is "learning by doing" important?

A STUDY OF DOING-BASED LEARNING*

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This is the second in a series of articles discussing the Doing-Based Learning study.

Knowing something and knowing how to do something are very different things. In past years the world has recognized the U.S. as a leader in education and a nation of doers and innovators. U.S. schools produced these innovators who kept our economy strong and our country secure. However, the ability of U.S. schools to produce citizens with those abilities seems to have ebbed, and our innovative prominence has eroded.

It appears that over the past several decades the approach to education has been to prepare students for standardized (high-stakes) tests versus teaching them how to apply knowledge (Archbald & Newmann, 1988; Martinez & Stager, 2013). Possessing knowledge is very important. However, being able to draw upon and apply that knowledge is necessary to adequately function in life and the reason why learning is so important. In a study identifying a means to improve students' statistical thinking, Sedlmeier (2000) found that, "learning by doing has a large and lasting effect on how well people can solve conjunctive probability tasks" (p. 227). In support of the Activity Based Learning approach, in 2011 Robert Yager (Professor of Science, University of Iowa) posed the question: "Why is there not more attention to all students (and teachers) actually "doing" science in every K-16 science classroom"? (p. 62).

"*This report identifies the methods used, results, and recommendations to improve student STEM education success.*"

The purpose of this study is to determine the extent to which U.S. public school elementary and secondary education science, technology, engineering, and mathematics (STEM) students are doing activities in their classrooms. This is the second in a series of articles discussing the "Doing-Based Learning" study. The first article (Moye, Dugger, Starkweather, 2014) identified the study and selected findings from the first round of this four-year study. This report identifies the methods used, results, and recommendations to improve student STEM education success.

Ongoing international studies and other standardized measures have provided performance data on the quality of education for students in participating countries. These studies include data collection on cognitive knowledge but do not have a strong emphasis on measures related to doing. Measuring cognitive knowledge and not the ability to apply that knowledge comes with controversy. To a great extent, the emphasis is on high-stakes standardized testing, while there is very little focus on measuring the ability for students to use that knowledge.

During the time that the U.S. has increased focus on standardized testing, "there has been a marked increase in the share of jobs that require creative problem-solving skills." (PISA, n.d. para. 1). Dis-

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cussing their performance on the 2012 Programme for International Student Assessment (PISA) Problem Solving Assessment, the "students in the United States perform slightly above the average (500 points) of the 28 OECD countries that took part in the assessment." (PISA, n.d. para. 2). Further, the PISA report identified that only 18.2% of U.S. students reached "the baseline level of proficiency in problem solving—meaning that, at best, they are only able to solve very simple problems that do not require thinking ahead" (PISA, n.d., para. 5).

Trends in International Mathematics and Science Study (TIMSS) reveals similar results. In 2011: "At Grade 4, the United States was among the top 15 education systems in mathematics" (NCES, n.d.a., para. 3) and "at Grade 8, the United States was among the top 24 education systems in mathematics" (NCES, n.d.a., para. 9). In fourth grade, the United States was "among the top 10 education systems in science" (NCES, n.d.b., para. 3) and "at Grade 8, the United States was among the top 23 education systems in science" (NCES, n.d.b., para. 9).

Education leaders should ask: Are we satisfied that U.S. students are deemed average? Are we using all available resources to improve U.S. students' STEM and problem-solving skills? Martinez and Stager submit that,

> The past few decades have been a dark time in many schools. Emphasis on high-stakes standardized testing, teaching to the test, de-professionalizing teachers, and depending on data rather than teacher expertise has created classrooms that are increasingly devoid of play, rich materials, and the time to do projects. (2013, p. 1).

