Applying the Congruence Principle of Bloom's Taxonomy to Develop an Integrated STEM Experience through Engineering Design

By Paul A. Asunda and Sharita Ware

ABSTRACT

The concepts of interdisciplinary integration are interconnected beyond a theme, such that they cut across subject areas and focus on interdisciplinary content and skills, rather than subject-based content and skill (Drake, 1991; 1998; Jacobs, 1989). However, in today's learning environments, learning outcomes that teachers anticipate from their students and instruction are tied to educational standards. According to the principle of congruence in instructional design, in any situation, learning goals, anticipated outcomes, instructional strategies, and assessment methods should be carefully matched when designing a learning episode. To this end, this article presents a thought process by which the engineering and technology, science, and math teachers may reflect upon when preparing an integrated STEM course utilizing an engineering design process and the congruence principle of Bloom's taxonomy.

Key Words: STEM, STEM integration, congruence principle, Bloom's taxonomy, engineering design, assessment

INTRODUCTION

Our ever-changing, increasingly global society has brought forth challenges that are interdisciplinary, and many require the integration of multiple disciplines, specifically STEM concepts to solve them (National Academies, 2006). Integrated STEM has been seen as a vehicle to meet this objective. Ideas behind integration of interdisciplinary courses are intersected beyond a given goal, emphasizing connections between subject areas and focusing on interdisciplinary content and skills, rather than subject-based content and skills (Drake, 1991; 1998; Jacobs, 1989). It has been perceived that STEM disciplines offer a rich amalgamation of experiences that provide contextual cross-cutting concepts embedded in technological problem- based activities that can be realized through engineering design. The teaching of STEM integration should not only focus on content knowledge but also should include problem-solving skills and inquiry-based instruction (Wang, Moore, Roehrig, & Park, 2011). However, Honey, Pearson, and Schweingruber (2014) posited that designers of integrated STEM education initiatives must be explicit about the goals they aim to achieve and design the integrated STEM experience purposefully to achieve these goals. They also need to better articulate their intentions about why and how a particular integrated STEM experience will lead to particular outcomes and how those outcomes should be measured.

In the field now called engineering and technology, the educational message has been "technological literacy for all," clearly advocating a general educational philosophy. Hill (2006) posited that in the absence of an extant high school subject area to develop proficiency in engineering design, technology education courses naturally offered a continuum of experiences that emphasized engineering design principles. These experiences require that students identify probable solutions to problems designed in a context, as they experiment with simulated resources that mirror everyday technological systems. Such systems may include mechanical, structural, fluid, electrical, electronics, optical, thermal, biological, and materials technologies. Through the combination of these technologies, students follow the same procedures used by engineering teams in solving real-world problems as they develop products, processes, or systems that support human enterprises and institutions (Smith & Gray, 2009).

Custer (2000) noted a unique opportunity for the field through curriculum integration; he posited that "if the technology education profession is successful with an integration agenda, we could well find ourselves at the core of education in the 21st century. But integrated learning environments will be very different, the risks and demands will be considerable" (p. 130). It follows that the infusion of engineering design into technology education through problem-solving activities that culminate into projects, offers students opportunities to develop critical thinking skills, technical, and STEM literacy knowledge, and helps them to learn innovative practices. For these reasons, integrative STEM education, which promotes learning through connections among science, mathematics, technology education, and other general education subjects, is wholly consistent with the ideology of the profession. *This article presents a thought process by which the congruence principle of Bloom's taxonomy may guide the engineering and technology, science and math teachers as they design and develop an integrated STEM course utilizing an engineering design process as the basis.*

The Standards, Backward Design, and Developing Congruent Integrated STEM

In today's learning environments, outcomes that teachers anticipate from their students and instruction are tied to educational standards. Proponents of standard-based educational reforms claim that standards offer teachers a congruent process in designing their instructional practice. By specifying what knowledge or skills students must demonstrate, standards point toward the instructional practices that teachers could employ (Cohen, 1996; Darling-Hammond, 2004; Rowan, 1996).

