learning by doing study:

ANALYSIS OF SECOND-YEAR RESULTS*

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"This study identifies that science, technology, engineering, and mathematics teachers feel that students benefit from learning by doing.

This is the third of a series of reports discussing the Doing-Based Learning study. The first report (Round 1) (Moye, Dugger, & Starkweather, 2014a) introduced the study, defined "doing" in the context of this study, described why students "doing" in the classroom is important, why there is a need for this study, and also provided some selected findings from the first round of surveys. The second report (Round 2) (Moye, Dugger, & Starkweather, 2014b) identified the methods used and results of the first-round data. This report identifies the purpose of the study, identifies where the survey methods may be found, provides the number and percentages of responses, selected findings, and the future of this longevity study.

The purpose of this study is to determine the extent to which U.S. public school students are doing activities in their classrooms. This five-year study asks elementary and secondary (middle and high school) science, technology, engineering, and mathematics (STEM) teachers to respond to 13 statements concerning students doing in their classrooms. The first two statements are general in nature and were used at all grade levels. The remaining 11 statements are grade-level-specific and based on *Next Generation Science Standards*, *Standards for Technological Literacy*, and *Common Core State Standards for Mathematics*. Study methodology details can be found in Moye, Dugger, and Starkweather, 2014a, and Moye, Dugger, and Starkweather, 2014b.

The researchers sent emails to 5,232 teachers across the United States. The emails contained a cover letter explaining the study and provided a URL encouraging teachers to participate.

FINDINGS

This round was open for teacher participation from March 1 until April 15, 2015. To be eligible to participate in this study, teachers needed to identify themselves as science, technology, engineering, and/or mathematics (STEM) teachers. Many responding teachers identified themselves as other than STEM teachers, and therefore were not included in this study. For example, some responding teachers were family and consumer science, automotive, health care, physical education, as well as other content area teachers. There were a total of 1,351 eligible teachers participating in this round. Of that number, 296 were elementary teachers, 254 secondary science, 606 secondary technology and engineering, and 195 secondary mathematics teachers. Teachers were asked to respond to two general statements. The statements were designed to determine how teachers felt about students learning by doing in the classroom. Table 1 identifies the first two statements, the number of teachers who responded "Yes," and the total number of responses to each statement. Data for both Rounds 1 (2014) and 2 (2015) are included.

*This research article is a result of an ITEEA/FTEE (Dugger/Gerrish endowment) research project.

Table 1. General Statements, Number of Yes Responses/Total Responses, and Percentage of Yes Responses.

Statement	2014 Elem. Yes	2015 Elem. Yes	2014 MS & HS Science Yes	2015 MS & HS Science Yes	2014 MS & HS TE Yes	2015 MS & HS TE Yes	2014 MS & HS Math Yes	2015 MS & HS Math Yes
1. I believe that students benefit from doing activities to support learning.	433/437 99.1%	296/296 100%	399/404 98.8%	253/254 99.6%	540/544 99.3%	601/605 99.3%	282/285 98.9%	192/195 98.5%
2. Given the time and resources, I would assign my students more projects to do in class.	422/437 96.6%	288/296 97.3%	382/404 94.6%	242/254 95.3%	515/544 94.7%	568/606 93.7%	272/284 95.8%	177/195 90.8%

Of the 296 elementary teachers who responded to Statements 1 and 2, 243 responded to Statements 3 through 13. Table 2 identifies elementary school Statements 3 through 13, the number of teachers who responded "Yes," the total number of respondents, and the percentage of teachers indicating "Yes" to each statement. Elementary-level data for both Rounds 1 and 2 are included. The last row of the table contains the number of "Yes" responses/total responses and percentages of doing in courses. The researchers derived this information by adding the number of "Yes" responses in the Elem. column and divided that number by the total number of responses.

Table 2. Round 1 and 2 Elementary School Statements, Number of Yes Responses/Total Responses, and Percentage of Yes Responses.

