THE ITEEA 6E Learning byD*e*SIGN™ Model

MAXIMIZING INFORMED DESIGN AND INQUIRY IN THE INTEGRATIVE STEM CLASSROOM

In April, 2013, the role of technology and engineering in schools and classrooms shifted forever.

BY BARRY N. BURKE, DTE

> *We must view this as an opportunity to Engage, Explore, Explain, eNGINEER, Enrich, and Evaluate in every school and every classroom.*

When the *Next Generation Science Standards* (*NGSS*) document, (NRC, 2013) was released in April 2013, teachers in the profession had mixed emotions. Many viewed the standards as invasive to their classrooms, while others found them a refreshing take on what technology and engineering educators have been doing for years. The reality is that *NGSS* provides an opportunity to *Engage, Explore, Explain, eNGINEER, Enrich,* and *Evaluate* technology and engineering programs and classrooms within the school and greater community. As stated by Sanders (2011), *NGSS* validates an integrative STEM approach by recognizing that technology and engineering provide opportunities for students to develop deeper knowledge about science.

The question is—"*How should we look at design and inquiry*?" Most technology and engineering educators would say they have been doing both for years. Others would say that inquiry should be done in science, while design should be done in technology and engineering. Curriculum designers everywhere look for the perfect way to plan and integrate content in order to give students the want and need to learn. Can we legitimately combine inquiry and design in a way that makes sense and builds on the ability to deliver Integrative STEM—by strengthening the T and E (Technology and Engineering)? How can we implement research-based strategies using engineering concepts to ensure that materials developed have a strong Integrative STEM focus?

I propose that a new, modified model, based on the Biological Sciences Curriculum Study's (BSCS) 5E Instructional Model (Bybee, 1997), will maximize the concepts of *Design and Inquiry* in an *Integrative* way (Sanders, 2009). The ITEEA 6E Learning byD*e*SIGN™ Model provides a student-centered framework for instruction that leverages the T and E of STEM as it integrates content in a purposeful and informed way.

BSCS 5E INSTRUCTIONAL MODEL

Many are familiar with the BSCS 5E Instructional Model. Developed by the Biological Sciences Curriculum Study (BSCS), the 5E model is a learning cycle based on a constructivist view of learning (Rowrich, 2005 p.29). The objective of a constructivist model is to provide students with experiences that make them reconsider their conceptions. Then students "redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment" (Bybee 1997, p. 176). The 5E model provides a planned sequence of instruction that places students at the center of their learning experiences, encouraging them to explore, construct their own understanding of scientific concepts, and relate those understandings to other concepts (Rowrich, 2005 p.29).

In 2004, ITEEA's STEM⌖Center for Teaching and Learning (STEM⌖CTL) adopted the BSCS 5E Instructional Model. All of the standards-based materials used in the Engineering byDesign™ Model Program are developed around the BSCS framework.

CONCEPTS, CONTEXTS, AND MODELS IN TECHNOLOGY AND ENGINEERING CLASSROOMS

There exists in the profession much discussion about "what" should be taught in classrooms. Some would argue that, as long as students are using their hands, it does not matter. Many would point to the technological literacy standards and say this is the content for technology and engineering (technological literacy). The evolution from skills-based to an emphasis on technological literacy creates many opportunities when channeled to content.

When looking at the conceptual base for technology and engineering, STEM⌖CTL is using the following Contexts and Concepts (Rousouw, 2005) as the basis for developing classroom materials and professional development.

Contexts Based on Personal and Global Concerns	Themes, Subconcepts, and Social Contexts
• Food	• Design
• Energy	• Modeling
• Health & Safety/Security	• Systems
• Shelter	• Resources
• Transport/Mobility	• Human Values
• Water	

Modeling plays a significant role in the conceptual base. Often we think of models as real objects that look or act like the real artifact. A model is a system that is used to describe (or interpret) another system of interest in a purposeful way. Understanding models usually involves a variety of diagrams, concrete models, experience-based metaphors, and other expressive media (Lesh, 2010 p7).