According to the principle of congruence in instructional design, in any situation, learning goals and outcomes, instructional strategies, and assessment methods should be carefully aligned (Chyung & Stepich, 2003; Gagne, Wager, Golas & Keller, 2005; Dick, Carey, & Carey, 2008). To achieve congruence, instructional design models suggest identifying intended learning outcomes that mirror objectives of a course and determining the types of learning activities that represent these objectives. Wiggins and McTighe (2005) capture the principle of congruence through the backward design process, a three-stage process that teachers can use to develop integrated STEM courses. More specifically, to start this process, teachers begin by asking themselves: What is worthy and requiring of understanding? To answer this question, one must consider local, state, and national standards. If the answer from this first question is not based on the standards, it is probably not worthy of teaching and learning (Reeve, 2002; Wiggins & McTighe, 2005).

Standards are the driving force behind today's education and they should be addressed in lesson design. Teachers of engineering and technology education have subscribed to Standards for Technological Literacy (STL) as a vehicle to integrate engineering design principles and concepts into the curriculum. The ITEEA board of directors (2009) stated that the content contained within the STL standards was the basis for students to develop 21st Century STEM- related knowledge —the very core of abilities needed for students to become advanced problem solvers, innovators, technologists, engineers, and knowledgeable citizens. Additionally, recent standards being integrated into the curriculum like the Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS) seek to focus teachers on helping students make connections across the disciplines (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; NGSS, 2013). The underlying principles that inform both sets of standards are active engagement of students in authentic tasks, support for development of conceptual knowledge and reasoning, and application of knowledge in real-world contexts (Honey et al., 2014). Hence, standards present the content (knowledge and abilities) that teachers should utilize to develop contextual authentic tasks that support the development of conceptual knowledge and critical thinking leading to STEM literacy. It can then be argued that, for teachers to develop congruent integrated STEM courses, the backward design process helps students understand connections made between subject areas and internalize cross-cutting concepts rather than memorize them. In this way, learning outcomes and objectives serve as a cornerstone for the development of an integrated STEM course, helping to determine the instructional strategies and assessment methods that will be used which, in turn, helps to ensure the congruence of the instruction (Chyung & Stepich, 2003).

Instructional Practices that May Reflect Integrated STEM in the Curriculum

Furner and Kumar (2007) noted that, "an integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (p. 186). Integrated STEM has been viewed as an approach to teaching and learning in a manner such that the curriculum and content of the four individual STEM disciplines seamlessly merge into real-world experiences contextually consistent with authentic problems and applications in STEM careers. Such integration may refer to making meaningful connections between core disciplinary practices of each STEM domain being integrated, with the goal of using this integrated knowledge to solve real-world problems (Mobley, 2015). The integration of STEM concepts can then be visualized as follows, consider (see Figure 1) the content of units in Sciences, Mathematics and Engineering/ technology education. Due to the overlap of concepts identified in these units, they may be considered for integration through a problem-based learning activity that culminates into a project enabling students to operationalize STEM concepts. In addition, the content and assessment type identified in the area that these disciplines intersect need to be clearly specified to assess learning outcomes. A second approach (see Figure 2) can be viewed as follows; units from the Sciences and Engineering/technology Education have been integrated. A unit from Mathematics is integrated with a unit from Engineering/ technology Education. Dugger (2010) noted that there are a number of ways that STEM can be taught in schools today. One way is to integrate one of the STEM disciplines into the other three (e.g., integrating engineering aspects into science, technology and mathematics). And a more comprehensive way is to infuse all four disciplines into each other and teach them as an integrated subject matter. In this regard, Erekson and Shumway (2006) noted that a full interdisciplinary model, in which the content from two or more disciplines are merged, has the potential to be very effective in technology education. Although this model appears to show promise, it also appears the most elusive. Thus, achieving congruence in designing learning experiences that simulate an integrated STEM course has revealed the challenges of making connections across the STEM subjects. Honey et al. (2014) suggested that instructors should build in their teaching *opportunities that make STEM connections explicit to students and educators (e.g., through appropriate scaffolding and sufficient opportunities to engage in activities that address connected ideas).*