Statement My students have…	2014 Elem. "Yes"	2015 Elem. "Yes"
3. …developed an object, tool, process, or system that included several criteria for success and constraints on materials, time, or cost.	198/365 54.2%	133/243 54.7%
4. …constructed an object using the design process.	196/365 53.7%	138/243 56.8%
5. …designed and built a product or system.	174/365 47.7%	119/243 49%
6. …controlled variables to conduct an investigation that produced data serving as evidence.	222/365 60.8%	149/243 61.3%
7. …performed an activity to solve a design problem.	198/365 54.2%	145/243 59.7%
8. …generated and compared multiple solutions to a design problem based on the criteria and constraints of that problem.	153/365 41.9%	116/243 47.7%
9. …built a model and then improved the design to better meet requirements.	170/356 46.6%	118/243 48.6%
10. …tested and evaluated solutions for a design problem.	157/365 43%	114/243 46.9%
11. …built and used a model to communicate their solutions to a problem.	162/365 44.4%	116/243 47.7%
12. …built something designed to meet specific criteria and constraints.	217/365 59.5%	131/243 53.9%
13. …used a computer program to model and simulate a solution to a problem.	80/365 21.9%	60/243 24.7%
Total Yes Responses/Total Responses and Percentage of Doing in Courses	1927/4015 48%	1339/2673 50.1%

Table 3 identifies middle school Statements 3 through 13, the number of teachers who replied “Yes,” the total number of responding teachers, and the percentage of teachers indicating “Yes” to each statement. Of the 425 middle school teachers who responded to Statements 1 and 2, 366 responded to Statements 3 through 13. Eighty-three were science, 218 were technology and engineering, and 65 were mathematics teachers. The last row of the table contains the number of “Yes” responses/total responses and percentages of doing in courses. As with the elementary data, the researchers derived this information by adding the number of “Yes” responses in each column and dividing that number by the total number of responses in those columns.

Table 3. Round 1 and 2 Middle School Statements, Number of Yes Responses/Total Responses, and Percentage of Yes Responses.

Statement **My students have…**	**2014** **MS Sci.**	**2015** **MS Sci.**	**2014** **MS Tech. & Eng.**	**2015** **MS Tech. & Eng.**	**2014** **MS Math**	**2015** **MS Math**
3. …developed a solution to be tested and then modified it on the basis of the test results.	94/133 70.7%	61/83 73.5%	173/194 89.2%	192/218 88.1%	49/104 47.1%	26/65 40.0%
4. …created a tool or model to address an individual or societal need or want.	51/133 38.3%	37/83 44.6%	139/194 71.6%	161/218 73.9%	18/104 17.3%	11/65 16.9%
5. …tested and evaluated a design in relation to pre-established requirements.	92/133 69.2%	64/83 77.1%	177/194 91.2%	199/218 91.3%	34/104 37.7%	21/65 32.3%
6. …made a model to test for solutions to a problem.	85/133 63.9%	65/83 78.3%	169/194 87.1%	190/218 87.2%	52/104 50%	28/65 43.1%
7. …completed an activity that demonstrated how humans use natural resources that have positive and negative short- and long-term consequences.	71/133 53.4%	47/83 56.6%	100/194 51.5%	119/218 54.6%	18/104 17.3%	5/65 7.7%
8. …created a model by applying criteria and constraints.	90/133 67.7%	64/83 77.1%	171/194 91.8%	202/218 92.7%	46/104 44.2%	28/65 43.1%
9. …designed and used instruments to gather data.	92/133 69.2%	57/83 68.7%	129/194 66.5%	144/218 66.1%	47/104 45.2%	36/65 55.4%
10. …analyzed and interpreted data to determine similarities and differences in findings.	120/133 90.2%	79/83 95.2%	146/194 75.3%	168/218 77.1%	84/104 80.8%	52/65 80%
11. …solved a design problem by developing an object, tool, process, or system.	69/133 51.9%	47/83 56.6%	165/194 85.1%	193/218 88.5%	26/104 25%	15/65 23.1%
12. …performed an experiment to solve a design problem.	88/133 66.2%	60/83 72.3%	137/194 70.6%	165/218 75.7%	21/104 20.2%	19/65 29.2%
13. …identified the characteristics of a design that performed the best during a test process.	79/133 59.4%	58/83 69.9%	158/194 81.4%	183/218 83.9%	18/104 17.3%	12/65 18.5%
Total Yes Responses/Total Responses and Percentage of Doing in Courses	931/1463 63.6%	639/913 70%	1671/2134 78.3%	1916/2398 79.9%	413/1144 36.1%	253/715 35.4%

