

# LEARN BETTER BY DOING



The final report of an  
ITEEA/FTEE Research Project



# WELCOME TO ITEEA'S INTERACTIVE LEARN BETTER BY DOING GUIDE

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## DOING: A NATIONAL EDUCATION IMPERATIVE

Americans feel that taking technology and engineering classes and developing interpersonal skills are the two most important aspects of school quality. (PDK, 2017).

Parents want their children to do well in school. But, what does it mean to do well? For more than 150 years, student academic success has been measured by standardized tests (NEA, n.d.). Whereas standardized testing is a means by which students are measured, it should not be the only measure used to determine their success. Assessing students' cognitive ability is only part of the equation. In today's fast-paced technological society, **Americans feel that "testing doesn't measure up" (PDK, 2015, p.K3)** and that, in U.S. schools, **"academic achievement isn't the only mission" (PDK, 2017, p.K3). Americans feel that schools should prepare students to succeed in life (PDK, 2017).** Preparing students for life will require them to do more than just remember information long enough to pass a test. Successful citizens will have to draw upon information to solve real-world problems throughout their lives.

**The financial cost of an education in the United States is among the highest in the world (NCES, 2017). However, student achievement, compared to other industrialized nations, is not commensurate with that cost (PRC, 2017).** Could it be that students are learning primarily through cognitive means and not learning by doing enough standards-based hands-on activities in their classrooms?

National-level assessments designed to determine what students know are very common, but assessing what students can do is almost nonexistent. In order to measure what students can do, schools must measure their critical-thinking and problem-solving skills. Valid assessments can only occur if students are afforded the opportunity to do hands-on activities based on real-world scenarios. To date, only once, through the work of the National Assessment Governing Board, **has our nation measured students' "ability to 'do' engineering or produce technology...to gauge how well students can apply their understanding of technology principles to real-life situations" (NAGB, 2013, p.2).**

Doing activities provide people with feelings such as gratification, a sense of accomplishment, and a measure of what one knows and is able to do. Most importantly, doing is a major process for learning and gaining knowledge. The Learn Better by Doing Study focused on doing that applies to STEM education. Doing is defined as: "a tactile/hands-on process of technological problem solving starting with human needs and wants that leads to the principles of innovation such as designing, making/building, producing, and evaluating" (Moye, Dugger, and Starkweather, 2014, p.24)





Students doing hands-on activities in U.S. public schools may not be as common as it once was. The U.S. was once a leader in education: a nation of doers and innovators. Schools produced students who kept the country's economy strong and secure. The U.S. no longer produces the same number of innovative citizens it once did. **The concern is, what changes must occur to reverse this negative trend (CTEq, 2016)?**

Where does doing occur in U.S. public schools? What kind of standards-based, hands-on activities are K-12 STEM students doing in their classrooms? The Learn Better by Doing Study sheds light on those questions.

Three study instruments asked elementary, middle, and high school STEM teachers to respond "Yes" or "No" to thirteen statements (Moye, Dugger, and Starkweather, 2014). Two general statements were asked of all teachers. The remaining statements were based on ***Standards for Technological Literacy (STL) (ITEA/ITEEA, 2000/2002/2007)***, ***Next Generation Science Standards (NGSS) (Achieve Inc., 2013)***, and ***Common Core State Standards for Mathematics (CCSSfM) (CCSSO, 2010)***. Those statements asked teachers if their students performed specific standards-based, hands-on activities. This four-year study received responses from 5,910 teachers (1,285 elementary; 1,437 secondary science; 2,083 secondary technology and engineering; and 1,105 secondary mathematics).

This report provides findings from the Learn Better by Doing Study, illustrating how students doing activities in the classroom supports their success in school as well as in life. The following section provides a sampling of those findings.

