1

Design Squad

Inspiring a New Generation of Engineers

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Figure 1.1 *Design Squad* TV Crew

Image courtesy of WGBH Educational Foundation.

In February 2007, the first kids' TV program dedicated to engineering premiered on PBS. Geared for upper elementary and middle school students, *Design Squad* pits two teams of teenagers against each other in high-energy, high-drama engineering competitions intended to solve real-world problems for real-world clients (see Figure 1.1). As a television series, *Design Squad* aims to inspire its young viewers—to show that engineering is accessible, doable, and most of all, fun. At the same time, *Design Squad* pushes the audience experience beyond passive viewing to include active, hands-on involvement in engineering activities. The television program is integrated into a powerful multiplatform initiative that reaches its young audience through a content-rich, highly interactive website and a wealth of educational materials. These materials are designed to deepen students' understanding of science concepts and the engineering design process, provide opportunities for teamwork and hands-on problem solving, and present engineers as creative problem solvers who design things that matter and improve people's lives.

Of course, to make the greatest impact on kids, we, the producers of *Design Squad*, need you, educators from across the country, to use these materials with your students—to introduce hands-on engineering activities in your classrooms, discuss with your students what engineers do in the real world, and grow your students' conceptions of what engineering is. In turn, we aim to make the process as easy as possible by providing materials that are geared to your needs, based on sound research, compatible with national standards, and easily accessible to teachers in all settings.

Educators know how powerfully hands-on exploration can impact young students' learning. This is why *Design Squad* has created a model for how to use open-ended, kid-driven, hands-on activities as a hook to get kids (and educators!) to engage in engineering (see Figure 1.2). We also know that teachers use resources in a variety of ways, depending on years of experience, teaching style, curriculum needs, time available, and students' learning needs. With this in mind, our goal is always to provide flexibility in our educational materials—offering not only self-contained lessons, but also units and activities that may be used separately or integrated into other lesson plans or curricula.

Negative stereotypes about engineering—that it's nerdy, tough, and for boys only—have discouraged many kids from considering engineering as a field of study or potential career choice. WGBH's research findings have shown that young people often hold such an opinion because they have no or little idea what engineering is or what engineers do. This conclusion is further supported by separate research conducted as part of the National Academy of Engineering's *Changing the Conversation* project. Through this research, we have learned that messages about engineering—which disproportionately emphasize the extraordinary math and science skills needed and the challenges inherent in these jobs—are off-putting to youth. Rather, *Design Squad* aims to emphasize the positive aspects of the field—that it's a collaborative, creative, and socially relevant endeavor.

The Parents and Educators section of *Design Squad*'s Emmy Award-winning website (http://pbskids.org/designsquad/) contains all the resources you need to bring engineering to life in your classroom. These include 8 educator guides, 46 half-hour TV episodes, 24 short career profiles of engineers, 62 animations of STEM concepts, 78 short videos, online training resources, and 63 hands-on activities. And it's all free!

Expanding Your Skills

Are you looking for ways to integrate the design process (also known as practices of engineering) into your lessons? Are you new to leading hands-on activities? Want to get kids excited about engineering? *Design Squad* offers a suite of free, online professional development resources. Check them out by clicking the "Training" link at http://pbskids.org/designsquad/parentseducators.

Leading Hands-On Engineering Activities Online Workshop. Use this free, 75-minute, self-paced tutorial to help you build skills and confidence in leading hands-on, open-ended engineering activities with kids. It will enable you to see what the design process looks like in the classroom, learn a host of implementation strategies, and experience the fun and relevance of engineering.

Training Others. Train volunteers, parents, and mentors how to lead engineering activities with kids. This 1-hour slide show comes with talking points, printable handouts, and preparation tips.

Training Video. Watch how an educator creates a rich, multifaceted learning experience for kids by integrating video resources into a hands-on activity from *Design Squad*'s Mission: Solar System educator's guide.

How-to Sheets. Find helpful how-to sheets in the front section of each guide. Topics covered include Introducing the Design Process, Talking to Kids About Engineering and Invention, Setting up an Engineering/Invention Club, Hosting an Event, and Working With Kids.

Figure 1.2 Engineering Success!