Table 4 identifies high school Statements 3 through 13, the number of teachers who responded “Yes,” the total number of responding teachers, and the percentage of teachers indicating “Yes” to each statement. Of the 630 high school teachers who responded to Statements 1 and 2, 571 responded to Statements 3 through 13. Of those teachers, 142 were science, 325 were technology and engineering, and 104 were mathematics teachers. The last row of the table contains the number of “Yes” responses/total responses, and percentages of doing in courses. As with Tables 2 and 3, the researchers determined the percentage of doing by adding the number of “Yes” responses in each column and dividing that number by the total number of responses.

Table 4. Round 1 and 2 High School Statements, Number of Yes Responses/Total Responses, and Percentage of Yes Responses.

Statement My students have…	2014 HS Sci.	2015 HS Sci.	2014 HS Tech. & Eng.	2015 HS Tech. & Eng.	2014 HS Math	2015 HS Math
3. …developed a solution to a complex, real-world problem, based on scientific knowledge and student-generated sources of evidence.	111/220 50.5%	91/142 64.1%	245/308 79.5%	269/325 82.8%	68/151 45%	45/104 43.3%
4. …built a model of something to simulate the interactions between systems such as energy, matter, or information flow.	124/220 56.4%	95/142 66.9%	217/308 70.5%	226/325 69.5%	34/151 22.5%	23/104 22.1%
5. …created a presentation communicating the specifications and results of a design process used to meet a need.	90/220 40.9%	77/142 54.2%	242/308 78.6%	257/325 79.1%	52/151 34.4%	33/104 31.7%
6. …built a model using specified criteria and constraints.	154/220 70%	106/142 74.6%	285/308 92.5%	298/325 91.7%	70/151 46.4%	47/104 45.2%
7. …identified and applied criteria and constraints to develop a system or product.	94/220 42.7%	82/142 57.7%	275/308 89.3%	283/325 87.1%	54/151 35.8%	38/104 36.5%
8. …performed research to determine criteria and constraints driven by a societal problem.	96/220 43.6%	63/142 44.4%	184/308 59.7%	190/325 58.5%	40/151 26.5%	22/104 21.2%
9. …developed a solution to a major global challenge such as the need for improved health or supplies of clean water and food.	39/220 17.7%	31/142 21.8%	80/308 26%	63/325 19.4%	13/151 8.6%	3/104 2.9%
10. …applied the design process to evaluate an existing design or to collect data.	105/220 47.7%	86/142 60.6%	239/308 77.6%	256/325 78.8%	50/151 33.1%	30/104 28.8%
11. …built a prototype and checked it for quality and efficiency.	53/220 24.1%	49/142 34.5%	247/308 80.2%	269/325 82.8%	21/151 13.9%	17/104 16.3%
12. …used computer simulations to predict the effects of a design solution.	54/220 24.5%	41/142 28.9%	168/308 54.5%	188/325 57.8%	35/151 23.2%	15/104 14.4%
13. …evaluated a design solution by using conceptual, physical, or mathematical models to check for proper design.	44/220 20%	47/142 33.1%	216/308 70.1%	223/325 68.6%	42/151 27.8%	23/104 22.1%
Total Yes Responses/Total Responses and Percentage of Doing in Courses	964/2420 39.8%	768/1562 49.2%	2398/3388 70.8%	2522/3575 70.5%	479/1661 28.8%	296/1144 25.9%

To arrive at the secondary doing percentages, the researchers added the total middle and high school "Yes" responses in each course column and divided that sum by the total responses in that column. The results were that 56.8% (1407/2475) of secondary science students were doing in class, 74.3% (4438/5973) of technology and engineering students were doing in their classrooms and laboratories, and in secondary mathematics there were 29.5% (549/1859) of students doing in their classes. Figure 1 is a graphic illustration of the secondary data.

