AWESOME TOY TRAINS

By Larry Singleton

We all have memories of the things we have made with our hands. From my first tree house at the age of eight, my project ideas have driven my learning. Those experiences designing, problem solving and building have helped to shape me and to develop lifelong skills. As a Drawing and Design teacher, I have the opportunity to offer similar experiences to my students.

Engaging Students by Encouraging Creativity

In the Introduction to Drafting and Design Course I teach, students are expected to acquire the basic knowledge and skills in order to create drawings that meet the standards set by the American National Standards Institute (ANSI). They are also expected to learn how to use hand-drafting tools and computer-aided design (CAD). Furthermore, the course standards require students to master freehand sketching skills, hand-lettering techniques and drawing to scale with proper line types.

All these techniques can be taught by reproducing given examples; but that is boring! On the flip side, these same skills can be taught if students produce the plans for something they designed themselves, which is much more engaging! When you give students a challenge that has a clearly designed problem, parameters that guide them and an opportunity to see their own finished product, they will construct their own learning process!

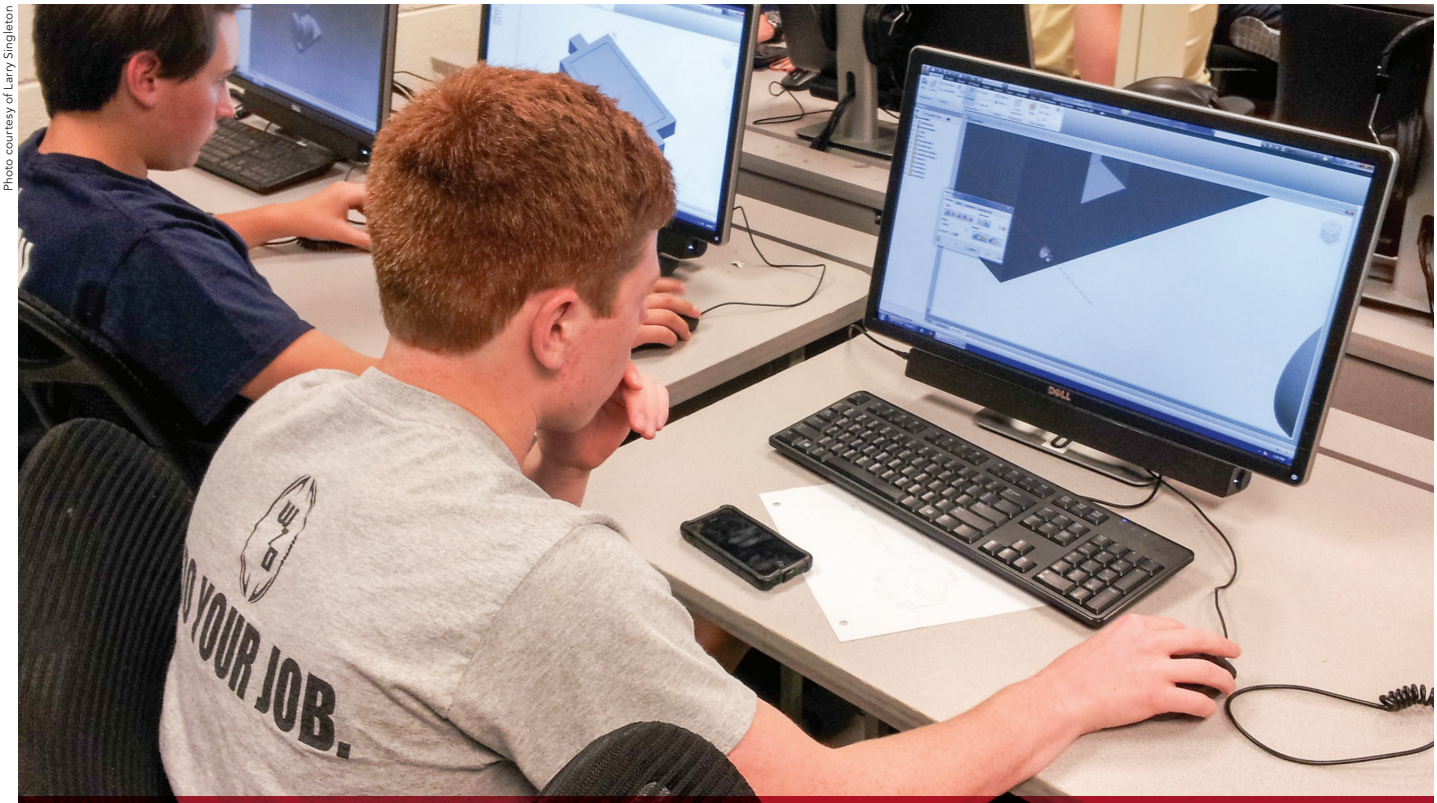
Helping Students Succeed in STEM

According to the research of Sorby and Bartmaans (1996), 3D design activities result in improvement of visual spatial abilities. "Although individuals vary in spatial performance, research has shown that most, if not all, of the component skills can be improved through training and practice" (Sorby, Drummer, Hungwe, & Charlesworth, 2005). When you consider these findings, along with Nora Newcombe's 2010 article in *American Educator* which posits that "scores of high-quality studies conducted over the past 50 years indicate that spatial thinking is central to STEM success" (Newcombe, 2010), the value of this curriculum becomes apparent.

Design With PRIDE

Students begin their projects with a process that I call "Design with PRIDE" (Singleton, 2016), which I will explain in more depth in the following sections. The first step is to identify the problem and/or possibilities. The next step is the research phase; they also receive instruction before they begin developing ideas and iterations. The design and development phase that follows is when students learn and practice the skills needed to produce drawings that meet ANSI standards. Students are highly motivated when they know that their drawings will lead to actual prototypes. The Awesome Toy Trains project outlined here will illustrate the effectiveness of creating a teaching/learning environment that embodies the Maker Movement.

Photo courtesy of Larry Singleton



▲ Students assemble virtual 3D models in Autodesk Inventor® and produce the actual part plans from that software platform.

The Problem, Possibilities and Parameters

