. It is critical that

learner preconceptions be identified, confronted, and resolved.

- Organizing Knowledge Around Core Concepts — *providing a foundation of factual knowledge and conceptual understanding*. Organizing information can be a powerful way to increase a child's understanding and retention while developing key scientific abilities.
- Supporting Self-Regulation — *instructional strategies that help students take control of their learning*. Children need opportunities to test out their ideas in a safe and nurturing environment under the guidance of a trained learning facilitator.

Recommendations

Since the early 1920s, 4-H has been actively engaged in the development of science education materials. It is not the goal of this report to indict the quality nor the effectiveness of 4-H science education materials developed to date. In fact, several pieces in the current National 4-H Curriculum Collection embody best practices in non-formal experiential design along with presenting a proper balance between SET content and abilities.

Based on the review of the literature, we suggest that 4-H adopt the National Research Council's (NRC) *National Science Education Standards* as the guiding set of principles for its SET curriculum planning and development process. Although standards do exist for Technology and Engineering, we believe they take the organization down distinctly divergent pathways — focusing on highly specialized classroom disciplines rather than on applied interpretations for non-formal youth development organizations

like 4-H. By adopting the NRC's National Science Education Standards, which include the practice of engineering and the use of technology, 4-H will be afforded a more contextual framework from which to provide a variety of meaningful and relevant SET experiences for youth. Figure 6 illustrates the connection that engineering and technology have within the national science standards and 4-H SET programming. Where the overlaps occur are well within the realm of program possibilities for 4-H.

A second recommendation is to adopt the 4-H SET Abilities Model put forth in this report. (See Appendix A.) This list of 30 distinct and measurable behaviors was assembled through an extensive review of the literature in the fields of science, engineering, and technology education. Emphasis has shifted from being solely on “the content to be learned” to “*how* students learn the content” and “*how* the content is taught.” The concept of always including core science content, a *science anchor*, and the inclusion of science abilities is an essential element of science reform that aligns well with Kolb's experiential model.

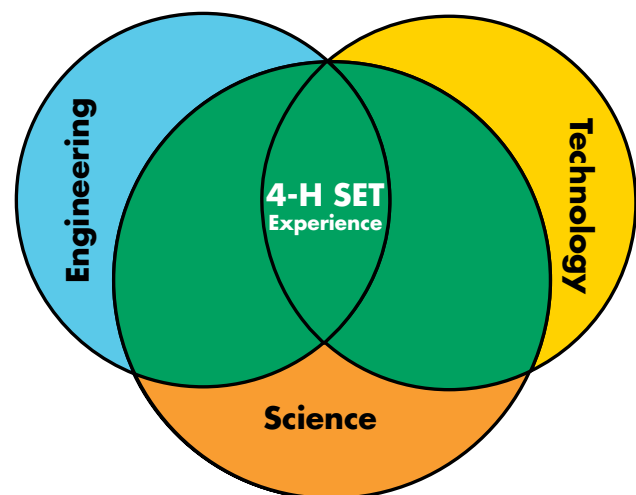


Figure 6. How engineering and technology connect with science through 4-H.

Afterword

From the authors: Regarding the absence of mathematics in our discussion of Science, Engineering, and Technology programming through 4-H: Unlike K-12 education, which addresses mathematics as an equal partner with Science, Technology, and Engineering (STEM) with distinct and measurable learning outcomes, 4-H has chosen to address mathematics in the context of Science, Engineering, and Technology programming. Calculating the rate of gain of a production animal, converting grams to centimeters in a recipe, estimating the altitude of a model rocket using trigonometry, squaring the corners on a piece of wood, and determining fertilizer rates by calculating the area of a corn field are just a few examples of the applied mathematics that can be learned through 4-H project work. The same can be said about reading and writing in 4-H. Just because 4-H members are encouraged to read their project books, follow directions, keep records, and write reports doesn't imply that 4-H is overtly and systematically addressing youth literacy issues. In 4-H, reading comprehension, writing, and applying math in meaningful ways are a few of the very important life skill outcomes that members will develop over time through 4-H project work.

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Definitions of SET Abilities

Build/Construct — Make by putting materials together.

Categorize/Order/Classify — Put objects or events in groups or classes.

Collaborate — To work together; applies both to the work of individuals as well as larger groups.

Collect Data — Record information in an organized fashion about objects and events that illustrate a specific situation.

Communicate/Demonstrate — Any one of several procedures involving various media that transfer information from one person to another.

Compare/Contrast — Evaluate *similarities* and *differences*.

Design Solutions — A written plan, also known as a *design brief*, that identifies a problem to be solved, its criteria, and its constraints.

Develop Solutions — A systematic strategy used to develop many possible solutions to solve a problem or satisfy human needs and wants.

Draw/Design — To plan out in systematic, usually graphic form; design a building; design a computer program.

Evaluate — The technique of examining and judging data presented.

Hypothesize — State a tentative generalization, which is subject to immediate or eventual testing by one or more experiments; to explain a relatively large number of events.

Invent/Implement Solutions — The practical application to fulfill a desired purpose.