To what extent U.S. students are learning by doing is another question education leaders could ask. The purpose of this study is to answer that question. The researchers developed three instruments, one each for the elementary, middle, and high school levels. The three instruments used asked teachers to respond "Yes" or "No" to 13 statements. The same first two statements were presented in all three instruments. The 11 subsequent statements were specific to each grade level (Grades 3-5, 6-8, and 9-12) and were based on *Next Generation Science Standards* (*NGSS*, 2013a), *Standards for Technological Literacy* (*STL*) (ITEA/ITEEA, 2000/2002/2007), and *Common Core State Standards for Mathematics* (*CCSS*, 2010). Grades K-2 were not included in this study because *NGSS* standards specific to Engineering Design begin at the third grade level. The *NGSS* authors state, "With increased maturity students in third through fifth grade are able to engage in engineering" (*NGSS*, 2013b, p. 52).

Often when items such as curricula are designated "standards-based," they may in fact only allude to those standards. The statements designed for this study were gleaned directly from *NGSS* and *STL*. The *Common Core State Standards for Mathematics* used were the "Standards for Mathematical Practice" (*NGSS*, 2013b. p. 138). For example, one of this study's middle school statements was "My students have analyzed and interpreted data to determine similarities and differences in findings." The statement was based on *NGSS* Middle School Engineering Design standard MS-ETS1-3, "Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success" (*NGSS*, 2013a, p. 86). The reader will find that the statement also reflects *Standards for Technological Literacy* Standard 13, Grade 6-8 benchmark, "Interpret and evaluate accuracy of information" (ITEA/ITEEA, 2000/2002/2007, p. 213). The researchers also provided a list of definitions to clarify the meaning of words and terms used in this study.

The instruments were validated by elementary, middle, and high school STEM teachers. The validating teachers were asked to "Agree" or "Disagree" that the statements reflected something that a teacher at their grade levels could expect their students to do in their courses. They were also given an opportunity to include any comments that they felt should be included in the study. The feedback was sufficient to consider the instruments valid.

The researchers prepared a cover letter introducing the study and asked for teacher participation. The cover letter explained the purpose of the study and explained how to use the links to access the list of definitions and survey instruments using SurveyMonkey. The researchers emailed the cover letters to each state science, technology, engineering, and mathematics specialist as well as the board of directors of state associations. The researchers also used the *U.S. News* Education List of Best High Schools website (*U.S. News*, n.d.) to identify email addresses of teachers in those schools. The *U.S. News* website also led to many school districts' elementary and middle school websites. The researchers ultimately sent emails to approximately 5,000 elementary, middle, and high school science, technology and engineering, and mathematics teachers, state supervisors, and association affiliate representatives.

This survey was open from March 1, 2014 until April 15, 2014. Although not all teachers responded to each statement, there was a total of 1,670 responding teachers. A total of 437 elementary, 404 middle and high school science, 544 middle and high

Table 1. Results of the Two General Statements

Statement	Elementary Yes	MS & HS Science Yes	MS & HS Technology & English Yes	MS & HS Math Yes
1. I believe that students benefit from doing activities to support learning.	433 of 437 99.1%	399 of 404 98.8%	540 of 544 99.3%	282 of 285 98.9%
2. Given the time and resources, I would assign my students more projects to do in class.	422 of 437 96.6%	382 of 404 94.6%	515 of 544 94.7%	272 of 284 95.8%

school technology and engineering, and 285 middle and high school mathematics teachers responded to the first statement. As for the second statement, the number of responses was the same, with the exception of one less middle and high school mathematics teacher (284 versus 285). For statements three through thirteen, 365 elementary teachers responded. At the middle and high school levels, there were 133 middle and 220 high school (total 353) science, 194 middle and 308 high school (total 502) technology and engineering, and 104 middle and 151 high school (total 255) mathematics teachers who responded.

The reader will see that there was a significant drop from the number of teachers who responded to Statements 1 and 2, and those who continued to respond to Statements 3 through 13.