ITEEA'S 6E LEARNING byD*e*SIGN™ MODEL

For purposes of developing an instructional model that blends design and inquiry, the BSCS 5E Instructional Model (Bybee, 1997), the conceptual base (concepts and contexts) as described in the Delphi study by Rousouw, Hacker, and de Vries (Rousouw, 2005), and the Informed Design Teaching and Learning Matrix (Crismond, 2012) were used. Additionally, mathematical modeling concepts (Lesh, 2010) were incorporated.

The basic premise of the **6E Learning byDeSIGN™ Model** was to develop a student-centered model that would blend design (context and concepts) and inquiry. Having used the BSCS 5E model for many years, there was always the struggle that design was not fully represented. To that end, this new model adds an "e" called ***eNGINEER***. It is in this phase or cycle where students truly design and model as engineers would.

What follows are descriptions of each of the six Es. Table 1 (pages 18-19) provides a summary of what a student will experience in each phase, as well as teacher expectations to facilitate the student learning. Much of the BSCS model has been incorporated and enhanced by integrating it throughout the concepts of eNGINEERING (design, systems, modeling, human values, and resources).

ENGAGE

The purpose of the ENGAGE phase is to pique student interest and get them personally involved in the lesson, while preassessing prior understanding.

During this experience, students first encounter and identify the instructional task. During the **ENGAGE** phase, students make connections between past and present learning experiences (prior knowledge), setting the organizational groundwork for upcoming activities. The purpose is to pique students' curiosity and encourage them to ask their own questions (Bybee, 1997).

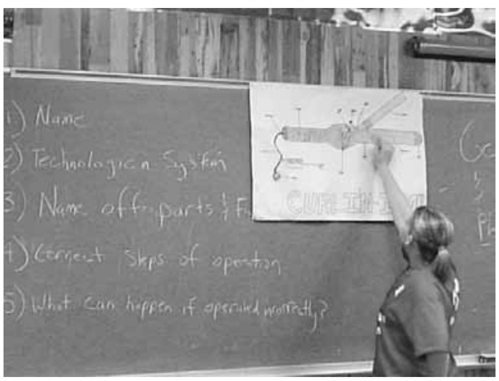
EXPLORE

The purpose of the EXPLORE phase is to provide students with the opportunity to construct their own understanding of the topic.

In the **EXPLORE** phase, students have the opportunity to get directly involved with phenomena and materials. As they work together in teams, students build a set of common experiences that prompts sharing and communicating. The teacher acts as a facilitator, providing materials and guiding the students' focus. The students' inquiry process drives the instruction during an exploration. Students are actively learning through inquiry-based science instruction and engineering challenges. Through Socratic Questioning, emphasis is placed on questioning, data analysis, and critical thinking. Through self-designed or guided exploration, students make hypotheses, test their own predictions, and draw their own conclusions (Bybee, 1997).

EXPLAIN

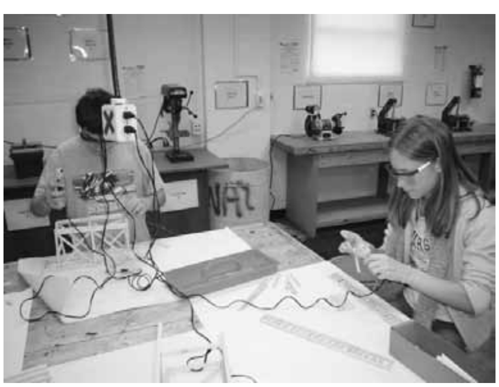
The purpose of the EXPLAIN phase is to provide students with an opportunity to explain and refine what they have learned so far and determine what it means.



EXPLAIN is the phase during which learners begin to communicate what they have learned. Language provides motivation for sequencing events into a logical format. Communication occurs between peers, with the facilitator, and through reflection and *Socratic Questioning*. The EXPLAIN phase introduces vocabulary in context and corrects or redirects misconceptions.

eNGINEER

The purpose of the eNGINEER phase is to provide students with an opportunity to develop greater depth of understanding about the problem topic by applying concepts, practices, and attitudes. They use concepts learned about the natural world and apply them to the man-made (designed) world.



eNGINEER is the phase of learning where learners use inquiry and integrate it with the concepts of engineering concepts to make informed design decisions in their solutions. They engineer creative solutions using **design, systems, modeling, resources,** and **human values** as the basis for development, construction, refinement, assessment, and redesign. "The materials used in this phase are designed to intensify learning in math and science and other core-curriculum subjects, and capitalize on the hands-on interdisciplinary nature of engineering" (Katehi, 2009, p.92).