#### Learn Better by Doing Study

The purpose of this study was to determine the extent to which U.S. public school elementary and secondary education science, technology, engineering, and mathematics (STEM) students were doing activities in their classrooms. From 2014 through 2017, more than 5,900 K-12 teachers participated, identifying where students were doing standards-based, real-world, hands-on activities in schools. The study was funded by the International Technology and Engineering Educators Association and the Foundation for Technology and Engineering Education through a Dugger-Gerrish Endowment. For complete study information, see [https://www.iteea.org/Activities/2142/Learning\\_Better\\_by\\_Doing\\_Project/50026.aspx#tabs](https://www.iteea.org/Activities/2142/Learning_Better_by_Doing_Project/50026.aspx#tabs)

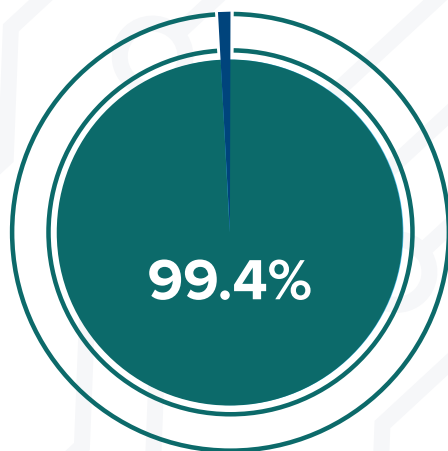
## Students Learn Better by Doing

Students learn better through doing; that is what K-12 science, technology, engineering, and mathematics (STEM) teachers tell us. Over 99% (5,877 of 5,910) of surveyed elementary and secondary STEM teachers feel that their students benefit by doing activities in their classrooms and 5,572 of 5,898 (94.5%) would have their students do more activities in class if they had the time and resources (see Figure 1).

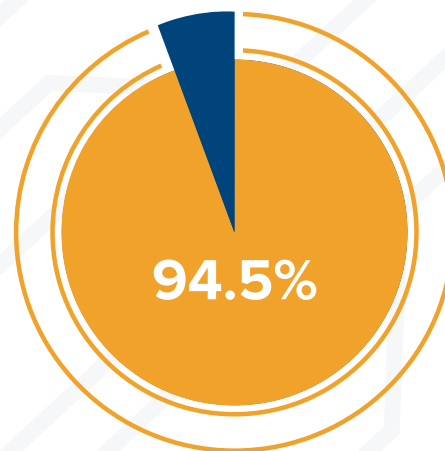
Who are better judges than teachers to determine how students learn? Teachers feel students learn by doing activities, but do not have the time and/or resources to assign more doing experiences. With this point in mind, it seems appropriate that students should be doing more standards-based, hands-on, activities in their classrooms.

### STEM teachers' feelings toward doing activities in their classrooms

Figure 1



STEM Teachers feel students benefit by doing activities in the classroom.



STEM Teachers would have their students do more if time and resources permitted.

## Technology and Engineering Students are Engaged in More Hands-on Activities

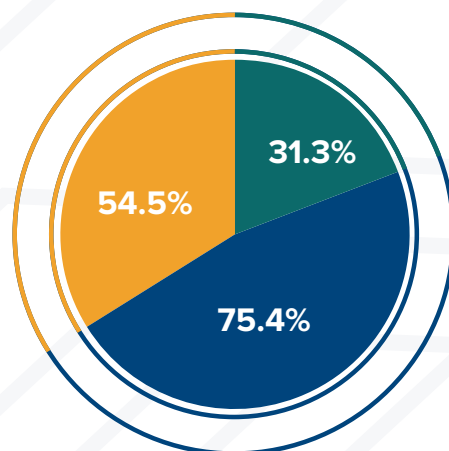
Students do activities that address the same national standards (STL, NGSS, and CCSSfM) in their STEM courses. But, technology and engineering students are completing most of these activities more frequently. Secondary technology and engineering teachers indicated that their students performed 75.4% (15,602 of 20,691) of the given activities. Science students did 54.5% (7,620 of 13,992) and mathematics students, 31.3%

(3,326, of 10,639) (see Figure 2). The data show that technology and engineering students are doing 20.9% more standards-based, hands-on activities than science, and 44.1% more than mathematics students.

Teachers feel students learn better by doing, and doing STEM occurs more frequently in technology and engineering classrooms. Students not enrolled in technology and engineering courses are missing opportunities to use hands-on activities that bring STEM to life.