BASIS FOR CONGRUENCE PRINCIPLE

Bloom's Taxonomy and the New Revised Bloom's Taxonomy

Bloom's Taxonomy is a hierarchical way of classifying thinking according to six cognitive levels of complexity. The lowest three levels include the following: **knowledge**, **comprehension**, and **application**. The highest three levels include: **analysis**, **synthesis**, and **evaluation** (Bloom & Krathwohl, 1956). Throughout the years teachers have encouraged their students to think through these cognitive levels and to operate at the higher levels when solving problems. For example, it has been perceived that a student functioning at the "application" level also has mastered the material at the "knowledge" and "comprehension" levels. To this end, the taxonomy is used as a framework for categorizing and classifying learning objectives according to the skill level required to meet desired learning outcomes. Outcomes describe what students are expected to know and be able to do by the end of a given instructional period. These outcomes relate to skills, knowledge, and behaviors that students attain as they progress through a given learning experience. Anderson and Krathwohl (2001) modified Bloom's taxonomy by adding another dimension of knowledge types: factual, conceptual, procedural,
and meta-cognitive. Factual knowledge can best be defined as the basic elements that all students must acquire within a discipline, whereas

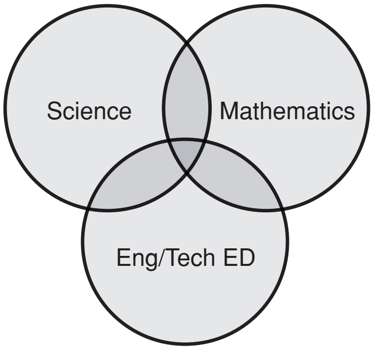


Figure 1. Integration of content units in Sciences, Mathematics, and engineering/ technology education.

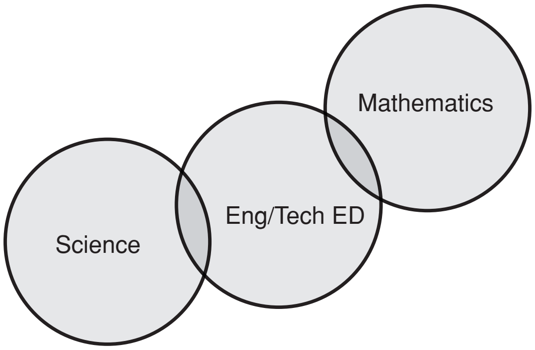


Figure 2. Integration of content units in Sciences, Mathematics, through engineering/technology education.

conceptual knowledge can best be defined as the understanding of inter-relationships among the basics of a discipline to the larger overall structure and explain how they function together. Procedural knowledge requires that students know how to conduct inquiry, understand and apply techniques and methods using appropriate procedures, and metacognitive dimensions require that students are aware of their own knowledge level, including the knowledge and use of heuristics. Anderson and Krathwohl renamed the earlier hierarchy of levels from nouns to verbs. A brief summary of the adaption and extension of Anderson and Krathwohl's (2001) revised Bloom's taxonomy follows:

1. Remember: recognizing, recalling (repeating verbatim): state [for example, the steps in the procedure for changing a flat tire].
2. Understand: interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining (demonstrating understanding of terms and concepts): explain [in your own words the concept of design].
3. Apply: executing, implementing (applying learned information to solve a problem): calculate [how much materials one may require to complete a given construction project].
4. Analyze: differentiating, organizing, attributing, checking, critiquing using existing criteria (breaking things down into their elements, formulating theoretical explanations or mathematical or logical models for observed phenomena): explain [why mass might affect the velocity of a given object].
5. Evaluate: (a) "Critiquing" based on self-designed/chosen criteria, (b) "Deciding" in the light of larger context, human values and ethics, (making and justifying value judgments or selections from among alternatives): select [from among available options for expanding production capacity, and justify your choice].
6. Create: generate, plan, and produce (creating something, combining elements in novel ways): make up [a homework problem involving material covered in class this week].

