

Doing Good Science

in Middle School

A Practical STEM Guide

Including 10 New & Updated Activities

Expanded  *Edition*

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Preface

A middle school science classroom was once described to us as “a nuclear reaction about to happen, on an hourly basis.” At the time, that description was meant to illustrate the unstable, unpredictable, and at times irrational behavior of a group of middle schoolers. Years later, we know that the behavior in question is pretty typical, but it can be significantly more challenging to deal with when middle-grade students are confined to neat rows of desks and numbed by textbooks, teacher-centered instruction, and lack of meaningful interaction with peers or their teachers.

In this book, we propose opportunities for learning and teaching amidst the sound and fury of a different sort of explosive (but productive) middle school science classroom. In our experience, good science—by which we mean activity-based STEM instruction—promotes the unexpected and delightful development of adolescent middle school students.

For us, good science constitutes a shift away from the textbook-centered direct instruction that emphasizes discrete factual knowledge claims and passive observation of science phenomena toward active, learner-centered, hands-on and minds-on investigations conducted to some degree by students themselves. Good science and middle school learners are very compatible, as we’ll explain in Chapter 1.

Who are we? We are four educators who worked together in Mesa, Arizona, in a school district that has embraced good science instruction since 1974. We are among those who have come to enjoy the blossoming intellects, often comical behaviors, and insatiable curiosity of middle schoolers and who *choose* to work with them! With more than 130 years’ combined experience in the profession, we’ve gathered a lot of ideas to share. We know from our interactions with educators around the country that relatively few quality resources exist to assist science teachers “in the middle,” and this was a central impetus for writing and then updating *Doing Good Science in Middle School*.

Our book is aligned with *A Framework for K–12 Science Education* (2012) and the *Next Generation Science Standards* (2013), which set forth eight practices that are fundamental to understanding the nature of science:

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations

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- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

We've used the *Framework* (2012), *NGSS* (2013), and the *Common Core State Standards* (2010) as the basis for recommendations to assist middle-grade science teachers, while unpacking the *NGSS* to make them more easily accessible. Throughout the book, we kept in mind teachers who work in self-contained team formats as well as departmentalized middle school configurations.

Our work here is meant to meet other important objectives but above all, we intend it to be teacher-friendly. We wrote *Doing Good Science* as practitioners, for practitioners. In this book, you will find

- a comprehensive overview of science and engineering practices, STEM, and inquiry-based middle school science instruction, aligned with the *Framework* and the *NGSS*;
- a conscious connection to the *Common Core* literacy and math skills embedded in the *NGSS* that help determine—and are fostered by—student success in good science instruction;
- 10 teacher-tested activities that integrate STEM with literacy skill-building (with emphasis on safety in the science classroom);
- information on best instructional practices including argumentation and formative assessment, along with useful print and Web-based resources, science associations, workshops, and vendors;
- a solid foothold for new teachers to help them teach science and engineering practices while better understanding their often enigmatic middle-grade students; and
- an opportunity for veteran teachers to reaffirm that what they do is “good science.”

We hope readers will find this book easy to use. It can be read in its entirety or perused section by section as a reference for lesson and unit planning and as a basis for evaluating and modifying existing lessons. It will help teachers explain to their principals why their classes at times need to be noisy, bustling, and “social” to be effective.

We also hope this book is for some readers a point of departure from relying solely on teacher-centered methods with passive text- and worksheet-dependent curricula and in favor of the active learning potential and rich teaching opportunities that good science makes possible in the middle grades.

Let the journey begin!

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CHAPTER 1

Good Science and the Middle School Learner

Socialization, Autonomy, and Structure

Whether you are a veteran of the middle-level classroom or a relative newcomer, your success with students in these grades will depend on your ability to adjust instruction to the cognitive, emotional, developmental, social, and psychological demands of the middle school learner.

Even though their immersion in a digital world has further clipped their already scant attention spans, middle schoolers remain wired for the more active approach provided by good science instruction. As we stated in the preface, by *good science* we mean a shift from doing textbook- and teacher-centered instruction to conducting learner-centered investigations, framing and solving problems, engaging in field studies, developing and refining solutions for engineering problems, and performing experiments in which the teacher becomes a guide and resource rather than a director and source.

Science and Engineering Practices, as the *NGSS* term them, are the skills students need to develop to be able to “do” science and engineering. The practices are the mechanisms for varying degrees of student-directed discovery, autonomy, and heightened engagement in science and engineering activities. Using these skills, students acquire discrete content (called Disciplinary Core Ideas in the *NGSS*) and make connections across science disciplines via the Crosscutting Concepts.

Good science involves activity, choice, and independence. It also requires careful planning and structure that middle schoolers need and which allows them to thrive; we introduce these three main elements of the *NGSS* here because they need to be part of all that we do when planning good science lessons.

The Match Between Middle Schoolers and Good Science

Good science is highly compatible with the fundamental needs of adolescent learners, especially when their teachers understand the profound developmental changes with which these youngsters contend.

Conversely, traditional teaching methods that rely on textbooks, direct instruction, seatwork, PowerPoint slides, and lecture are successful depending on students’ abilities to endure extended periods of concentration, inactivity, and careful note taking—none of which is a particular strength of most 10- to 14-year-olds we’ve known. However, such teacher- and text-centered instructional strategies prevail in the vast majority of hundreds of science classrooms we’ve observed.

Consider Table 1.1, which illustrates the compatibility we’ve seen between the developmental traits of adolescents and the characteristics of good science as we define it.

Active teaching methods are compatible with the way middle-level students naturally learn, and support their intrinsic tendencies in developmentally appropriate ways. Middle school youngsters are not well-served by a curriculum founded on passive lecture and worksheets. Awareness of the developmental levels and cognitive parameters of 10- to 14-year-olds is paramount to effective middle school teaching in any subject.