### Percentage of doing in secondary education

Figure 2



Secondary percentage of doing

*\*Note: The sum of percentages not 100%*

■ Technology and Engineering      ■ Science      ■ Mathematics

### Elementary Students Learn Engineering Design by Planning and Using Tools to Manipulate Materials

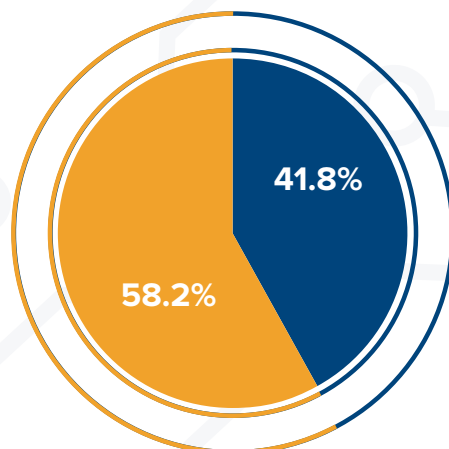
When asked if students used hands-on activities to apply constraints, such as time and cost, to develop an object, tool, process or system, 599 of the responding 1,030 (58.2%) elementary teachers said “Yes” (see Figure 3).

Scientists, technologists, engineers, and mathematicians use some form of engineering design process to solve problems (Katehi, Pearson, and Feder, 2009). The engineering design process involves determining and solving problems, many times by designing and making prototypes or models. Elementary students who learn and use an engineering design process will be able to use this method of doing to guide them in their future school and life experiences.



## Engineering design process in elementary education

Figure 3



Percentage of elementary school students who have or have not used a design process in class

■ Have used design process
 ■ Have not used design process

## Secondary Technology and Engineering Students Design and Model in Their Classrooms

Teachers were asked to respond “Yes” or “No” to six different activities involving design that their students could have completed in class. Three of these activities were at the middle school level and three at the high school level. Technology and engineering teachers responded that their students did activities involving design in 1,395 of 1,743 (80%) possible incidences. Science students did design activities in 800 of 1,413 (56.6%) possible incidences, and mathematics 339 of 945 (35.9%) possible incidences (see Figure 4). The data show that technology and engineering students were designing 23.4% more frequently than science students and 44.1% more than mathematics students.

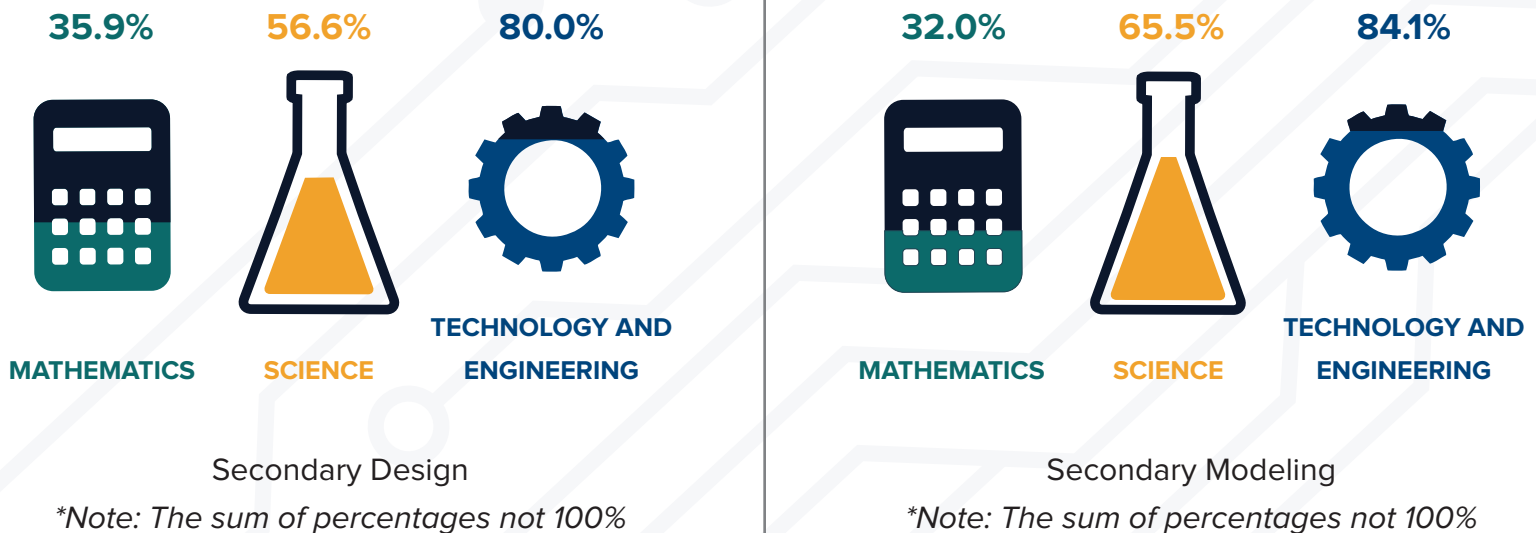
Teachers were also asked to respond “Yes” or “No” to six statements (three middle and three high school) involving modeling. Technology and engineering teachers responded “Yes” to 1,465 of 1,743 (84.1%) possible incidences. Science teachers indicated “Yes” in 925 of 1,413 (65.5%) possible incidences and mathematics in 302 of 945 (32%) possible incidences (see Figure 4). The data show that secondary technology and engineering students perform modeling 18.6% more frequently than science students and 52.1% more frequently than mathematics students.