PERCENT SECONDARY LEVEL DOING

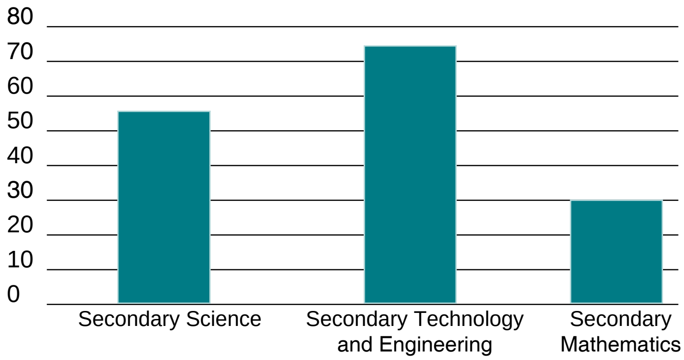


Figure 1. Round One Secondary Level Learning by Doing.

DISCUSSION

The researchers have identified the findings of this round and compared them to the first round of the study. Observations have been made to produce discussion about STEM teacher feelings concerning doing in the classroom. The page limitation given by the publisher restricts the length of this report; therefore, the researchers are restricted to the number of findings and interesting points provided.

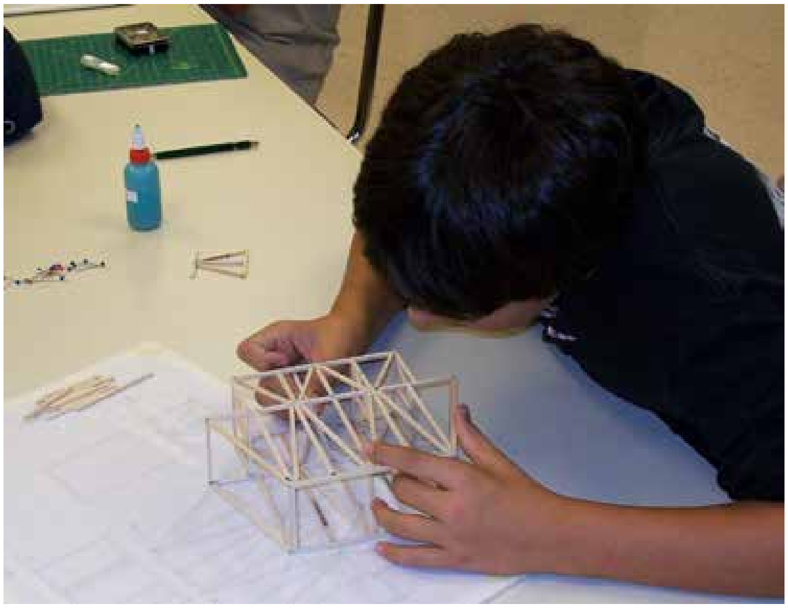
Overall, fewer teachers responded to this round of the study. In 2014 (Round 1), 437 elementary teachers participated; in 2015 (Round 2), there were 296. Combining middle and high school data, in 2014, 404 science teachers participated; in 2015, 254. In 2014, there were 285 participating mathematics teachers, but that total decreased to 195 in this round. Technology and engineering teachers were the only population that increased in number. In 2014, 544 participated; in 2015 that number increased to 606. The reader should be reminded that not all of the teachers who responded to Statements 1 and 2 responded to the remainder of the statements.