Now to the project. With a toy company as the hypothetical client, teams of student design engineers will develop a new line of toy trains. In this first phase of the challenge, students must produce designs of a toy train set made of wood or polystyrene. They are given the parameters that must be followed for the size and scope of their designs, as well as the deadline for the production of prototypes that the hypothetical marketing and production staff will evaluate.

Divided into teams of four or five, each team begins the process by brainstorming ideas for the type of train they want to design and the various cars to be included. Each team member will be responsible for designing and prototyping a unique car, and each train must have one engine/locomotive and a caboose. The opportunity for each student to present his or her own idea for a car is a self-differentiating process; higher-achieving students generally choose to produce more complex designs, and students with less confidence choose to design a simpler car.

Research, Review and Receipt of Instructions

Before students begin working on conceptual designs, they independently research Google images of wooden toy train cars, and they are required to look over the designs on the class website (**https://sites.google.com/site/awesometoytrains**), which showcases the work of classes from previous years. This research equips them with a framework for their ideas. As they formulate ideas, I present detailed parameters to set reasonable limitations on their concepts. I also provide instruction on the tools, materials, fasteners and assembly methods they will be working with, which helps to ensure compatibility between all the train car designs. The limitations of what can and cannot be accomplished in building either wood or polystyrene prototypes sets the stage for finding design solutions.

Additionally, each student must write a description of his or her car design, which is shared and critiqued by his or her teammates. Articulation of these written descriptions and feedback from peers further prepare students to begin designing with realistic goals.

Ideation and Iteration

Now it's time to take their ideas and turn them into sketches. They must create a scaled oblique sketch of their toy train car—a process that is demonstrated via video. They know that these drawings will be assessed with the rubric "Do you have the 'NACC' for drawing?" which helps to ensure their designs are neat, accurate, correct (is it buildable?) and complete.

Teams must collaborate and help each other fix any issues with these sketches that are identified by the assessments. I allow students time to produce additional sketches with iterations and improvements of their initial ideas. This process also highlights the method of differentiation; while some students are working just to meet the minimum standards, others are challenged to go beyond the basics.

All photos courtesy of Larry Singleton

▲ Blade runners are effective tools for safe and easy cut out of individual parts.

▲ All wheels are fabricated with 2.5" hole saws mounted on small drill presses.

▲ Pre-drilled pilot holes make for easy installation of wheels.