Designing and modeling are key components in an engineering design process. By using a design process, students “can integrate various skills and types of thinking—analytical and synthetic” (Katehi, Pearson, and Feder, 2009, p.37). Also, “learning to design, students will master a set of abilities that will serve them well throughout their lives” (ITEA/ITEEA, 2000/2002/2007, p.5).

Students enrolled in technology and engineering courses have more exposure to engineering design processes and more opportunities to learn by using them. This exposure provides students with opportunities to develop and practice this valuable problem-solving tool.

### Percentage of students designing and modeling in secondary education

Figure 4



### Technology and Engineering Activities Promote Female Interest and Participation in STEM Education and Occupations

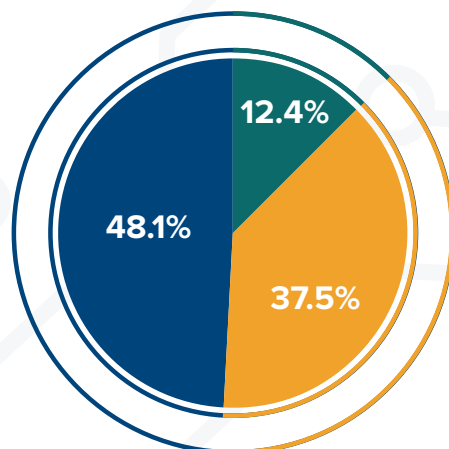
Teachers were asked to respond “Yes” or “No” to three different activities (two middle and one high school level) involving social and/or individual needs and wants that their students could have completed. Technology and engineering teachers responded “Yes” in 1,268 of the 2,634 (48.1%) possible incidences. Science teachers stated “Yes” in 663 of 1,770 (37.5%), and mathematics teachers, 163, of 1,312 (12.4%) possible incidences (see Figure 5). Secondary school technology and engineering students were assigned activities pertaining to social and/or individual needs and wants 10.6% more frequently than science students and 35.7% more than mathematics students.

Presenting exciting and relevant activities is important to maintain students’ interest and participation in school. Education leaders are interested in increasing students’ participation in STEM-related activities, continued education, and professions. Research shows that female students enjoy studies and occupations that directly benefit society and/or individual needs and wants (CTEq, 2016).

Technology and engineering courses present students (male and female) with more interesting and challenging real-world scenarios involving societal and/or individual needs and wants.