Image courtesy of WGBH Educational Foundation.

Introducing the Design Process

Engineers' initial ideas rarely solve a problem. Instead, they try different ideas, learn from their mistakes, and then try again. The steps engineers use to arrive at a solution are called the design process (see Figure 1.3). The design process is built into each *Design Squad* hands-on activity. As students work through an activity, they'll see that the steps of the design process encourage them to think creatively to solve a problem. The questions that follow will help you tie your students' work to specific steps of the design process.

Figure 1.3 Diagram of the Engineering Design Process

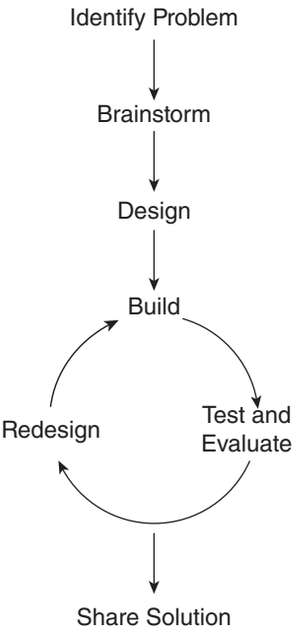

Image courtesy of WGBH Educational Foundation.

Brainstorm

- What are some different ways to tackle today's activity?
- Off-the-wall suggestions often spark *great* ideas. How creative can you be?

Design

- Which brainstormed ideas are really possible, given your time, tools, and materials?
- What are some problems you need to solve as you build your project?
- How can a sketch help clarify your design?

Build

- What materials will you need?
- What can you learn by looking at other students' projects?

Test, Evaluate, and Redesign

- Why is it a good idea to keep testing a design?
- What specific goal are you trying to achieve, and how will you know if you've been successful?
- How does the design meet the criteria for success?

Share Solutions

- What's the best feature of your design? Why?
- What were the different steps you did to get your project to work?
- What was the hardest problem to solve?
- Did you have to do something a few times to get it to work?
- If you had more time, how would you improve your project?

Using Video Clips of the Design Process in Action

A short video clip of each design process step can be found at www.pbslearningmedia.org/search/?q=design+process. By watching the *Design Squad* teams work through each step of the design process, students will learn to think creatively when solving a problem and strengthen their critical-thinking abilities. Also, if your class is struggling with any particular step or with group dynamics, these videos offer a convenient way to talk through an issue.

Identify the Problem (1½ minutes). Understanding the problem paves the way for solving it. This clip lets you emphasize to students the importance of defining the activity clearly before getting started. As a class, discuss how the *Design Squad* teams prepare to design and build furniture out of cardboard.

Brainstorm (1½ minutes). Coming up with many possible solutions is a powerful way to begin a project. This clip shows *Design Squad* teams generating lots of ideas for devices that a dancer can use in an underwater performance. As a class, discuss what made this brainstorm successful.

Design (1 minute). Now it's time to choose the best solution and plan how to build it. In this clip, the *Design Squad* teams squabble about when to stop designing and start building their specialized bikes. As a class, discuss possible solutions for moving a team forward when there is disagreement.

Build, Test, Evaluate, and Redesign (1 minute). Once kids settle on a design, it's time to build, test, and redesign it. This clip shows that things don't always work as planned. As a class, discuss how the *Design Squad* teams learn from their testing results and figure out how to redesign and make improvements.

Share Solutions (2 minutes). Presenting one's work to others is a constructive way to conclude a project. As a class, discuss how the *Design Squad* team's presentation validates the team's work, places it in a broader context, and lets the team members reflect on how effectively they communicated and collaborated.

Employing a Hands-On, Minds-On Approach to Engineering

Design Squad's hands-on activities

- use inexpensive, easy-to-find supplies;
- require minimal preparation time;
- allow for multiple solutions; and
- provide opportunities for adaptation or modification based on your students' interests and needs (see Figure 1.4).

Given the volume of *Design Squad* content available online, we want to ensure that teachers are able to quickly find what they are looking for. Thus, we have arranged all our resources on the website using the following topics: Force/Energy, Green, Health, Simple Machines, Sound/Music, Space and Transportation, Sports/Games, Structures, and Technology/Materials.