▲ Student teams work together to finish assemblies or sweep the shop floors.

Design and Development of Plans

From the sketches they have produced and approved as teams, they must now create their virtual CAD models in Autodesk Inventor®. Individual parts are drawn and then constrained together in the CAD model to reveal a "virtual assembly" of their unique design. Working collaboratively by sharing common part files is expected, and students gain valuable teamwork experience in the process. Any difficulties that some students have with the CAD software are quickly resolved with the help of other team members.

Once the drawings have been created, students print them out in preparation for the build phase of the project. Teams are required to collectively assess their plans and mathematically calculate the material requirements for their cars. They then merge their plans into a complete set for each team's train, and those plans are assessed again using the NACC rubric.

Exemplars and Exhibition

At this point students are "chomping at the bit" to begin building their prototypes. At the beginning of each lab session, I present safety instructions and demonstrate the proper use of tools, and then the work begins. This is an amazing thing to watch; student engagement is all but guaranteed! Students work in teams and together produce the parts necessary to build their trains. I end the lab sessions with a discussion that covers any design problems discovered, changes that need to be made, and a review of safety concerns and experiences.

During the build process, I allow and encourage them to take photos and capture short (5-10 second) video clips of their teammates at work. These photos, along with their sketches and drawings, will be used in required documentation for individual ePortfolios they maintain throughout the curriculum. During this phase of the challenge, they are also required to mark up their plans with any changes made to individual parts. This is a very important part of the design process and an equally important part of the learning process!

Publishing their designs is a unique part of the Design with PRIDE challenge because it leverages 21st-century technol-

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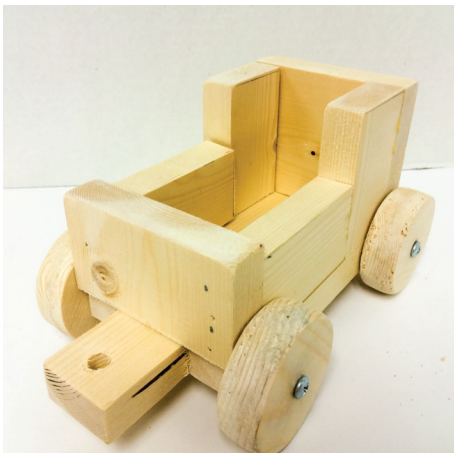

▲ As part of the Design with PRIDE process, students take photographs of their cars and include them in their ePortfolios.

ogy and incorporates it into the teaching. The idea of publishing student work for the whole world to see helps inspire them to engage in the process.

Teams photograph their individual cars and complete trains. Students are required to make changes to their models in CAD before they produce the virtual model images and ANSI drawings that are to be exported for publication. The teams work together to produce Google docs that showcase the images in a specified format.

We follow a similar process for publishing the drawings of the individual cars on the "cloud." All the drawings are put on the Awesome Toy Trains website (Google), linking the images to plans stored in the cloud. This is a pass/fail individual assignment, and students who do not provide correctly revised plans will not have their plans published.

A Google site is not as easy to work with as other platforms, but it can be published with restrictions on who is allowed to view it. The same is true for individual student ePortfolios which are updated and assessed at the conclusion of this project. Students must create new pages on their individual Google ePortfolio sites and post photos, virtual images, video clips, sketches and other artifacts, as well as written descriptions of the project, the process and their products. These are also assessed on the basis of pass/fail because this is not a web or graphic design course. Even without a demanding rubric, it is always amazing how beautiful some of the sites are!

A Valuable and Effective Experience

This project takes approximately 20 hours of class/lab time and covers every standard in the curriculum. Following the Design with PRIDE process ensures a high level of student engagement, and all students experience some measure of success. As their instructor, the job of facilitating learning and guiding/supporting students through the process is a joy! **Tech**

Larry Singleton, Ed.S., began teaching high school after 20 years as a residential designer/builder in the Atlanta, Georgia, area. He received the ACTE eTED Division Outstanding Research Award in 2015. E-mail him at singleton.larry@mail.fcboe.org.

Photo courtesy of Larry Singleton

▲ An example of one design team's unique train with all four cars hitched together and ready to roll. A couple of visitors from a Robot Design Project have hitched a ride!

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