ENRICH

The purpose of the ENRICH phase is to provide students with an opportunity to explore in more depth what they have learned and to transfer concepts to more complex problems.

ENRICH is the phase during which learners can transfer understanding and purpose to new situations and applications. They understand and are able to utilize the concepts "**Design**," "**Modeling**," "**Resources**," and "**Systems**" and apply them to "Human Values" in ways that enrich their understanding and their ability to transfer learning to new situations and problems.

EVALUATE

The purpose of the EVALUATION phase is for both students and teachers to determine how much learning and understanding have taken place.

EVALUATE, the final "E," is an ongoing diagnostic process that allows the teacher to determine if the learner has attained understanding of concepts and knowledge. Evaluation and assessment are not linear and should occur at all points (all phases) along the continuum of the instructional process. Some of the tools that assist in this diagnostic process are: rubrics, teacher observation, student interviews, portfolios, and project- and problem-based learning products. Video segments can be used to determine students' depth of understanding. Students will be excited to demonstrate their understanding through journals, drawings, models, and performance tasks (Bybee, 1997).

EndNotes

The **6E Learning byDeSIGN™** model can and will provide teachers and curriculum developers a systematic way to ensure that the T and E of STEM are fully integrated into the classroom. It is a natural unification and integration of *Design and Inquiry* that builds on the contexts of engineering in ways that maximize the content in both *Standards for Technological Literacy* and *Next Generation Science Standards*.

The STEM⊕Center for Teaching and Learning has begun to use the **6E Learning byDeSIGN™** instructional model in all of the materials developed (K-12) for the Engineering byDeSIGN™ model program. The framework has been integrated into the writing process as authors develop standards-based materials and the professional development model.

And finally—*Next Generation Science Standards* provides our profession with an opportunity to step in and showcase the integrative nature of technology and engineering in STEM classrooms. The debate in the profession will continue to evolve, but we must view this as an opportunity to *Engage, Explore, Explain, eNGINEER, Enrich, and Evaluate* in every school and every classroom. It goes back to the old saying used by multiple presidents and legislators since the 1960s—"If not now, when? If not us, who?" The answer to this is simple—now is the time, and we are the best qualified to **bring STEM to life**.

We welcome your feedback – please send me your thoughts at bburke@iteea.org.

REFERENCES

Bransford, J., Brown, A., & Cocking, R. (1999). *How people learn: Mind, brain, experience, and school.* Washington, DC: National Research Council. Retrieved from www.citeulike.org/group/9538/article/4434749

Burghardt, M. D. & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process in technology. *The Technology Teacher, 64* (1), 6-8.

Bybee, R. (2006). *The BSCS 5E instructional model: Origins and effectiveness.* Boulder, CO: BSCS. Retrieved from http://sharepoint.snoqualmie.k12.wa.us/mshs/ramseyerd/Science%20Inquiry%201%2020112012/Forms/AllItems.aspx (Choose: What is Inquiry Science [long version]).

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Crismond, D. P. & Adams, R. S. (2012). The Informed design teaching and learning matrix. *Journal of Engineering Education*, 101:738–797. doi: 10.1002/j.2168-9830.2012.tb01127.x.

Foundation for Critical Thinking. (2013). *The role of socratic questioning in thinking.* Retrieved from www.criticalthinking.org/pages/the-role-of-socratic-questioning-in-thinking-teaching-learning/522

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects.* Retrieved from www.sdsa.org/resources/publications/Engineering in K-12 Education.pdf

Lesh, R., et al. (2010). *Modeling students' mathematical modeling competencies.* Springer Science+Business Media. DOI 10.1007/978-1-4419-0561-1_1.