## Secondary percentages of societal/individual needs or wants activities, by content area

Figure 5



Percentage of Secondary STEM Students assigned societal/individual needs or wants activities

*\*Note: The sum of percentages not 100%*

■ Technology and Engineering
 ■ Science
 ■ Mathematics

### Doing Activities in Classrooms Decreases From Middle to High School in Each STEM Content Area—But to a Lesser Degree in Technology and Engineering Courses

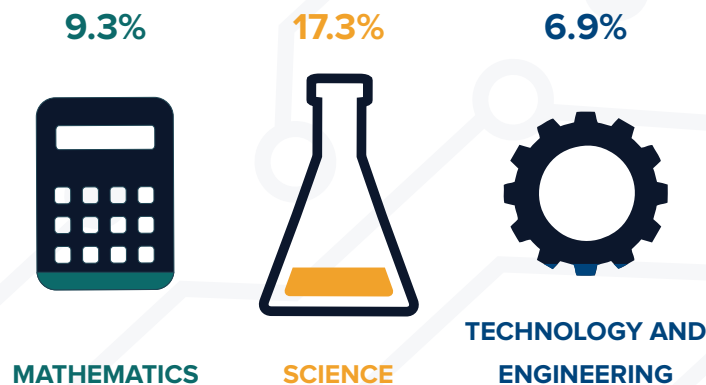
The percentage of doing decreased from middle to high school in each content area each year of this study. However, the percentage of doing decreased less in technology and engineering classrooms than it did in science and mathematics classrooms. Students doing activities in middle school technology and engineering classes was at 79.5%, and high school 72.6%, a decrease of 6.9%. Students doing activities in middle school science classrooms was at 65%, and 47.7% in high school, a decrease of 17.3%. In the middle school mathematics classrooms, the percentage of doing activities was at 37.6%, while at the high school level it was 28.3%, a decrease of 9.3% (see Figure 6).

When comparing the data, activities in science classrooms decreased 10.4% more than technology and engineering. The decrease in mathematics was 2.4% greater.

Many students become less interested in their studies while in high school (NRC, 2004). Could there be a correlation between the decrease of doing hands-on activities and students' losing interest in school? If so, technology and engineering courses could help promote secondary education students' interest and academic success.

## Percentages of doing decrease from middle to high school

Figure 6



Percentage decrease of doing from middle to high school

*\*Note: The sum of percentages not 100%*

## Education Leaders Can Also Learn by Doing

The Learn Better by Doing Study produced substantial information. The data reveal that K-12 teachers of science, technology, engineering, and mathematics feel that students learn better by doing and that their students should be doing more. The study also reveals the types of standards-based, hands-on activities students perform in their K-12 STEM classrooms.

Students will only benefit if we take advantage of what research data tells us. (CTEq, 2016).

Leaders are encouraged to take necessary actions to improve students' academic literacy and problem-solving skills. While there may be other areas in which improvements could be made, the following are recommendations encouraging action.

**“Statistically, my students score higher on assessments after they have completed a project that supports their learning.” - Middle School Mathematics Teacher**

## RECOMMENDATIONS:

### **State agencies and universities should conduct research to determine the effects of doing in K-12 STEM subjects.**

The Learn Better by Doing Study focused on the percentage of students doing hands-on activities in K-12 science, technology, engineering, and mathematics classrooms. It is presumed that hands-on classroom activities improve student achievement. However, research should be conducted to determine to what extent doing in the classroom improves student knowledge and application of that knowledge.

### **Research agencies such as the National Science Foundation, human development organizations, or the National Center for Educational Statistics should promote research to determine if doing is an incentive to learning.**

Presenting students with hands-on activities maintains their interest. Researchers should study the extent to which doing affects student achievement in school and life.

### **STEM researchers should conduct research to determine the advantages of doing from infancy (i.e., playing, manipulating, discovering, building, creating, etc.) through adulthood.**

Children learn by doing. Doing includes playing that continues into adulthood. But to what extent does this “play” improve young people’s understanding of and ability to function in their culture and environment? This “play” could lay the foundation for how students will learn throughout their lives.