The first two statements were designed to find teachers' opinions concerning students doing projects in their classrooms. Table 1 identifies the two general statements asked at both elementary and secondary levels, the total number of responses, the number and percentage of elementary, and the combined number of middle school and high school teachers in each

Table 2. Elementary School Statements, Total Responses, Total/Percentage "Yes"

Statement	Total Elementary Response	Total Elementary "Yes"
3. My students have developed an object, tool, process, or system that included several criteria for success and constraints on materials, time, or cost.	365	198 (54.2%)
4. My students have constructed an object using the design process.	365	196 (53.8%)
5. My students have designed and built a product or system.	365	174 (47.7%)
6. My students have controlled variables to conduct an investigation that produced data serving as evidence.	365	222 (60.8%)
7. My students have performed an activity to solve a design problem.	365	198 (54.2%)
8. My students have generated and compared multiple solutions to a design problem based on the criteria and constraints of that problem.	365	153 (41.9%)
9. My students have built a model and then improved the design to better meet requirements.	365	170 (46.6%)
10. My students have tested and evaluated solutions for a design problem.	365	157 (43%)
11. My students have built and used a model to communicate their solutions to a problem.	365	162 (44.4%)
12. My students have built something designed to meet specific criteria and constraints.	365	217 (59.5%)
13. My students have used a computer program to model and simulate a solution to a problem.	365	80 (21.9%)
Total Responses/Percentage of Doing in Courses	4015	1927 (48%)

subject area who indicated “Yes” to each statement. Technology and engineering teachers were grouped together because of the impossibility of distinguishing between the two types of teachers that use similar content.

Of the 437 elementary teachers who responded to Statements 1 and 2, 365 responded to the remainder of the statements (3-13). Table 2 identifies the statements and total number and percentage of elementary teachers responding “Yes” to each statement. The last row of the table contains the total responses/percentage of doing in courses. The researchers derived this data by adding the number of responses in the Total Elem. Resp. column and dividing that number by the total number of “Yes” responses.

Four hundred and thirty-one middle school teachers responded. Of those, 133 were science, 194 were technology and engineering, and 104 were mathematics teachers. Table 3 identifies the statements as well as the number and percentage of the teachers responding “Yes” to each statement. The last row of the table contains the total responses/percentage of doing in courses. The researchers derived this data by adding the number of responses in each column and dividing that number by the total number of “Yes” responses.

Six hundred seventy-nine high school teachers responded. Of those, 220 were science, 308 technology and engineering, and 151 were mathematics. Table 4 identifies the statements as well as the number and percentage of the teachers responding “Yes” to each statement. The last row of the table contains the total responses/percentage of doing in courses. The researchers derived this data by adding the number of responses in each column and dividing that number by the total number of “Yes” responses.

Table 3. Middle School Statements, Total Responses, Total/Percentage “Yes”

Statement	MS Science	MS Technology & Engineering	MS Math
3. My students have developed a solution to be tested and then modified it on the basis of the test results.	133 94/70.7%	194 173/89.2%	104 49/47.1%
4. My students have created a tool or model to address an individual or societal need or want.	133 51/38.3%	194 139/71.6%	104 18/17.3%
5. My students have tested and evaluated a design in relation to preestablished requirements.	133 92/69.2%	194 177/91.2%	104 34/37.7%
6. My students have made a model to test for solutions to a problem.	133 85/63.9%	194 169/87.1%	104 52/50%
7. My students have completed an activity that demonstrated how humans use natural resources that have positive and negative, short- and long-term consequences.	133 71/53.4%	194 100/51.5%	104 18/17.3%
8. My students have created a model by applying criteria and constraints.	133 90/67.7%	194 178/91.8%	104 46/44.2%
9. My students have designed and used instruments to gather data.	133 92/69.2%	194 129/66.5%	104 47/45.2%
10. My students have analyzed and interpreted data to determine similarities and differences in findings.	133 120/90.2%	194 146/75.3%	104 84/80.8%
11. My students have solved a design problem by developing an object, tool, process, or system.	133 69/51.9%	194 165/85.1%	104 26/25%
12. My students have performed an experiment to solve a design problem.	133 88/66.2%	194 137/70.6%	104 21/20.2%
13. My students have identified the characteristics of a design that performed the best during a test process.	133 79/59.4%	194 158/81.4%	104 18/17.3%
Total Responses/Percentage of Doing in Courses	1463 931/63.6%	2134 1671/78.3%	1144 413/36.1%

