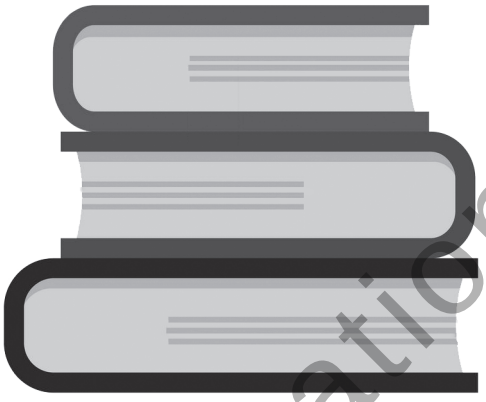
Novel Engineering, K–8

An Integrated Approach to Engineering and Literacy

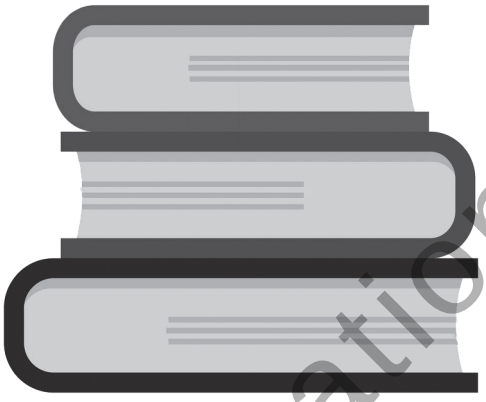
Elissa Milto, Merredith Portsmore, Jessica Watkins,
Mary McCormick, and Morgan Hynes

Hawker Brownlow Education a Solution Tree company



Contents

Contents



Preface

Novel Engineering is an innovative approach to including engineering in K–8 classrooms. As we've worked on Novel Engineering, we have been encouraged by the excitement that students and teachers have shown for their work during Novel Engineering units. One of the things we are excited about is that students have taken ownership of their learning and are able to navigate the steps of an engineering design process (EDP)—creating functional solutions to problems they have identified in texts. Of course, students would not be able to do this without the support and freedom given to them by their teachers. Many of the teachers with whom we've spoken have reflected that their own teaching has changed because they're better able to recognize what their students are thinking and understand their work.

In the United States, K–12 engineering education has gone from relative obscurity 20 years ago to part of the national science standards today. As it has evolved, we have seen that there are different ways of incorporating engineering into classrooms. Often, K–12 engineering activities are used as a vehicle to motivate or deliver science and math content, or they are stand-alone experiences for students to learn engineering with limited connections to science and math. In addition, they often do not emulate the experiences of real-world engineering.

Professional engineers have rich contexts in which they design. They have multiple stakeholders with different needs they must translate into design requirements; they have constraints on materials, time, or solution types they need to account for and balance; and they must address regulations and ethical issues. Professional engineers in these contexts are skilled at finding problems, identifying requirements, and balancing trade-offs. Often, when we transpose engineering into K–12 settings, some of the richness and wonderful messiness of real-world engineering is lost in activities that specify the problem and all the requirements for students. Engineering curricula for K–8 students are often

constrained both in problem definition and in material and solution diversity. These activities are great ways for students to engage in elements of engineering design and are often necessary with the realities of school, but they don't allow students to participate in the full design process.

Novel Engineering represents a significant shift in thinking about how engineering knowledge can codevelop with other disciplines, usually literacy but frequently social studies or another core subject. Novel Engineering works to replace real-world clients and contexts with those from literary texts to offer students opportunities to enter into engineering design practices that are messy, ill-defined, and without predetermined "correct" answers or paths through the EDP. Novel Engineering has shown a new model for engineering integration in which two disciplines are truly dependent on each other—and an approach where students are able to navigate the two successfully.

This book aims to support educators as they do Novel Engineering in their own classrooms and teacher educators as they work with preservice teachers. There are many teachers who have done Novel Engineering or have attended in-person professional development workshops, but the number of interested teachers and the range of locations make it impossible to meet with all teachers who would like to implement Novel Engineering with their students. It is our hope that through this book, we will be able to share Novel Engineering with a greater number of teachers.

This book will not only describe the Novel Engineering approach but also present case studies that allow readers to practice noticing student thinking and begin anticipating what students may do and say. In addition, this book will walk readers through the planning of a Novel Engineering unit so they can use the books they already include in their curriculum as part of a unit. By including Novel Engineering in the classroom, teachers give students the chance to engage in all steps of an EDP in a way that is personally meaningful.

Novel Engineering began in 2010 as a research project supported by the National Science Foundation. The first phase of the project was to understand what engineering looks like at the elementary school level. We examined what the engineering students were doing and what that looked like within an integrated context. As the research progressed, we also looked at Novel Engineering in middle schools and with students with language-based learning disabilities. Throughout the project, we collaborated with teachers to help us understand a teacher's point of view.