### **The International Technology and Engineering Educators Association should develop a taxonomy of doing.**

A taxonomy of doing would help content assessment developers and leaders to ensure that correct curriculum content and activities are properly utilized as students progress through school, work, and life. A taxonomy may currently exist for curricula, but there is no taxonomy of doing describing the appropriate level of activity for students at specific grade, and/or ability levels.

### **State educational leadership should develop quality teaching practices that effectively implement doing activities in all subject areas.**

It is necessary for teachers of all content areas to know and understand the substance of what they teach. It is important for students to understand how doing real-world activities will help them apply what it is that they are expected to learn. In other words, supply students with an appropriate answer to the question, “Why do I need to know this?” The level, quality, and benefit of all activities should be based on national content standards.

### **State educational leadership should develop standardized doing assessments.**

State leaders should develop standardized assessments that focus on student ability to recall and apply knowledge. Examples of such assessments are found in the National Assessment of Educational Progress – Technology and Engineering Literacy (NAEP-TEL) Assessment Framework (NAGB, 2013).



**The National Center for Educational Statistics and state statistical centers should study the correlation between the level of doing standards-based, hands-on, real-life classroom and laboratory activities and achievement levels in standardized STEM assessments.**

There are few studies focusing on the amount of doing in classrooms and laboratories and how it affects student standardized test success. Researchers could determine if students' STEM knowledge improves by doing valid classroom activities. This improvement could potentially enhance content areas outside of STEM courses.

**Content standards developers should create teacher in-service professional development pertaining to the implementation of doing in classrooms and laboratories.**

Teachers are the driving force in the classroom. All teachers have instructional abilities but migrate to what they feel comfortable teaching and how they teach it. Additionally, in recent years, instructional focus has been to prepare students to perform well on standardized tests. If the focus is to change, to encourage students to learn by doing, teachers must learn what information is to be taught and how to challenge students to apply that content with hands-on activities.

**Teachers and educational researchers should study the effects of learning by doing using new technologies such as artificial intelligence, simulation, computerization, etc.**

Teaching tools and methods continue to change and will potentially be much different as we progress further into the 21st Century. Leaders must

understand and contemplate changes to instruction and activities encouraging student learning. These changes need to be organized and formed into teacher professional development experiences.

**STEM educators should promote the importance of doing as a fundamental characteristic of learning.**

Researchers must determine what changes should be made to encourage more doing in classrooms. Once determined, educational leaders should deliver to K-12 classrooms the changes needed to improve and increase learning by doing.

**National education and alternative school leaders should promote doing outside the public school environment.**

Learning beyond the school building is common in the internet age. Educational leaders should determine extracurricular/cocurricular learning possibilities and promote those opportunities to students. Opportunities, such as student organizations (e.g., Technology Student Association (TSA), SkillsUSA, Science Clubs, etc.), require students to use skills needed to properly function as 21st Century citizens.

**The International Technology and Engineering Educators Association should replicate the Learn Better by Doing Study to identify and compare trends.**

The Learn Better by Doing Study reveals where doing occurs in U.S. public schools and how frequently students do hands-on activities in STEM classrooms. This study should be replicated annually to determine the longitudinal frequency

of doing in U.S. public schools. Continuing to determine the extent to which doing is utilized in the science, technology, engineering, and mathematics classrooms is important.

## ENGINEERING THE WAY FORWARD

This study began from a concern that students doing activities in schools might be on the decline. Throughout the history of education, tinkering, manipulative activities, and hands-on experiences have played an important role in learning (CTEq, 2016). However, due to an emphasis on high-stakes standardized testing, learning by doing experiences do not occur in science and mathematics courses as frequently as teachers would like. Technology and engineering students still experience learning by doing in their classrooms. This fact provides opportunities. But, we can only take advantage of these opportunities if we recognize them, change opinions about old stereotypes, and break down boundaries.

Historically, science and mathematics have been more valued than technology and engineering. Certainly, students must learn science and mathematical laws and principles, but STEM education is incomplete without technology and engineering. STEM requires students to practice (do something with) the laws and principles that they learn. The Learn Better by Doing Study was constructed using national science, technology and engineering, and mathematics standards. Study data show that technology and engineering students practice learning by doing more frequently than do science and mathematics students.