Bloom & Krathwohl, (1956) indicated that ideally researchers in each major field would use this taxonomy to develop their own unique objectives and language. They suggested that a discipline-specific taxonomy could offer assessment with greater details, with influences from experts in their respective fields, and break down the categories into subcategories and levels of education with new groupings and combinations.

The Accreditation Board for Engineering and Technology (ABET) evaluates every engineering-related program (departments and interdisciplinary course programs) in the United States and determines whether they meet certain standards (ABET, 2013). According to Felder and Brent (2004), this body determines whether the said programs and courses meet ABET- defined criteria and benchmarks that lead to realization of identified standards. Prior to a review of a program, instructors seek to evaluate the appropriateness of the educational objectives, the extent to which the specified outcomes result in the objectives, and whether they incorporate specific attributes specified by ABET. For engineering and technology education programs these would be ABET (Outcomes 3a–3k).

As STEM initiatives become the driving force of educational change through K-16, Clark and Ernest (2010) argued that all instructors would say that they want their students to master higher level thinking skills as reflected by the revised Bloom's taxonomy. To this end, the design of integrated STEM activities should focus on the extent to which the course's learning objectives map onto the outcomes, the feasibility of the specified outcome assessment and continuous improvement processes, and the seriousness with which the program is implementing those processes. Chyung and Stepich (2003) suggested that Bloom's taxonomy of educational objectives was instrumental in making sure there was congruence among the planning, instruction, and assessment process of design learning experiences.

ROLE OF ENGINEERING DESIGN IN ENGINEERING AND TECHNOLOGY EDUCATION

Researchers, (Ereckson & Custer, 2008; Pinelli & Haynie, 2010; Wicklein, 2004) advocated for engineering as the focus for technology education because engineering provides a solid framework to design and organize curriculum, while providing an ideal platform for integrating mathematics, science, and technology. According to Atman et al. (1999) design is a central element of engineering, and all engineers perform some type of design function. Likewise, Warner and Morford, (2004) stated that design is fundamental to the study of technology, and design cannot be fully appreciated without an understanding of technology. This statement implies that, if technology is to be fully understood, then the concepts of design must be comprehended. The Standards for Technological Literacy (ITEA, 2000/2002/2007) Standards 8, 9, 10, and 11 highlight design concepts to be introduced throughout the K-12 curriculum. Hailey et al. (2005) posited that the design process described in Standard 8 for students in Grades 9-12 is very similar to the introductory engineering design process described in freshman engineering design textbooks, specifically the book by Eide, Jenison, Mashaw, and Northrup (2002). Hailey et al. (2005) noted two exceptions as highlighted in Figure 3, and Mosborg, Adams, Kim, Atman, Turns, and Cardella (2005) affirmed that the number of stages in these diagrams ranged from a few to several dozen, depending on the detail and complexity with which the design process is rendered.

Today, the field is witnessing exponential growth of engineering practices, STEM- related curriculums (e.g., Project Lead the Way, STEM Academy, CISCO investment in STEM, and Microsoft Math Partnership) are being introduced at the K-12 curriculum level. Additionally, the federal government in financial years 2009, 2010, and 2011 offered approximately $867 million to support activities related to STEM education and increased outreach activities that support STEM initiatives through organizations like the National Aeronautics and Space Administration (NASA), The National Science Foundation programs (President's Council of Advisors on Science and Technology, 2010).

Classical Engineeringy Design process

(from introductory engineering text by Eide, et al.)