The Novel Engineering team had a broad understanding of the interaction among engineering and education research, educational tool development, and classroom implementation. The research team included individuals with back-

grounds in engineering, engineering education, psychology, literacy, science, education, and special education. Teachers participating in the research portion of the project functioned as partners, offering unique insights into the team's research and implementation. This diverse team allowed us to understand what was happening with students from a multitude of perspectives.

In addition to this background experience, the team worked directly with students while they were engineering. This allowed us to see what worked and what did not work and to better understand what students were capable of doing. This understanding of classroom dynamics and our partnerships with classroom teachers helped us develop not only the Novel Engineering approach but also the professional development experience.

Overview

Novel Engineering is an integrated approach to teaching engineering and literacy in elementary and middle school classrooms. Through this approach, students use literature as the basis for engineering design challenges, drawing information from the text to identify engineering problems, considering characters as clients, and using details from the story to impose constraints as they build functional solutions to the characters' problems.

For example, students who read the book *Danny the Champion of the World* by Roald Dahl identified Danny's father falling into a pit and getting stuck as a problem and then built and tested functional models to solve that problem (i.e., to get his father out of the pit) in a way that used resources appropriate to the story's setting. As students work on the text-based engineering projects, they also engage in productive and self-directed literacy practices. Novel Engineering tasks are truly interdisciplinary efforts in which students engage in both engineering and literacy activity. One teacher said, "That kids are using problem-solving skills based on basic engineering strategies, and it's an interdisciplinary unit combining science, math, and English language arts. … I think it's great—[it] gets kids to think in a different way." Since Novel Engineering began, we've been consistently excited by the work students have done and where our partnerships with teachers have led the project.

Novel Engineering continues to advance how students interpret classroom activities and how that interpretation influences the abilities and practices students leverage for learning. In Novel Engineering, we see students navigate classroom constraints, constraints presented by the text, and constraints of the real world. Engineering education literature often talks about students' limitations or inabilities. Novel Engineering's research findings add to the conversation about young students' sophisticated abilities and knowledge, and they push for more

work on unpacking the significance of context for students (Watkins, Spencer, and Hammer 2014).

Through our research, we've found that Novel Engineering benefits students in multiple ways. It provides a context for students to more deeply engage with assigned reading texts, whether they be in English language arts or history. The text serves as the basis for discourse, argumentation, and the sharing of ideas and thinking. In order to design for characters/clients, students need to make inferences and predictions based on what they've read that will influence their designs. There are many opportunities during a Novel Engineering unit for students to write, discuss what they have read, and argue for their point of view using evidence from the text.

In addition, the research conducted during the project has helped advance conceptions of what students are capable of with respect to engineering and how their capabilities are recognized in the classroom. Finally, Novel Engineering research has also advanced models and resources for preparing teachers to teach engineering, such as using videos of students engaged in engineering to develop teachers' abilities to notice when their students are showing emergent engineering skills.

Teachers have pointed out that Novel Engineering can reach students with different learning profiles—not just the "A students" who typically do well. For example, we've seen students with special needs excel at Novel Engineering; we've seen several instances of students with reading disabilities easily access a text supporting evidence for their design ideas. We've also seen students with significant organizational deficits manage the complex process of planning and realizing their ideas, which is often difficult to do when balancing multiple constraints and steps.

Wrap-Up

We know that readers will come to this book with a variety of backgrounds and experiences. It is for this reason that we imagine not everyone will read the book cover to cover and that readers may move between the chapters they feel best complement their experience levels with engineering and/or literacy. This book is broken into three sections: an overview of Novel Engineering's links to engineering and literacy, case studies, and logistical information for implementation.

We hope you enjoy reading this book and doing Novel Engineering with your students. We are continuously surprised by the amazing things we've seen students engineer and the discussions they've had about the books they read. We are sure you will be amazed by your students, as well.

Safety Considerations

Student safety is a primary consideration in all subjects, but it is an area of particular concern in science/engineering since students interact with tools and materials with which they are unfamiliar, posing additional safety risks. Teachers need to be sure that their rooms and other spaces are appropriate for the activities being conducted. That means that engineering controls such as proper ventilation, fire extinguishers, and eye wash stations are available and utilized properly. In addition, students should use sanitized indirectly vented chemical-splash goggles, safety glasses with side shields, nonlatex aprons, and vinyl gloves during all components of an investigation (i.e., setup, hands-on investigation, clean-up) in which they handle potentially harmful supplies, equipment, or chemicals. At a minimum, the eye protection provided to students must meet the ANSI/ISEA Z87.1 D3 standard.