The United States has not exhausted, nor does it fully utilize, all of its resources in efforts to improve students' STEM literacy. The facts are that U.S. students do not perform well on standardized tests, nor do they perform as desired on technology and engineering literacy assessments (CTEq, 2016). The report on the condition of STEM learning in the U.S. goes as far as to warn education leaders, "Without intentional strategies to expose many more young people to technology and engineering, we are leaving a critical aspect of students' education to chance" (CTEq, 2016, p.1).

The necessary actions are evident as found in the Phi Delta Kappa 49th Poll of Public's Attitude Towards the Public Schools. Students need to take more technology and engineering courses to prepare them for life (PDK, 2017).

Dr. John Dewey, a champion of doing in education noted, "If we teach today's students as we taught yesterday's, we rob them of tomorrow" (Goodreads, n.d., para. 11). If the United States were to follow Dr. Dewey's recommendation, our students would be doing and learning more in K-12 education. The simple fact is—Students Learn Better by Doing.

## REFERENCES

- Achieve, Inc. (2013). Next generation science standards (NGSS): For states by states. Washington, DC. The National Academies Press.
- Change the Equation (CTEq). (2016). Vital signs: Reports on the condition of STEM learning in the U.S. Retrieved from <http://changetheequation.org/left-to-chance>
- Council of State School Officers (CCSSO) and National Governor's Association Center for Best Practices (NGA Center). (2010). Common core state standards initiative: Standards for mathematical practice. Retrieved from <http://www.corestandards.org/Math/>
- Goodreads. (n.d.). John Dewey quotes. Retrieved from [https://www.goodreads.com/author/quotes/42738.John\\_Dewey](https://www.goodreads.com/author/quotes/42738.John_Dewey)
- International Technology Education Association (ITEA/ITEEA). (2000/2002/2007). Standards for technological literacy: Content for the study of technology. Reston, VA: Author.
- Katehi, L., Pearson, G., Feder, M. (Eds.). (2009). Engineering in K-12 education: Understanding the status and improving the prospects. Washington, DC: National Academies Press.
- Moye, J. J, Dugger, W. E., Jr., Starkweather, K. N. (2014). Learning by doing research introduction. *Technology and Engineering Teacher*, 74(1), 24-27.
- National Assessment Governing Board (NAGB). (2013). Technology and engineering literacy framework for the 2014 national assessment of educational progress. Washington, DC: NAGB.
- National Center for Educational Statistics (NCES). (2017). Education expenditures by country. Retrieved from [https://nces.ed.gov/programs/coe/indicator\\_cmd.asp](https://nces.ed.gov/programs/coe/indicator_cmd.asp)
- National Education Association (NEA). (n.d.). History of Standardized Testing in the United States. Retrieved from <http://www.nea.org/home/66139.htm>
- National Research Council and the Institute of Medicine (NRC). (2004). Engaging Schools: Fostering High School Students' Motivation to Learn. Committee on Increasing High School Students' Engagement to Learn. Board on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- Pew Research Center (PRC). (2017). U.S. students' academic achievement still lags that of their peers in many other countries. Retrieved from <http://www.pewresearch.org/fact-tank/2017/02/15/u-s-students-internationally-math-science/>

PDK International (PDK). (2015, September). Testing doesn't measure up for Americans. 47th annual PDK/Gallup poll of the public's attitudes about the public schools. Phi Delta Kappan, 97 (1), K1-K32. Arlington, VA: Author.

PDK International (PDK). (2017). Academic achievement isn't the only mission. Americans overwhelmingly support investments in career preparation, personal skills. 49th PDK/Gallup Poll of Public's Attitudes Toward the Public Schools. Retrieved from: <http://pdkpoll.org/results>

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Finally, appreciation is given to fellow professionals who so kindly shared their opinions and comments that helped create the direction and report for this study.

**"I attribute most of my students' success with algebraic concepts to the kinesthetic learning processes we used." - Middle School Mathematics Teacher**

**Students, just like most adults, learn better by doing." - Elementary Teacher**



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