- IDENTIFY THE NEED
- DEFINE THE PROBLEM
- SEARCH FOR INFORMATION
- IDENTIFY CONSTRAINTS
- SPECIFY EVALUATION CRITERIA
- GENERATE ALTERNATIVE SOLUTIONS

Engineering Analysis
Optimization Decision

Design specifications
(So it can be made)

Communications

Classical Engineeringy Design process

(from introductory engineering text by Eide, et al.)

- DEFINING A PROBLEM
- BRAINSTORMING
- RESEARCHING AND GENERATING IDEAS
- IDENTIFYING CRITERIA AND SPECIFYING CONSTRAINTS
- EXPLORING POSSIBILITIES

Selecting an approach
and developing a design making
a model of prototype. Testing and
evaluating the design specifications
Refining the design

Communicating process and results

Creating or making it

Figure 3. Engineering design process compared to technology education design process

These new initiatives and curricula imply that educators should design collaboration strategies and new instructional practices. As suggested by Chyung and Stepich (2003) Bloom's taxonomy still has merit as a guide for instructional planning for two specific reasons. First, it reminds educators that the key to effective instruction is the congruence or "degree of correspondence among the objectives, instruction, and assessment" (Anderson & Krathwohl, 2001, p. 10). Second, because it is analytical, it helps remind instructors that learning is made up of a complex array of cognitive skills. At the same time, it doesn't prevent them from designing instruction in a more dynamic way, in which a low-level cognitive skill can be learned in conjunction with a high-level cognitive skill. To this end, the integration of engineering design into technology education continues to provide the field with authentic learning experiences that are ideal education required to help nations to prosper in the technologically interdependent world in which we live. Responsibility for this falls on the engineering and technology education teacher working in collaboration with colleagues in science and math.

USING BLOOM'S TAXONOMY TO DEVELOP A CONGRUENT INTEGRATED STEM LESSON THROUGH ENGINEERING DESIGN

Haag, Froyd, Coleman, and Caso (2005) stated that data can only be collected on observable behaviors and ABET student outcomes do not define observable behaviors; therefore, learning objectives should be formulated for each outcome describing the desired observable student performance. This may imply that an engineering technology education teacher seeking to integrate STEM concepts into their curriculum may redesign traditional technology education problem-based activities into a STEM-integrated project that depicts a stated standard performance and desired outcome. Such projects may include (e.g., Cookie Package Design Challenge; Sustainable House Project, and more) that can be repurposed to deliberately help students realize how the STEM concepts being taught overlap in a given learning activity and how these lead to both the solving of a given design problem and the realization of a complete project product.

For the purposes of this article the authors utilized an air blaster car. The main focus of the design of this car revolves around four main areas: principles of aerodynamics involved with air blaster car construction, design of vehicle, construction of vehicle, and racing of vehicle. Such a lesson can be best illustrated as described by Figure 2 where scientific concepts that explain the principles of aerodynamics, and the mathematic principles behind racing the car (i.e., calculating speed based on the time the car will cover a given length, integrated with engineering technology principles behind design and construction of the vehicle). Given this activity, Wiggins and McTighe (2005) advocated for the backward design process, which prompts instructors to ask, how best do we go about designing the car, and what kind of lessons and practices are needed to master key performances? This approach also requires that educators operationalize the identified standards in terms of assessment evidence as they begin to plan a unit. Instructors are tasked with asking themselves, what they would accept as evidence that the students have attained the desired understandings and proficiencies.

The next steps will be to develop objectives, learning activities and materials, and evaluation of criteria for each of the four areas. At this point the congruence principle becomes particularly important. Maintaining the congruence among the objectives, learning activities, and evaluation criteria is critical to the effectiveness of the instruction. Congruent instruction means that learning activities are designed to support the objectives and that the evaluation methods are designed to assess important learning outcomes represented by the objectives. A curriculum mapping exercise would provide a snapshot of where educators stand in light of the anticipated learning outcomes that students will be able to demonstrate. Bloom's taxonomy of educational objectives is instrumental in making sure that there is congruence among the components of each module.