In addition, the matrix in Table 1.1, at the end of this chapter, can help you to align *Design Squad*'s hands-on activities to the science topics you are covering in your classroom.

Integrating Standards-Based, Hands-On Activities Into Your Science Curricula

Many of the activities described above are featured in *Design Squad*'s eight educator guides, which can be downloaded from the website. The educator guides contain simple pedagogical background, instructions, checklists, planning strategies, discussion tips, and reproducible handouts in English and Spanish. Through the use of the guides, you will be able to design units that can be integrated into other lesson plans or curricula to help support the Next Generation Science Standards (NGSS Lead States, 2013).

Educator's Guide. The Educator's Guide's 10 hands-on activities emphasize teamwork and creative problem solving. Kids build electronic dance pads, rubber-band cars, wind-powered sculptures, and ball launchers.

Figure 1.4 Hands-On Minds-On Activities

Image courtesy of WGBH Educational Foundation.

Figure 1.5 *Design Squad*'s design projects are very engaging

Image courtesy of WGBH Educational Foundation.

Event Guide. The Event Guide presents five activities especially suitable for use at lively, fun-filled events, such as a family night or science and engineering day. The Event Guide provides facilitators with an event checklist, reproducible activity sheets for five hands-on activities (also available in Spanish), and an evaluation form to help them plan and organize their event from beginning to end.

Activity Guide. The Activity Guide offers five hands-on activities for children ages 9–12 years (see Figure 1.5). In the activities, kids explore buoyancy by designing and building two kinds of boats, potential and kinetic energy by building a zip line and by using a rubber band to power a paddleboat, simple machines by building a mechanical arm, and tension and compression by building a paper table. The hands-on activity sheets are also available in Spanish.

Teacher's Guide. Written especially for middle school teachers of science, technology, engineering, and mathematics (STEM), the Teacher's Guide has 11 activities divided into three units—force, electricity, and sound—topics found in nearly every physical science curriculum.

On the Moon. NASA and *Design Squad* teamed up to produce a guide that offers kids in Grades 3–12 six hands-on activities that bring NASA's moon missions and engineering to life. Kids design and build projects related to living and working on the moon. For example, there are activities based on flying to and landing on the moon. Others focus on living and working on the moon, such as building a solar collector, a rover to traverse the moon's soft surface, and a crane to dig into it.

Mission: Solar System. NASA and *Design Squad* teamed up to provide six space-based hands-on activities for school and after-school programs serving children in Grades 4–8. They are designed to engage kids in engineering and in NASA's exploration of the solar system—and more broadly, to spark kids' interest in engineering and space science careers.

Invent It, Build It. *Design Squad* and Lemelson-MIT InvenTeams teamed up to develop a guide intended to spark the inventive spirit of kids ages 9–12 in school and after-school programs. Its six hands-on activities bring invention to life for kids, get them thinking like

inventors and engineers, and show kids how invention improves people's lives. Kids use their ingenuity to invent solutions to real-world problems. For example, they invent games; green packaging; inexpensive shelters; and convenient, all-purpose carry-alls. The full guide is available in both English and Spanish.

Adaptive Technologies Special Collection. *Design Squad* materials, along with resources from another PBS project called *Medal Quest*, help students explore how science, technology, engineering, and math support athletes with physical disabilities as they compete at elite levels.

Going Beyond the Classroom Through *Design Squad*'s Video Resources

Four types of video resources can be found on the Parents and Educators section of *Design Squad*'s website (http://pbskids.org/designsquad/parentseducators/: TV episodes, animations, video profiles, and demos of activities.

TV Episodes. Televised *Design Squad* episodes feature two teams of kids using their problem-solving skills as they take raw materials and transform them into workable solutions. *Design Squad* cast members use basic technology in a wide range of activities that have a scale and complexity that excite an audience—constructing cardboard furniture for IKEA, building 20-foot bridges, and converting kiddie toys into dragsters are just three examples. Its spin-off series, *Design Squad Nation*, showcases engineer co-hosts Judy and Adam as they travel across the country, working side by side with teens to turn their dreams into reality through engineering. Tackling an array of engineering projects—including a water-saving toilet and a human-powered flying machine—the show aims to get kids thinking about the creativity and fun involved in engineering projects.