In Statements 1 and 2, ninety-nine percent of the responding first-round teachers felt that students benefited from doing activities, and 95% of those teachers stated that they would assign their students more projects to do in class if they had the time and resources (Moye, Dugger, & Starkweather, 2014b). The second round revealed that elementary and secondary teachers still feel that students benefit from doing activities in the classroom—of the 296 elementary teachers responding to the survey, all 296 (100%) felt that students benefit from doing activities in the classroom. In this round, 1,055 secondary school science, technology, engineering, and mathematics teachers responded to the first statement. Two hundred fifty-three of the 254 (99.6%) science teachers, 601 of the 605 (99.3%) technology and engineering teachers, and 192 of the 195 (98.5%) mathematics teachers indicated that they felt that students benefit from doing activities in the classroom.

Concerning Statement 2, this round supports the first-round conclusions that, if given the time and resources, teachers would have their students do more in class. Of the 296 responding elementary teachers, 288 (97.3%) indicated that they would assign their students to do more projects if they could. Secondary teachers agreed with elementary teachers. Of the 1,055 responding middle and high school science, technology, engineering, and mathematics teachers, 242 of the 254 (95.3%) science teachers responded "Yes." Of the 606 responding technology and engineering teachers, 568 (93.7%) said "Yes." Of the 195 responding secondary school mathematics teachers, 177 (90.8%) also indicated that they would assign their students more projects if they had the time and resources.

Teachers were asked to respond either "Yes" or "No" to 11 standards-based statements. The same statements were used in 2014 and 2015, and therefore the responses can be compared. During the first round of this study the data indicated that secondary technology and engineering students were learning by doing more (74.6%) than were elementary (48%), secondary science (51.7%), and secondary mathematics (32.5%) students. Also, elementary students were learning by doing more (48%) than high school (46.5%) but less than middle school (59.3%) students. This round also found that secondary technology and engineering students are learning by doing more (74.3%) than are elementary (50.1%), secondary science (56.8%), and secondary mathematics students (29.5%). A change in this year's data indicates that secondary science students are learning by doing at a higher percentage than are elementary students. This point will be monitored in Rounds 3 and 4 of this study.

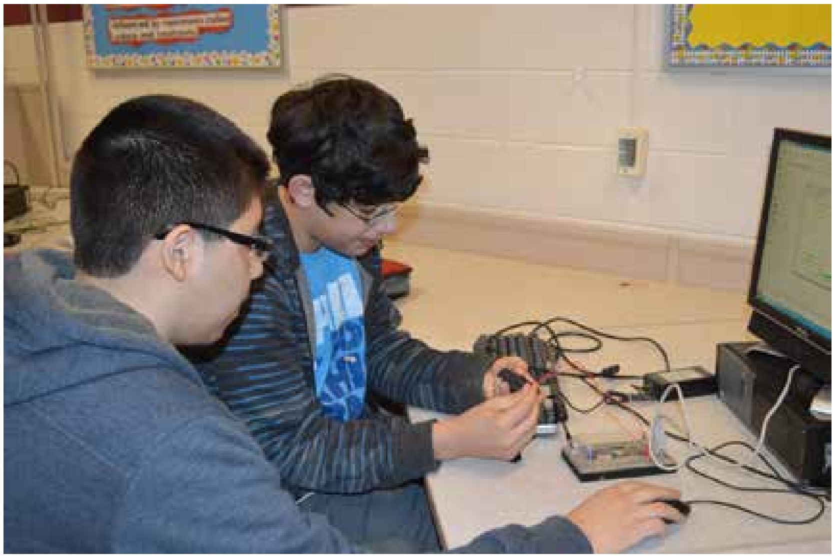
It is interesting to note that during this round, with the exception of secondary science, the number of teachers who indicated, "Yes" remained relatively constant. In 2014, doing in middle school science classes was at 63.6%; in 2015, it was at 70%, an increase of 6.4%. The increase was even greater at the high school level, (2014 – 39.8% and 2015 – 49.2%, an increase of 9.4%). In 2014, elementary teachers indicated that students were learning by doing at 48%, whereas the 2015 data show 50.1%, an increase of 2.1%. Middle school technology and engineering percentage increased by 1.6% (from 78.3% to 79.9%), but high school technology and engineering percentage dropped .3% (from 70.8% in 2014 to 70.5% in 2015). Mathematics teachers reported a decrease of doing in their classrooms at both the middle (-.7%) and high school (-2.9%) levels respectively. Because there was a decrease in the number of science and mathematics teachers who participated in this (2015) round, it is difficult to draw specific conclusions. But, with the substantial increase in science teacher responses, one would have to ask if the responding science teachers are having their students do more in class as a result of implementing *Next Generation Science Standards*, or for some other reason that is driving more doing in the classroom.