Remember also to review and comply with all safety policies and procedures that have been established by your place of employment. Teachers must practice proper disposal of materials and proper maintenance of all equipment. The National Science Teaching Association (NSTA) maintains an excellent website (*www.nsta.org/safety*) that provides guidance for teachers at all levels. The site also has safety acknowledgment forms for each grade level. These forms are for students to review with their teachers and must be signed by parents/guardians.

Safety Notes are included in certain chapters to highlight specific safety concerns that might be associated with particular lessons. The safety precautions associated with each investigation are based in part on the use of the recommended materials and instructions, legal safety standards, and better professional safety practices. Selection of alternative materials or procedures for these investigations may jeopardize the level of safety and is therefore at the user's own risk.

Reference

Watkins, J., K. Spencer, and D. Hammer. 2014. Examining young students' problem scoping in engineering design. *Journal of Precollege Engineering Education Research* 4 (1): 43–53.

An Overview of Novel Engineering in the Classroom

The best way to begin this book is to sketch out what Novel Engineering can look like in a classroom. We've seen the book *Wonder* by R. J. Palacio used in several fifth-grade classrooms and are going to present a composite of these classrooms. Although there is variety among the classrooms and students, there are many similarities. *Wonder* is the story of Auggie, a fifth-grade boy who was born with a severe facial difference and is entering school for the first time. The book begins from his perspective and then switches to include the perspectives of the other characters. The teachers have several learning goals for students that include having students think intensely about the characters and the overarching themes of acceptance and friendship. This requires students to think about multiple characters' perspectives and make inferences about their thoughts and feelings. As the teachers read the book, they pause to give students time to discuss the problems that arose and to discuss, as engineers, how they might solve those problems.

As groups are engaged in discussion, the teacher walks around the room and listens to the discussions. One group wants to address the discomfort that the main character, Auggie, feels while eating in the school cafeteria. Due to his facial structure, Auggie is very messy when he eats and feels embarrassed. As two students, Samuel and Mateo, begin to consider solutions to this problem, it becomes evident that they are drawing on details of the story and making spontaneous inferences, all in service of understanding the design context. For example, they describe how they think Auggie feels, cite specific passages in the text, and infer the reason for those feelings—all of which help them empathize with Auggie about how it might feel to be bullied. They also generate a map of the cafeteria based on setting descriptions, consider the social landscape of an elementary school, and come up with a list of foods that may be easier for him to eat in public.

The following is an excerpt of a conversation between the two students. The conversations throughout this book are numbered so that if teachers are discussing them in groups, they can use the numbers to refer to students' statements.

1. **Samuel:** He doesn't like to eat with everyone.
2. **Mateo:** He could just not eat in the cafeteria, maybe in a classroom with a teacher?
3. **Samuel:** No, he is in school to be with the other kids. We need to make something so he can eat in the cafeteria. What can we ...
4. **Mateo:** He'll be afraid people will look at him.

5. **Samuel:** We can make something that will let him eat and make it less messy.
6. **Mateo:** Okay. How can it be less messy so the food doesn't fall out? Maybe something that catches food but blocks his mouth?
7. **Samuel:** It can be like a fork but hides his mouth.

The following day, the group begins building a device that will help Auggie eat with less mess. As in most Novel Engineering classrooms, the students are provided with a list of available teacher-supplied materials when they begin to plan, which typically include a variety of cheap and recyclable materials such as tape, paper clips, cardboard, string, and cloth. A suggested list of materials is included in Appendix A (p. 223).

Samuel and Mateo propose to test their device using a range of foods, such as a yogurt, apples, and cheese. As they test their device, they are reminded by the teacher to record their findings in an engineering journal so they can share findings with the class and make changes, if needed, the following day. While sharing their findings with their classmates, the students describe their design choices and rationale, the way they tested their design, and how they intend to improve it. Samuel and Mateo want it to look as much like a traditional fork as possible so Auggie will not feel self-conscious. With that in mind, they include a small guard that helps keep food in his mouth.

In many Novel Engineering units, a writing assignment is included as part of a final culminating activity. In Samuel and Mateo's class, students have been instructed to write a journal entry as Auggie, describing how the engineering solution helped him overcome the problem. The pair of boys write about how Auggie felt less fear during lunchtime and is now able to talk to a friend at the lunch table. The students make projections about how their device would help Auggie gain confidence, which in turn would affect his life. In this example, Samuel and Mateo organically worked through an engineering design process (EDP) without being required to follow the process as a checklist; rather, they were allowed to move naturally through the steps. We will discuss the EDP used in Novel Engineering in the next two chapters.

After their first Novel Engineering experience, teachers often say that their students exceeded their expectations. In the previous example, Samuel and Mateo thought deeply about how Auggie might feel in different situations, such as eating in a school cafeteria or meeting new people. They also made inferences from the text and used their knowledge of the characters to project how different scenarios might play out. The teacher spoke with students as they worked, which