Animations. Dynamic animations elucidate science concepts such as "What is sound?" and "How does buoyancy float a boat?"; technology concepts like "How do servos work?" and "What is wireless transmission?"; and engineering concepts like "How do suspension and truss bridges differ?" and "What is a prototype?".

Video Profiles. Through these short videos, viewers meet engaging young engineers who demonstrate that engineering is a rewarding and creative career where you get to work with great people, solve interesting problems, and design things that matter. These segments air at the end of each episode and are available for download on the website. For instance, Debbie Theobald, mother of three, is part of a team developing BEAR, a robot that rescues people from dangerous situations. ("While science and math are very important, there's a lot that goes into it—teamwork, creativity, imagination, being able to see the opportunities from the future.") Another engineer, Evan Thomas, works on water recovery and purification systems for NASA and volunteers for Engineers Without Borders in Rwanda.

Demos of Activities. Many of the hands-on activities are accompanied by videos that demonstrate how to do them. Many teachers find it helpful to watch these videos by themselves to prepare for conducting the activity with their students. Other teachers have told us that they like to show the videos to their students after they have completed the activity so that students can compare their own results.

Sharing and Playing on the *Design Squad* Website

The *Design Squad* website (http://pbskids.org/designsquad) is an online destination for kids, tweens, and teens that promotes the following messages: *You are creative and can solve problems. You can make things that help people. You can dream big. Join* Design Squad *and let's build something together.* On the site, kids can post real-life solutions to real-world problems and respond to challenges by sketching and building their own prototypes. They can also play games that promote the design process and hands-on experiences with science concepts.

Fidgit. With this game, players employ their problem-solving and engineering skills to save small, cute creatures called Fidgits. The aim of the game is for players to use a variety of objects to design rooms through which they can bounce, flip, and roll their Fidgits to safety. Players who want to follow their own path can also build their own custom rooms from scratch. After logging in, they can then save and exchange their rooms with friends who are also playing the game. Fidgit's overarching goal is to help kids strengthen and build their engineering design process skills—observing, brainstorming, designing and building, testing and evaluating, and revising and testing again—while learning along the way that engineers rarely solve a problem on their first try.

Fidgit Factory. Fidgit Factory asks kids to help beloved Fidgit characters get ready for a dance party before the power runs out, while simultaneously giving kids an inside look at how circuits work. Players must first set up their factory by successfully building a circuit that will power its Fidgit-building machines, and then fulfill orders for different types of Fidgits. The game's primary audience is kids between second and fourth grade. It introduces them to fundamental concepts of circuits.

String Thing. String Thing is an interactive game in which students can change a virtual string's tension, length, and gauge to create different musical pitches. It is a great accompaniment to *Design Squad*'s hands-on Build-a-Band activity.

Deepening Your Students' Knowledge of Engineering

Evaluation has shown that *Design Squad* has had a significant positive impact on students' understanding of engineering and attitudes toward engineering.

Knowledge. Students exposed to *Design Squad* learned more about key science constructs (i.e., electrical circuits, sound, Newton's Laws, force, and air pressure) than students who were not exposed to *Design Squad* (Paulsen & Bransfield, 2010).

Design Process Skills. *Design Squad* increases children's design process skills. In a pre- and post-test, kids were asked to think about the steps they would take in designing and building a birdhouse. The number of design process steps that they correctly selected increased significantly from pre to post. Also at pre and post, in order to see if kids included any design process steps in their open-ended response, they were asked to write the best way to go about designing and building something. The number of kids who included *thinking of solutions/brainstorming* and *redesign* also increased significantly. Finally, after watching *Design Squad*, a significantly higher

number of kids mentioned *brainstorming* and *redesign* when discussing how to design and build a paper bridge or a device to launch a ball (Vaughan, Bachrach, Tiedemann, & Goodman, 2008).

Attitudes. *Design Squad* significantly improved students' attitudes toward engineering, changing their stereotypes about engineering—for the better. After watching, middle school students, especially girls and minorities, viewed engineering as creative, rewarding, and socially relevant (see Figure 1.6). They were less likely to believe the stereotype that "engineering is boring" (Paulsen & Bransfield, 2010).