National Research Council. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Roussouw, A., Hacker, M., & de Vries, M. J. (2011). Concepts and contexts in engineering and technology education: An international and interdisciplinary Delphi study. *International Journal of Technology and Design Education* (November 2011). Retrieved from http://download.springer.com/static/pdf/236/art%253A10.1007%252Fs10798-010-9129-1.pdf?auth66=1389103429_d23942cf0c4acd75e9fcbf0ac90e5155&ext=.pdf

Rohrich, K. & Morgan, E. (2005). *Picture perfect science lessons: Using children's books to guide inquiry, Grades 3-6.* NSTA Press, Arlington, VA. Retrieved from http://learningcenter.nsta.org/files/PB186X-4.pdf

Sanders, M. (2009). Integrative STEM education: Primer. *The Technology Teacher, 68*(4), 20–27.

Sanders, M. (2012). Integrative STEM education as "best practice." In *Proceedings of the 7th Biennial International Conference onTechnology Education Research* (pp. 103–117). Queensland, Australia. Retrieved from www.griffith.edu.au/__data/assets/pdf_file/0005/514769/2012-TERC-Volume-2-of-2.pdf#page=109

Barry N. Burke, DTE is Director of ITEEA's STEM⊕Center for Teaching and Learning. He can be reached at bburke@iteea.org.

Table 1. What a student will experience in each phase of the six Es.

Phase	OVERVIEW	The Student:	The Teacher:
ENGAGE	**The purpose for the ENGAGE phase is to pique student interest and get them personally involved in the lesson, while pre-assessing prior understanding.** During this experience, students first encounter and identify the instructional task. During the ENGAGE phase, students make connections between past and present learning experiences, setting the organizational groundwork for upcoming activities. The purpose is to pique students' curiosity and encourage them to ask their own questions. (Bybee, 1997)	• Becomes familiar with concepts • Checks for understanding • Clarifies the Big Idea and connects with the Enduring Understandings (Wiggins & McTighe) • Identifies what they know, need to know, and want to learn • Contributes to identification and development of objectives for the lessons • Researches • Interacts with materials and equipment (etc.) • Identifies "Human Values" as they relate to the Big Idea and Enduring Understandings • Makes entries in the Engineering Design Journal (EDJ)	• Asks questions • Gathers materials • Researches and presents major concepts • Connects learning to prior knowledge and experiences • Describes the Design Process • Introduces how Human Values are important • Oversees safety and skills instruction • Encourages and guides initial EDJ entries • Assesses student understanding to direct instructional strategies.
EXPLORE	**The purpose for the EXPLORE phase is to provide students with the opportunity to construct their own understanding of the topic.** In the EXPLORE phase, the students have the opportunity to get directly involved with phenomena and materials. As they work together in teams, students build a set of common experiences that prompt sharing and communicating. The teacher acts as a facilitator, providing materials and guiding the students' focus. The students' inquiry process drives the instruction during an exploration. Students are actively learning through inquiry-based science instruction and engineering challenges. Through Socratic Questioning, emphasis is placed on: questioning, data analysis, and critical thinking. Through self-designed or guided exploration, students make hypotheses, test their own predictions, and draw their own conclusions (Bybee, 1997).	• Forms generalizations about major concepts • Participates as part of a team • Participates in team and class discussions • Engages in "Modeling" activities (predictive analysis) • Compares team data as it relates to the criteria and constraints • Makes entries and develops additional questions in EDJ	• Introduces Modeling (COPA-constraints, optimization, and predictive analysis) concepts • Reiterates the Design Process • Encourages student participation in discussions • Uses Socratic Questioning – seeking to understand, then seeking further understanding through additional questioning • Facilitates student team processes • Encourages EDJ entries and student reflection
EXPLAIN	**The purpose for the EXPLAIN phase is to provide students with an opportunity to explain and refine what they have learned so far and determine what it means.** EXPLAIN is the phase during which learners begin to communicate what they have learned. Language provides motivation for sequencing events into a logical format. Communication occurs between peers, with the facilitator, and through reflection and Socratic Questioning. The EXPLAIN phase introduces vocabulary in context and corrects or redirects misconceptions (Bybee, 1997).	• Applies concepts, principles, and theories related to "Systems" • Uses "Modeling," "Human Values," and "Systems" (Roussouw, 2010, p 422) to develop proposed solutions to problems • Uses the Design Process to form explanations • Makes entries and explains concepts in EDJ • Uses a variety of information and communication technologies and skills	• Introduces the concept of Systems and how they interact • Reiterates the Design Process • Uses Socratic Questioning – seeking to understand, then seeking further understanding through additional questioning • Leads class discussions • Corrects misconceptions • Provides appropriate resources • Questions students to ensure that connections are made to broader contexts • Encourages EDJ entries and student reflection

Table 1, continued.