In this round, 243 elementary teachers responded to Statements 3 through 11. When comparing the 2014 and 2015 data, there were fewer respondents, but a higher percentage of doing. Overall the percentage of elementary learning by doing increased by 2.1 percent from the first to the second round (2014 – 48%, 2015 – 50.1%). In the 2014 round, teachers identified the students using a "computer program to model and simulate a solution to a problem" (Statement #13) as receiving the lowest percent (21.9%). In this round, although the percentage increased by 2.8%, elementary teachers again identified this statement as the lowest percentage of "Yes" responses (2014 – 21.9%, 2015 – 24.7%). Further review found that with the exception of one statement (#12), the percentages of "doing" in elementary classrooms increased in every statement. The exception involved students building something designed to meet specific criteria and constraints. In 2014, elementary teachers indicated in 5 of the 11 statements that their students completed those activities 53.7% or more of the time. During this round, teachers identified the same five statements as those with the highest percentages. More middle school technology and engineering teachers responded to Statements 3 through 13 than in the first round of this study (2014 – 194, 2015 – 218). However, there were fewer participating science (2014 – 133, 2015 – 83) and mathematics (2014 – 104, 2015 – 65) teachers.

With this round, middle school science teacher percentages increased in 10 of the 11 statements (#9 did not increase). The overall middle school percentage of science students learning by doing in class increased 6.4%. Doing in middle school technology and engineering classes increased by 1.6%, but the reported percentage decreased in middle school mathematics classes by .7%. The 2014 round found that there were only three occurrences where middle school science teachers indicated a higher "Yes" response than did technology and engineering teachers on the 11 doing statements. This round revealed the same results in the same three statements (#7, 9, and 10). In 2014, mathematics teachers had no higher percentage of "Yes" responses than science and only one higher than technology and engineering teachers (#10). Again, this round identified the same results. Statement #10 involves students analyzing and interpreting data to determine similarities and differences in findings.

As with middle school, more high school technology and engineering teachers participated in Round 2 of the study than in Round 1 (2014 – 308, 2015 – 325). Similarly, there were fewer science teacher participants (2014 – 220, 2015 – 142) and mathematics participants (2014 – 151, 2015 – 104). Science percentages increased in all 11 statements. In 2014 there were no instances where high school science or mathematics teachers reported a higher "Yes" response than did technology and engineering teachers with Statements 3 through 13. In this round, science teachers identified one statement (#9) in which their students were learning by doing more than technology and engineering teachers. Science teachers indicated that their students have developed a solution to a major global challenge such as a need for improved health or supplies of clean water and food 21.8% of the time. Only 19.4% technology and engineering teachers replied, "Yes" to that statement. It should be noted that this statement received the lowest percentage from all STEM teachers (science, 21.8%; technology and engineering, 19.4%, and math, 2.9%) This lowest percentage of any statement was also the case in 2014. In 2014, high school mathematics teachers responded "Yes" more frequently than science teachers in only one occurrence (#13). This was not the case in this round. In 2014, high school math teachers did not



report “Yes” in any statements more frequently than did science or technology and engineering teachers.

Focusing on a teacher demographic point, 82 secondary school teachers identified themselves as STEM or a combination of two or more content area teachers. To confirm this information the researchers sent emails to the 74 teachers who supplied their email addresses. Of the 74 teachers, 33 responded. Nineteen of the responding teachers indicated that they were technology and engineering teachers, seven indicated science, and four were mathematics teachers. Three teachers indicated that their school divisions actually considered them STEM teachers. Although there were more technology and engineering teachers who participated in this round, it is interesting that in more than half the cases, those teachers who initially identified themselves as STEM teachers were actually technology and engineering teachers.