Behaviors. *Design Squad* increased students' interest in engineering programs. After watching *Design Squad*, nearly two-thirds of students were interested in participating in an engineering after-school program, compared to just below one-third prior to viewing (Vaughan et al., 2008).

Figure 1.6 Students engaged in *Design Squad* activities see engineering in a new light

Image courtesy of WGBH Educational Foundation.

Deepening Teachers' Knowledge of Engineering

Design Squad also provides educators with the tools they need to develop their own knowledge and attitudes about engineering.

Knowledge. *Design Squad* helps teachers learn how to use hands-on activities to teach students the design process. Teachers have reported back that the challenges helped them put ideas together, learn for themselves what works and what does not work, and formulate guided questions to help students come to their own understandings (Paulsen & Bransfield, 2010).

Design Process Skills. After using *Design Squad* resources, teachers reported that they better understood the engineering design process and increased their knowledge of engineering careers (Paulsen, Green, & Carroll, 2011).

Attitudes. Evaluation has shown that the *Design Squad Educator's Guide* increased teachers' comfort in talking to their students about engineering and using hands-on engineering activities in their classrooms (Paulsen, 2009; Paulsen & Bransfield, 2010).

Talking to Students About Engineering

Kids are influenced equally by what they see and what they don't see. Technical occupations, such as engineering, are much less obvious to young people than, for example, medicine or teaching. This is especially true for many girls and minorities, who, without role models, have little opportunity to imagine themselves in engineering. In fact, for

those kids who have no contact with engineers, such careers often seem either unattainable or "not for them." According to one study of girls' attitudes toward engineering,

> High school girls believe engineering is for people who love both math and science. They do not have an understanding of what engineering is. They do not show an interest in the field, nor do they think it is "for them" (EWEP, 2005, p. 18)

Similarly, a study of public perception of engineers and engineering found widespread misunderstanding of what engineering is, what engineers do, and what it takes to become an engineer (NAE, 2008).

Design Squad goes a long way to address this issue by presenting viewers with diverse, positive role models who experience engineering as a fun and engaging process. Beyond using the *Design Squad* resources, you can also weave in the following talking points when discussing engineering with your students.

What's an Engineer?

Engineers dream up creative, practical solutions and work with other smart, inspiring people to invent, design, and build things that matter. They are changing the world all the time.

What Do Engineers Do at Work?

- Think creatively: Engineering is an ideal outlet for imagination and creative problem solving—the perfect field for independent thinkers.
- Work with great people: Engineering takes teamwork. As an engineer, you'll be surrounded by smart, creative, inspiring people.
- Solve problems and design things that matter: Engineers improve people's lives by tackling problems, improving current designs, and coming up with solutions no one else has thought of.
- Change the world and make a difference: Among many other pursuits, engineers develop systems that save lives, prevent disease, reduce poverty, and protect our planet.

How Do Engineers Make the World a Better Place?

Here are some things engineers do to help improve people's lives:

- Create a more fuel-efficient car
- Design a lighter bike frame
- Invent a more powerful superglue
- Create a satellite that detects drought around the world
- Develop a state-of-the-art cell phone
- Invent an artificial retina for the blind
- Develop a feather-light laptop
- Design clothing that repels mosquitoes

Hearing From Other Teachers

We're gratified to hear how our teachers have used these resources, and what features they find especially helpful. Here's what some of them have to say:

> "[Teamwork] creates a better learning experience for them and allows them to discuss designs as they work."

"I planned groups so that they could help each other. They also watched other groups. Several told me that they wish all our labs were on engineering design."

"One team was . . . so excited that they had been able to stack five books on top of the [paper] table they built—and they were still going!"

Conclusion

Design Squad does what television does best—it provides powerful images that show young people that engineering is a great way to solve real problems. In doing so, it demystifies engineering and reveals it as something that every kid can do. But that's not the end of the story. *Design Squad* also provides kids with a way to try out what they've seen on television through a robust education initiative that puts hands-on, standards-based activities into classrooms. In all of its endeavors, the project has incorporated messages that change kids' attitudes about engineering, emphasizing the teamwork, social benefits, and creativity of engineering. With your help in the classroom, *Design Squad* will be able to reach its ultimate goal: to smooth the pathway from a student's initial awareness of engineering to his or her career as a professional engineer.