Table 4. High School Statements, Total Responses, Total/Percentage "Yes"

Statement	HS Science	HS Technology & Engineering	HS Math
3. My students have developed a solution to a complex real-world problem, based on scientific knowledge and student-generated sources of evidence.	220 111/50.5%	308 245/79.5%	151 68/45%
4. My students have built a model of something to simulate the interactions between systems such as energy, matter, or information flow.	220 124/56.4%	308 217/70.5%	151 34/22.5%
5. My students have created a presentation communicating the specifications and results of a design process used to meet a need.	220 90/40.9%	308 242/78.6%	151 52/34.4%
6. My students have built a model using specified criteria and constraints.	220 154/70%	308 285/92.5%	151 70/46.4%
7. My students have identified and applied criteria and constraints to develop a system or product.	220 94/42.7%	308 275/89.3%	151 54/35.8%
8. My students have performed research to determine criteria and constraints driven by a societal problem.	220 96/43.6%	308 184/59.7%	151 40/26.5%
9. My students have developed a solution to a major global challenge such as the need for improved health or supplies of clean water and food.	220 39/17.7%	308 80/26%	151 13/8.6%
10. My students have applied the design process to evaluate an existing design or to collect data.	220 105/47.7%	308 239/77.6%	151 50/33.1%
11. My students have built a prototype and checked it for quality and efficiency.	220 53/24.1%	308 247/80.2%	151 21/13.9%
12. My students have used computer simulations to predict the effects of a design solution.	220 54/24.5%	308 168/54.5%	151 35/23.2%
13. My students have evaluated a design solution by using conceptual, physical, or mathematical models to check for proper design.	220 44/20%	308 216/70.1%	151 42/27.8%
Total Responses/Percentage of Doing in Courses	2420 964/39.8%	3388 2398/70.8%	1661 479/28.8%

FINDINGS, DISCUSSION, AND RECOMMENDATIONS

This is the second report of the findings of the study of Doing-Based Learning. The first report, published in the September 2014 issue of *Technology and Engineering Teacher* (Moye, Dugger, & Starkweather, 2014), described the purpose of the study and identified some of the key points found in the first round of surveys. This report provides the methods used to develop and administer the study as well as the specific results found in the first round.

The purpose of this ongoing study is to determine to what extent students are learning by doing in U.S. public schools. The first two statements teachers were asked to answer were designed to determine if teachers felt that students benefit from doing activities to support learning. Overwhelmingly, 99% of the responding teachers felt that students benefit from doing activities. A total of 95% of the teachers stated that they would assign their students more projects to do in class if they had the time and resources. The responses to these two statements identify that teachers feel that learning by doing is a very valuable tool and should be used.

The researchers used *Next Generation Science Standards*, *Standards for Technological Literacy*, and *Common Core State Standards for Mathematics* to develop statements that are common across the science, technology, engineering, and mathematics (STEM) content areas. Based on the first round of surveys, when asked to respond either “Yes” or “No” to 11 different standards-based statements, the data reveal that middle and high school technology and engineering students are learning by doing more (74.6%) than are elementary (48%), middle and high school science (51.7%), and middle and high school mathematics (32.5%) students. Overall, elementary students learn by doing more (48%) than high school (46.5%) but less than middle school (59.3%) STEM students.

Three hundred sixty-five elementary teachers responded to survey Statements 3-13. With the exception of the statement concerning students using a computer program to model and simulate a solution to a problem (21.9% said “Yes”), elementary teachers indicated that at least 41.9% of the time their students performed all the activities in their classes. In 5 of the 11 statements, 53.8% or more of the teachers identified that their students did those activities in class.