Table 1.1. Compatibility Between Middle Schoolers and Good Science

Adolescent Traits	Good Science Characteristics
Curiosity and interest in learning	Develops questioning skills; emphasis on “doing” science
Varying cognitive levels (shift from concrete to abstract reasoning)	Uses multiple scientific practices, cultivates different learning styles
Need for relevance, to connect learning to prior knowledge	Emphasizes experiment, experience, problem-based learning
Increased sense of independence	Emphasizes discovery learning
Need for social interdependence	Emphasizes collaboration and cooperative, project-based learning
Relatively short attention spans; easily bored, easily distracted	Uses activity-based instructional design; rote learning de-emphasized
Need for validation; insecurity, fear of failure; developing self-concept	Provides opportunities for noncompetitive authentic assessments; fosters environment supportive of risk-taking
Simultaneous need for autonomy and structure	Offers degrees of teacher influence/guidance and differentiation
Need to be acknowledged as an “adult”	Learner-centered, rather than teacher-centered

Typically Atypical

Until the mid- to late-1990s, relatively little research focused on middle-level learners compared with studies of older and younger children. Indeed, there is such a range of maturity and development in middle school students that it is difficult to find agreement about what these young people should even be called: Adolescents? Emerging adolescents? “Tweens”?

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Good Science and the Middle School Learner

Whatever we call them, middle school students are not children, and they are not adults; yet, they can display the delightful and aggravating characteristics of both groups, and in dizzying succession, with little or no way to predict which will happen next. One day they want recess, and the next they want to drive your car. Needless to say, while abundant research in developmental psychology happily explains their behavior profile, middle schoolers make life interesting for their teachers.

In his now-classic guide to happy coexistence with middle schoolers, Rick Wormeli observes that “young adolescents are moving through one of the most dynamic stages of development in their lives. As teachers, we might have to bushwhack through the hormonal tendrils on a daily basis, but it’s worth the effort to find the gold inside each child” (2001, p. 7).

Adolescents are coming to terms with rapidly increasing knowledge of themselves, their world, and their place in it; in any group of tweens, maturity levels swing dramatically between individuals. Some are already launching into puberty and toward sexual maturity and may find it difficult to relate with their peers who still enjoy playing with dolls and Legos. Tweens are excited and excitable, though their engagement plummets toward the tail end of their short attention spans. Mood swings are dramatic and common; most middle schoolers are developing a more complex sense of humor; reactions are typically extreme and often accompanied by telltale teen eye-rolling, exasperated sigh-grunts, and the classic added syllable, “-uh”—as in, “NO-uh,” “beCAUSE-uh,” and more.

All of this is exacerbated by the impact of the digital media competing for their attention, interest, and hours that we’d like them to be sleeping.

For some youngsters, the middle school years are exciting and affirming, and for others, awkward and unsettling. Teachers at this level need to be especially sensitive and vigilant toward their students who manifest symptoms of depression or worse.

In any case, this sweeping range of social, physical, emotional, and intellectual maturation makes it difficult to generalize about “what works” in teaching middle school students, beyond the need to diagnose and monitor developmental progress throughout the school year. “Getting young adolescents to pay attention and learn is 80% of our battle in middle schools. The rest is pedagogy” (Wormeli 2001, p. 7). On a very basic level, teachers of middle schoolers should have a tolerance for ambiguity and a fundamental willingness to be flexible. (They also need, and middle schoolers really appreciate, a sense of humor.) To some extent, we believe teachers can learn to be spontaneous—to find comedy in inopportune displays of bodily functions, to lose precious class time to an evasive cockroach on the ceiling—but if a prospective middle grades teacher finds that her need to finish a

chapter or get through a lesson overrides her willingness to tolerate the odd “accidental” belch or to spend a few minutes calmly swatting an overhead roach amidst much fanfare, she might not be cut out to work with this breed of student. Effective middle school teachers enjoy interacting with students at this age.

If flexibility and spontaneity are assets in a middle school teaching assignment, it is equally important for us to turn our attention to the adolescent need for structure.

Need for Structure

Given the profound, rapid, and sometimes confusing array of changes middle schoolers experience between grades 5 and 8, it is not surprising that they seek stability to varying extents and in different ways. Above all, middle-level students need the structure provided by classroom procedures because it makes school a safe, protected, predictable environment in a surrounding world that for many of them is as unstable and unpredictable as their own mood swings. Their newfound freedom is alternately thrilling and frightening, and their limited experience with autonomy leaves most adolescents in need of some degree of order and security. It is common for adolescents to fluctuate between demanding independence and welcoming direction from adults who they know care about them as individuals.

A substantial amount of our foundational moral development takes place during these years, when young people begin to associate actions with consequences and the broader ethical structures that support moral judgments. What is right, what is wrong, and why? How far is too far, and why? Thus, middle grades students depend on and will necessarily test the structure provided by classroom expectations and rules. If a middle grades educator successfully teaches procedures, students adopt the routines as their own so that structure (and rules) becomes a source of comfort rather than confrontation.

If, on the other hand, the teacher posts the rules without taking time to teach them, points to them when a student gets out of hand, and demands explanations for “misbehavior,” there’s bound to be continued testing and experimenting from the students (“accidental” belches and tipped chairs are favorites, for example). Middle schoolers understand the difference between control and support, manipulation and respect; they resent being treated like children, even when they behave childishly. Mutual respect is part of their worldview—and nothing cultivates respect more successfully than teachers who frame their expectations and procedures in terms perceived by middle schoolers as “adult to adult.” In our experience, respect is most likely to be enjoyed by teachers who understand and set their expectations with attention to the fears, insecurities, goals, demands, and motivations of middle grades youngsters. (See more on classroom management in Chapter 5.)