Bloom's original taxonomy was used to determine the levels of the objectives for each module and to design learning activities through which students would accomplish those objectives. Prior to developing learning activities, the authors determined the levels in the taxonomy for each objective. Because the learning sequence and processes are interdependent, it was listed as the highest level from the taxonomy, in conjunction with lower, supporting levels. These are summarized in Table 1.

Table 1: *Standards, Levels of Objectives, and Knowledge Dimension*

STL/NGSS Standards	Objectives	Levels in RBT	Knowledge dimension in RBT
STL8-10-MS NGSS-MS-PS3-1.	Research pertinent information on underlying principles of aerodynamics with air blaster car construction	Remember and Understand	Factual
STL9, 16-MS, MS-PS3-3., MS-PS3-4.	Recognize principles of Newton's Third Law of Motion and how it relates to air blaster car competition	Understand and Apply	Conceptual
STL9, 16-MS MS-PS3-2.	Explain how mass, friction, and design of air blast car relate to its movement	Understand and Apply	Procedural
STL9-11-MS MS-PS3-4., MS-PS3-5.	Utilize the process of engineering design to design and develop a drawing design which shows understanding of air blaster concepts and construct a prototype car, present the model to peers	Apply, Analyze, Create and Evaluate	Meta-cognitive

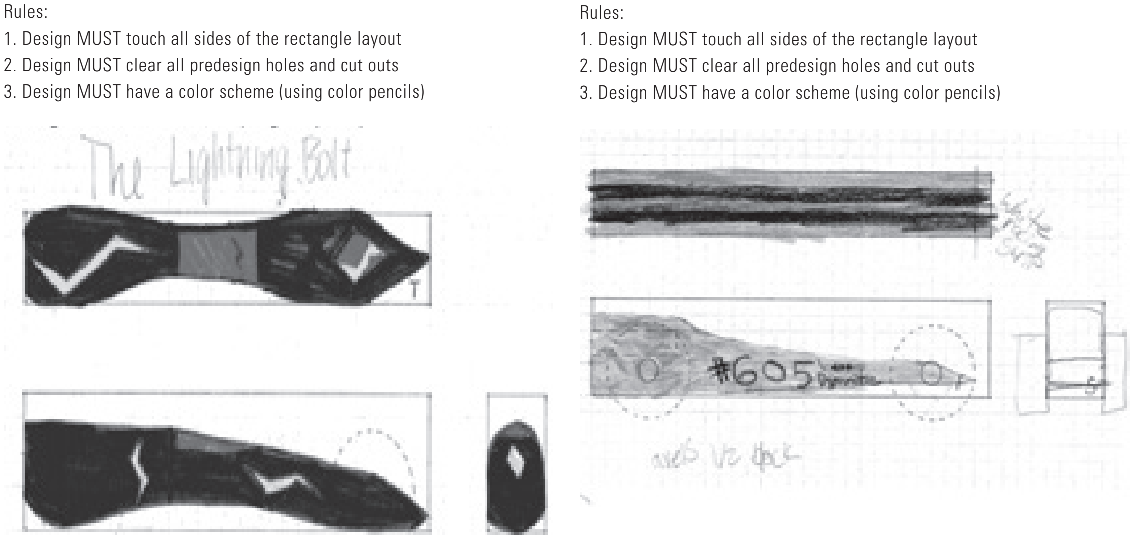
DEVELOPING LEARNING ACTIVITIES FOR THE REMEMBER AND UNDERSTAND LEVEL (FACTUAL) DIMENSION

Research: Students were asked to conduct research into underlying principles of winning car designs. This could entail students' finding information about the basics of aerodynamics as it relates to cars and, specifically, the underlying principles into construction of these cars. Students may be asked to informally demonstrate their knowledge and comprehension of factual knowledge into the design of at least three different designs based on the aerodynamic design of the cars.