Teachers in each of the STEM content areas provided many written comments. Due to the space limitation of this article, not all of the comments can be identified and discussed. One high school science teacher stated, “would LOVE to do more projects! This is where [students] retain the most information.” A high school technology and engineering teacher included a recommendation that the authors echo, “Sadly we still focus on the TEST—our focus should be on HOW the student can use what we’re teaching, and in order to do that we MUST do more.” These are only two of the many comments in which STEM teachers state that they support the "learning by doing" approach. In Statements 3 through 13, middle and high school teachers indicated (26 responses) that they plan to have their students do the stated activities some time in the future. Not having enough planning and class time (22 responses) to do the activities are indicators that teachers would like to have their students doing more in class.

Also in responses to Statements 3 through 13, high school science teachers (6 responses) commented that “extra curricular” and “homework” contributes to the lack of time to do additional projects. One high school mathematics teacher said, “I struggle with how much homework and activities the students are already dealing with and assigning what I know would be an amazing assignment. An amazing assignment is no longer good when it causes more sleep deprivation.” In an already tight class schedule, assigning students extracurricular and homework activities creates an extra burden on students and teachers. What science and mathematics teachers may consider extracurricular could possibly be an activity technology and engineering teachers presently assign students in their courses. For example, the high school results reveal that 43.6% of the science teachers, 26.5% of mathematics, and 59.7% of technology and engineering teachers said “Yes” to Statement 8 (My students have performed research to determine criteria and constraints driven by a societal problem). These findings indicate that science and technology and engineering teachers have their students perform activities that require research using criteria and constraints driven by a societal problem more frequently than do mathematics teachers.

There were only three occurrences where middle school science teachers indicated a higher “Yes” response on the 11 doing statements than technology and engineering teachers. Mathematics teachers had no higher percentage of “Yes” responses than science and only one higher than technology and engineering teachers.

At the high school level there were no instances when science or mathematics teachers had a higher “Yes” response then technology and engineering on the 11 doing statements. Mathematics teachers responded “Yes” more than science in only one occurrence. Technology and engineering had a significantly higher number of “Yes” responses (11 of 11) than both science and mathematics.

This report identifies both a problem as well as a solution to that problem. The problem is that U.S. students are not performing well on high-stakes standardized tests and leave secondary schools without being able to do something with the knowledge they learn in school. This study reveals that teachers feel that students benefit from doing activities to support learning and if they were given the time and resources, those teachers would assign their students more projects to do in class. Of course, time and resources are very limited. One high school mathematics teacher stated, “Finding time with Common Core is becoming a bit of a problem.” Another high school mathematics teacher’s comment suggested a resolution when he or she stated, “I would love to speak to a science teacher who has done this and apply it to the mathematics classroom.” Another example of the solution was identified when a middle school technology and engineering education teacher stated, “It would be nice to join with Math and Science in our building to do different projects.”

State and local departments of education should review their science and mathematics programs to determine the extent to which their teachers are having students do projects or activities in their classrooms. Then, they should evaluate their technology and engineering programs to determine if those programs are being fully utilized in support of science and mathematics programs. This utilization would require STEM teachers to collaborate with each other to integrate lectures, activities, and assessments needed to encourage student success.

This study provides educational leaders with the data needed to produce data-driven, logical decisions. Technology and engineering programs are resources that are already established in most middle and high schools across the nation. The question is, are those programs being fully utilized? This article identifies the results of round one of four rounds of the Doing-Based Learning study. The researchers are currently conducting round two of this study until April 15, 2015. Using the same survey instruments and methods, the researchers will solicit input from as many STEM teachers as possible. The results of the second through fourth rounds of this study will also be published in this journal. If you would like to participate in the next round of this study, you may access the instruments by following this link: www.iteea.org/DoingProject.pdf.

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