Phase	OVERVIEW	The Student:	The Teacher:
eNGINEER (Extend/Elaborate)	**The purpose of the eNGINEER phase is to provide students with an opportunity to develop greater depth of understanding about the problem topic by applying concepts, practices, and attitudes. They use concepts learned about the natural world and apply them to the man-made (designed) world.** eNGINEER is the phase of learning where learners use inquiry and integrate it with the concepts of engineering concepts to make informed design decisions in their solutions. They engineer creative solutions using design, systems, modeling, resources, and human values as the basis for development, construction, refinement, assessment, and redesign. "The materials used in this phase are designed to intensify learning in math and science and other core-curriculum subjects, and capitalize on the hands-on interdisciplinary nature of engineering" (Katehi, 2009, p.92).	• Applies concepts, principles, and theories related to "Design" and how "Resources" guide decision-making • Uses "Design," "Modeling," "Human Values," "Resources" and "Systems" to develop proposed solutions to problems • Uses creativity to design and build solutions • Uses the Design Process to test and redesign solutions against criteria and constraints • Identifies problems and uses Modeling to predict redefined solutions • Applies "what if" concepts to different contexts • Controls quality of designed solutions • Makes entries and explains eNGINEERing connections in EDJ	• Introduces the concepts of Design and Resources, describing how they interact • Reiterates the Design Process • Facilitates student learning through use of inquiry and design • Elaborates understanding of design failures • Provides students with resources for the application of engineering solutions • Guides students in the application of quality control methods • Encourages EDJ entries and student innovation
ENRICH	**The purpose for the ENRICH phase is to provide students with an opportunity to explore in more depth what they have learned and to transfer concepts to more complex problems.** ENRICH is the phase during which learners can transfer understanding and purpose to new situations and applications. They understand and are able to utilize the concepts "Design," "Modeling," "Resources," and "Systems" and apply them to "Human Values" in ways that enrich their understanding and their ability to transfer learning to new situations and problems (Bybee, 1997).	• Understands the Design Process and applies it to new situations • Enriches the understanding of eNGINEERing concepts to different contexts and applications • Conducts appropriate research • Enters data in Inventors logbook • Considers "spinoffs" and technology transfer based on the basic design	• Provides students with resources for identifying new applications of design concepts • Questions students to ensure that connections are made to broader contexts • Guides students in producing effective communication through EDJ entries
EVALUATE	**The purpose for the EVALUATION phase is for both students and teachers to determine how much learning and understanding has taken place.** EVALUATE is an ongoing diagnostic process that allows the teacher to determine if the learner has attained understanding of concepts and knowledge. Evaluation and assessment is not linear and should occur at all points (all phases) along the continuum of the instructional process. Some of the tools that assist in this diagnostic process are: rubrics, teacher observation, student interviews, portfolios, projects, and problem-based learning products. Video segments can be used to determine students' depth of understanding. Students will be excited to demonstrate their understanding through journals, drawings, models, and performance tasks (Bybee, 1997).	• Demonstrates an understanding of the eNGINEERing concepts "Design," "Modeling," "Resources," and "Systems" and applies them to "Human Values" in their solutions • Uses self-assessments to determine if they have learned what they identified in the Engage phase as important to know or do to be able to develop solutions to the problem. This double-check is done in each of the six phases. • Completes (formative and summative) assessment activities according to established rubrics • Uses the EDJ to provide daily and periodic evidence of progress toward learning goals identified at the outset.	• Uses pre-assessment tools to identify student learning needs, wants, and deficiencies • Facilitates and engages students to understand "Design," "Modeling," "Resources," "Systems," and "Human Values" throughout the learning process • Ensures that student learning is based on *STL*, CCSS, and *NGSS* • Uses a variety of formative assessment tools throughout each phase • Explains rubrics and other assessment tools • Provides feedback on online formative and other assessment tools. • Utilizes knowing and doing assessment tools to evaluate program effectiveness.