Students were expected to recall the underlying principles of aerodynamics in car design using terms that they elicited from the research activity and elaborate on them using more common terms to illustrate aerodynamic designs (e.g., shape, sleek outline, sometimes relating to with examples to show comprehension of the concepts). The teacher should give students opportunities where they can connect the factual to conceptual knowledge as they progress through the activity. This connection should help students construct and deconstruct knowledge as they understand and apply principles of Newton's Third Law of Motion and how it relates to air blaster cars through small group discussions. Through this process students may demonstrate the intended level of learning (comprehension) and then go beyond that to demonstrate an unanticipated higher level of learning (e.g., application, analysis, synthesis, or evaluation) by connecting factual to conceptual knowledge.

LEARNING ACTIVITIES FOR THE APPLICATION AND ANALYSIS LEVELS (PROCEDURAL) DIMENSION

Based on discussions that ensue, the teacher should design classroom experiences that give students an opportunity to explore and explain how force, mass, friction, and design parameters relate to an air blaster car. By explaining and demonstrating the application of force on an object causes an acceleration of that object, that is, the more force you have, the faster an object goes, and helping students comprehend that force is not the only factor in the movement, or acceleration of an object. Other factors such as the friction, air or fluid resistance, and pressure may affect the acceleration as well. The students may be asked the following questions: Why is it important to be aware of how force and mass affect acceleration? What other factors may play a role? Why? How? Students eventually will be expected to apply these principles to the design of a car, Figure 4. Students can provide feedback to sketches of prototype cars for each other, and the can also provide examples of where they have seen these principles used. This method helped students consider different views of the same situation, promoting application and analysis.



Rules:
1. Design MUST touch all sides of the rectangle layout
2. Design MUST clear all predesign holes and cut outs
3. Design MUST have a color scheme (using color pencils)

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Figure 4. Students' sketches depicting factual and conceptual levels of Bloom's taxonomy

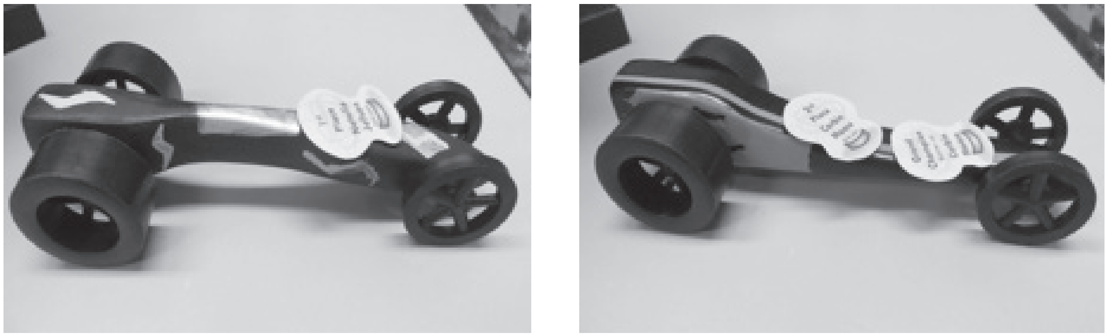

Figure 5. Students' prototypes depicting conceptual and procedural levels of Bloom's taxonomy

Figure 6. Students' prototypes depicting procedural and meta-cognitive levels of Bloom's taxonomy

Table 2: *Suggested Evaluation Procedure for Air Blaster Car Project to Integrate STEM concepts*