Infer — Explain an observation in terms of one's previous experience.

Interpret/Analyze/Reason — Determine the nature and relationship of the parts of the whole. Find a pattern inherent in a collection of data. This process leads to stating a generalization or drawing conclusions. In an experiment, it is the process by which one establishes the relationship between controlled factors and the outcome.

Measure — A procedure by which one uses an instrument to estimate a quantitative value associated with some characteristic of an object or event.

Model/Graph/Use Numbers — Devise a scheme or structure that will describe specific real objects or events.

Observe — The most basic process of science, in which learners use their senses to obtain information about themselves or the world around them.

Optimize — To make the best or most of a condition.

Organize/Order/Classify — Put into working order; get together and arrange.

Plan Investigations — Use a body of techniques, often referred to as the Scientific Method, for considering *phenomena* and acquiring *knowledge*, including the elements of hypothesis development, prediction, and the effects and limits of observation and based on gathering *observable*, *empirical*, *measurable* evidence, subject to the principles of *reasoning*.

Predict — Projecting future observations on the basis of previously known information.

Problem Solve — Part of the *thinking* process considered the most complex of all *intellectual* functions, that includes *problem finding* and *problem shaping*.

Question — Raise an uncertainty, doubt, or unsettled issue that may be based on the perception of a discrepancy between what is observed and what is known by the questioner.

Redesign — To draw, sketch, or plan again.

Research a Problem — An active, diligent, and systematic process of inquiry aimed at *discovering*, *interpreting*, and *revising facts*. Is usually associated with the output of *science* and the *scientific method*.

State a Problem — The first step in the engineering process focused on assessing/creating the need in order to define the problem to be solved.

Summarize — To make a brief statement giving the main points or substance of a matter.

Test — To verify or falsify an expectation with an observation, often as part of an experiment within the scientific method.

Troubleshoot — A systematic search for the source of a problem so that it can be solved.

Use Tools — Manipulate objects, instruments, and materials as a means of furthering a learner's understanding, appreciation, and application of scientific knowledge.

Appendix A: A Summary of Commonly Identified SET Abilities.

Summary of SET Abilities	Question	Plan Investigation	Observe	Predict	Hypothesize	Measure	Collect Data	Interpret/Analyze/Reason	State a Problem	Research a Problem	Problem Solve	Design Solutions	Develop Solutions	Invent (implement solutions)	Build/Construct Prototype	Use Tools
National Science Education Standards (NSES)	x	x	x	x	x	x	x	x	x	x	x	x		x		x
Benchmarks for Science Literacy	x	x	x	x		x	x	x	x	x		x	x	x	x	x
Inquiry and the National Science Education Standards	x	x	x	x	x	x	x	x								x
Excellence in Environmental Education	x	x					x	x								
Ohio Academic Science Standards	x		x	x			x	x	x			x		x		x
Massachusetts Science and Technology/Engineering Curriculum Frameworks	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Standards for Technological Literacy (STL)										x	x	x	x	x	x	
National Educational Technology Standards (NETS)							x	x		x	x		x	x		
Ohio Academic Technology Standards							x			x	x	x			x	
PBS Build Big series										x	x		x	x	x	
National Engineers Week Future City Competition										x	x	x	x	x	x	
Project Lead the Way										x	x	x	x	x	x	
Teach Engineering Resources K-12										x	x	x	x	x	x	
Engineering Is Elementary: Engineering and Technology Lessons for Children											x					
Science Process Skills	x	x	x	x	x	x	x	x	x	x	x					
Learning and Assessing Science Skills	x			x	x		x	x			x					

Appendix A (continued): A Summary of Commonly Identified SET Abilities.

Summary of SET Abilities	Infer	Draw/Design	Model/Graph/Use Numbers	Organize	Summarize/Relate	Categorize/Order/Classify	Test	Troubleshoot	Evaluate	Redesign	Optimize	Communicate	Collaborate	Compare/Contrast	
National Science Education Standards (NSES)	x		x	x	x	x	x	x	x	x	x	x	x	x	
Benchmarks for Science Literacy			x	x	x							x			
Inquiry and the National Science Education Standards			x	x		x	x		x	x		x			
Excellence in Environmental Education			x	x											
Ohio Academic Science Standards	x	x	x						x	x		x	x	x	
Massachusetts Science and Technology/Engineering Curriculum Frameworks		x	x		x		x		x	x	x	x	x	x	
Standards for Technological Literacy (STL)				x				x	x		x	x			
National Educational Technology Standards (NETS)			x						x			x	x		
Ohio Academic Technology Standards						x	x	x	x			x			
PBS Build Big series			x				x	x	x	x					
National Engineers Week Future City Competition			x				x	x	x	x		x			
Project Lead the Way							x		x	x		x			
Teach Engineering Resources K-12		x	x				x		x	x	x	x	x	x	
Engineering Is Elementary: Engineering and Technology Lessons for Children							x		x	x	x	x			
Science Process Skills	x			x	x		x			x		x	x	x	
Learning and Assessing Science Skills	x		x	x	x		x						x	x	





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