By answering “Yes” or “No” to the study statements, teachers identified the activities they did or did not assign in their classrooms. However, teachers may feel that there may be more to the answer than just “Yes” or “No.” Teachers were given an opportunity to add a comment to each statement. Elementary teachers submitted 248 comments. At the secondary level, science teachers submitted 116 comments, technology and engineering 489 comments, and mathematics teachers 90 comments. The comments varied but, when analyzed, certain themes arose.

Commenting on Statement #1 (I believe that students benefit from doing activities to support learning), elementary teachers used the term “hands on” 22 times to identify how students “gained from actually doing something rather than learning about it from books, lectures, etc.” One elementary teacher stated, “I love activities, because they [students] enjoy learning.” Secondary education teachers used the term “hands on” 7 times. A middle school science teacher stated, “You CANNOT learn science out of a textbook! You can only learn science by doing labs and using your skills.”

It is interesting that secondary science teachers responded “Yes” more frequently to Statement #2 in this round than the first round where technology, engineering, and mathematics teachers responded “No” more frequently. Some teachers provided comments concerning Statement #2. The elementary teachers confirmed that “time” and “testing” were the greatest issues they faced. Providing an indication of why the percentage may have decreased in this round, two middle school technology and engineering teachers wrote, “We are maxed for projects…” and “My entire curriculum is project-based. As such, I cannot do more.” Two high school technology and engineering teachers wrote, “Most of my class is project-based, so am not sure how there would be much more.” and “I already offer a full range of projects for students.”

There were many comments that supported the idea of learning by doing. For example, two middle school mathematics teachers stated, “I attribute most of my students’ success with algebraic concepts to the kinesthetic learning processes we used” and “Statistically, my students score higher on assessments after they have completed a project that supports their learning.” One elementary teacher wrote, “Students, just like most adults, learn better by doing.” These statements are but a few of the comments teachers provided that support the idea of learning by doing. But teachers also realize that time and resources are an issue preventing them from presenting their students with more hands-on activities to do in class.

RECOMMENDATIONS

Researchers should conduct further research on areas identified in this report. Some recommended areas are:

- Determine if science students are doing more in class as a result of implementing *Next Generation Science Standards* or if something else is driving more “doing” in the science classroom.
- Investigate how to get more teachers to participate in the next two rounds.

Previous Learning by Doing articles are available to view at:

Article 1 - www.iteea.org/Resources/PressRoom/2014/Oct/LBDArticle1.pdf

Article 2 - www.iteea.org/Resources/PressRoom/2014/Oct/LBDArticle2.pdf

- Encourage additional STEM teacher participation in Rounds 3 and 4 of this study.
- Promote how technology and engineering programs bring STEM education to life by using the learning by doing method of instruction.
- Determine if respondents who were more likely to be doing in their classrooms and laboratories responded to this survey as compared to those who were are not as likely to care about doing.

CONCLUSION

To conclude this report, the researchers would like to quote one middle school technology and engineering teacher's comment: "Students need to comprehend the connection with the real world by doing. Simulations help them train and try different scenarios, but the real-world kinesthetic tactile experience of problem solving, building, and learning from doing is SO valuable."

This study identifies that science, technology, engineering, and mathematics teachers feel that students benefit from learning by doing. These teachers indicated that they would have their students do more in class if they were given the time and resources. This study identifies that technology and engineering students are learning by doing more than science and mathematics students. Educational leaders should review technology and engineering programs in their schools to determine if they are being fully utilized in support of science and mathematics (and other academic) programs.

This article identifies the results of Rounds 1 and 2 of four rounds of the Doing-Based Learning study. The researchers are currently conducting Round 3 of this study until April 15, 2016. Using the same survey instruments and methods, the researchers will solicit input from as many STEM teachers as possible. The results of the third and fourth rounds will be published in this journal. Elementary and secondary STEM teachers are encouraged to participate in this study and can do so by following this link: www.iteea.org/DoingProject.pdf. Please feel free to contact the authors if there are any questions concerning this research study.

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