STL/NGSS Standards	RBT Dimension	Activity corresponding to Original bloom cognitive processes	Suggested Evaluation
STL8-10-MS NGSS-MS-PS3-1.	Factual	Students to submit portfolio of sketches that document initial research of challenge, criteria and constraints they experienced used to design air blaster car, Car Design Sketches.	Complete submitted portfolios with at least 2 sketches, detailing the challenge, criteria, and constraints in the context of performance improvement.
STL9, 16-MS, MS-PS3-3., MS-PS3-4.	Conceptual	Speed and weight of car: students to record weight of their cars in grams, race car three times on a race track and calculate the speeds of their cars by utilizing the formula Speed = Distance / Time. Compare the data from their findings to those of their peers, and be able to explain how the weight (mass) of their car impacted the rate of the speed it travelled.	Application of the Formula speed = distance/time upon students recording of weight of the car and tie to race on a specified length track. Students provide an explanation of how the mass of their car impacted the speed compared to at least 2 peers.
STL9-11-MS MS-PS3-2.	Procedural	Manufacture (cut, shape, sand, paint, and detail) car as per chosen design utilizing provided materials and tools. Weigh car and race car on track 3 times and record the speed	Application of the process of engineering design and STEM concepts to design and manufacture air blaster car.
STL9-11-MS MS-PS3-4., MS-PS3-5.	Meta-Cognitive	Project reflection, students to write about their overall experience with project. For example, how their compared to peers, and what would they change about their car to make it better, faster. More aerodynamic? Smaller wheels? Shorter race track?	Justification of their selection of given design, and how these design modeled the design process and STEM concepts compared to the design of 2 peers. A description of how they can improve their design or their peers utilizing the engineering design process.

They are required to keep a portfolio of sketches and drawings showing the development of the air blaster's final form. The design of this vehicle is not a linear process, and it is expected that many revisions of the design will occur. Thus, each student's car will have a different form that is based upon their design envelope (see Figure 5). Airblaster cars must be built to certain specifications to avoid interference with the propulsion system (i.e., placement of hole, wheels, launch system, guidance system, and the prevention of failure or destruction during testing). During the construction process, the students will learn to use tools, machines, and safety equipment, and they will identify potential safety hazards associated with them. Finally, the testing of the car will lead to both a self- evaluation as well as a peer evaluation process, as the vehicles are propelled down a track by compressed air (see Figure 6). The process of testing the cars will allow the students to compare and analyze the different designs for success and needed improvements. It is intended that a dialog between students will help further the design of the dragsters and improve results on the drag strip.

Evaluating Engineering Design Process Learning Outcomes Based on Bloom's Taxonomy

A backward design process as described by Wiggins and McTighe (2005) facilitates the design of an evaluation process. Each of the identified learning dimensions (i.e., outcomes, Bloom's taxonomy) guided the instructors in setting evaluation criteria that would be congruent with the learning objectives and standards. This evaluation maps the final products of a given task, to the learning objectives. Evaluating the design process regarding the degree to which the students have achieved identified learning outcomes with respect to integrating STEM concepts requires relevant, appropriate, and informative data upon which judgments can be based (Haag et al., 2005). A documented evaluation procedure (see Table 2) provides an approach to obtaining data relative to the process of engineering design in a technology education class project that may seek to integrate STEM concepts. Students could be provided the following guidelines for evaluations purposes.

CONCLUSION

The rich products of technology education provide a context for successful integration of STEM concepts into the K-12 curricula. However, designing instruction that offers meaningful experiences to meet the challenges of STEM integration in technology education is a difficult task for any educator. A conceptual framework offers educators a reference point to their instructional practices and standards and provides educators with a blueprint of expected learning outcomes. STL standards offer a starting point for designing learning activities while NGSS seek to help teachers identify cross-cutting concepts across STEM disciplines in the context of their teaching. Wiggins and McTighe (2005) have suggested backward design as a strategy to help students understand the connections between subject areas and internalize cross-cutting concepts. Chyung and Stepich (2003) emphasized that instructional components, such as instructional objectives, instructional activities, and assessment methods should be carefully matched to help students achieve the intended learning outcomes. In closing, this article presents a locus by which technology education instructors can incorporate STEM concepts into the K-12 curriculum. As instructors incorporate a backward design process to teach STEM concepts in technology education courses, Bloom's taxonomy can be a helpful guide in achieving congruence in integrating both cross-cutting concepts and how a particular integrated STEM experience may capture and enhance concepts that can be applied to solve complex challenges; it also may lead to both a particular outcome and the way in wish this outcome may be evaluated.

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