Table 1.1 Topical Strands Through *Design Squad* Activities

Activity	Electricity	Force/Friction	Pot/Kin Energy	Simple Machines	Structures	Buoyancy	Heat	Open-Ended	Culminating
2 Wheel Balloon Car		X	X	X	X				
4 Wheel Balloon Car		X	X	X	X				
Air Cannon		X		X	X				
Balance Magic		X						X	
Balloon Joust		X	X						
Blimp Jet		X				X		X	X
Build a Band		X						X	
Build a Better Lunchbox					X		X	X	
Confetti Launcher		X	X	X	X			X	
Convenient Carrier					X			X	
Customized Car		X		X					X
Dance Off	X								X
Dance Pad Mania	X								

(Continued)

Table 1.1 (Continued)

Activity	Electricity	Force/Friction	Pot/Kin Energy	Simple Machines	Structures	Buoyancy	Heat	Open-Ended	Culminating
Down to the Core		X	X	X				X	
Electric Gamebox	X		X					X	X
Electric Highway	X							X	
Extreme Kicking Machine		X	X	X	X			X	X
Feel the Heat		X					X		
Four Corners				X	X				
Get-Moving Game		X		X	X			X	
Glow Sticks	X								
Harmless Holder					X			X	
Headphone Helper		X						X	X
Heavy Lifting		X		X	X				
Helping Hand		X		X	X				
Hidden Alarm	X								
High Rise		X			X				
Hovercraft		X	X					X	
Indoor Slingshot		X	X		X				
Inspector Detector		X							
Invent Better World								X	X
Invisible Force		X	X						
Kick Stick	X		X					X	
Kicking Machine		X	X	X					
Kinetic Sculpture		X			X				X
Launch It		X	X					X	
Marshmallow Blaster		X							
Motorized Car	X	X		X					
On Target		X	X					X	
Paddle Power			X	X	X	X		X	
Paper Table		X			X			X	
Pop Fly		X		X				X	

Activity	Electricity	Force/Friction	Pot/Kin Energy	Simple Machines	Structures	Buoyancy	Heat	Open-Ended	Culminating
Robo Arm		X		X					
Robo Wheel		X	X	X					
Roving on the Moon		X	X	X	X				
Rubber-Band Car		X	X	X	X				
Sky Floater		X				X		X	
Sky Glider		X				X		X	
Soft Landing		X	X					X	
Speedy Shelter					X			X	
String Puppet		X							
String Thing		X							
Touchdown		X	X		X			X	
Treasure Grab		X		X					
Unpoppable Balloon		X							
Watercraft						X		X	
Zip Line		X			X			X	

References

Extraordinary Women Engineers Project (EWEP). (2005). *Extraordinary women engineers—Final report.* Retrieved from http://www.aacei.org/wpc/library/ExtraordinaryWomen-FinalReport.pdf.

National Academy of Enginering (NAE). (2008). *Changing the conversation: Messages for improving public understanding of engineering.* Retrieved from http://www.nap.edu/catalog/12187.html.

NGSS Lead States. (2013). *Next generation science standards: For states, by states. Volume 1: The standards.* Washington, DC: National Academies Press.

Paulsen, C. (2009). Design Squad Season 2 *final evaluation report.* Concord, MA: Veridian inSight and American Institutes for Research.

Paulsen, C. A., & Bransfield, C. P. (2010). *Evaluation of* Design Squad, Season 3: *Final report.* Concord, MA: Concord Evaluation Group, LLC.

Paulsen, C. A., Green, S., & Carroll, S. (2011). Design Squad Nation: *Evaluation report.* In support of National Science Foundation Grant No. 0917495. Concord, MA: Concord Evaluation Group, LLC.

Vaughan, P., Bachrach, E., Tiedemann, M., & Goodman, I. F. (2008). Design Squad: *Final evaluation report.* Cambridge, MA: Goodman Research Group.