Alabama Journal of Mathematics
42 (2018)
ISSN 2373-0404

Impact of Explore-Instruct Pedagogy on Student Learning: Solidifying teacher belief changes to productive!

Brandy G. Whitmire
Scottsboro Junior High

Jeremy Zelkowski
Department of Curriculum and Instruction
The University of Alabama

Teacher beliefs can greatly influence daily decision making with respect to many and all, curricular choices. This article shares from a 7th grade classroom experience centered on shifting towards productive beliefs about student learning and problem solving. Many measures solidify the explore-instruct pedagogy as a foundation for productive beliefs.

Introduction

I wanted to find a pedagogical strategy that could promote problem-solving growth in my students. Initially, I expected any pedagogical shift to challenge my students and expected resistance. Students have generally resisted any changes I have made as a first-decade teacher. I would expect many mathematics teachers feel similar to me. In the past few years, I had become frustrated with some of my student outcomes, particularly beyond short-term learning. I had begun to think much more deeply about students' learning, beliefs, and attitudes.

I spent time reading and reflecting about my own practices and beliefs with respect to the eight Effective Mathematics Teaching Practices (National Council of Teachers of Mathematics, 2014) and the eight Standards for Mathematical Practice (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). I felt myself needing to shift my own beliefs from unproductive to productive with respect to the Effective Teaching Practices. More so, I wanted to see my students' learning, perseverance, and beliefs with problem solving improve and increase their engagement in the Mathematical Practices.

As I continued to read and reflect, three studies began to guide my thinking. Loehr, Fyfe, and Rittle-Johnson (2014) studied explore-instruct methods to improve student perseverance in problem solving with 2nd-graders. This study shaped my initial thoughts about what I needed to do as a teacher to get students to solve problems. The students in the study showed they could learn conceptually and procedurally as well or better than by traditional instruct-solve instruction. Westermann and Rummel (2012) studied the impact of delayed instruction (e.g. explore-instruct) on problem solving ability at the university level. Similarly, students in "think, ask, understand" classes outperformed direct-instruction classes after enough exposure to the changed instruction. Finally, Richmond et al. (2015) studied inquiry-based instruction which includes explore-instruct methods in a non-math higher education classroom. This study outside of the mathematics classroom solidified my thinking of the two mathematics classroom studies regarding problem solving. I (Author Zelkowski) saw a mindset shifting in (author Whitmire) in that for productive beliefs to continue evolving in light of student resistance, she would need to resist herself and find hard evidence of improving student outcomes. We share this journey.

Changing my Approach in one Class - A Stepping Stone

I chose my first period (Class A) of regular grade level students and an upcoming unit on a previous area of struggle to begin planning for a change from my past-year's approach. The Alabama 7th grade course of study includes all of the Common Core standards in the domain of statistics and probability. The unit included standards for the cluster: Investigate chance processes and develop, use, and evaluate probability models [7-SP5, 7SP-6, 7-SP7 (a,b), and 7-SP8 (a,b,c)]. The unit spanned nearly four weeks of lessons and assessment. I chose Class A so I would be able to be well prepared with time after school to have my plans well outlined and enough time to reflect each day on how the changes were evolving for one group of students.

Class A (16 students) was taught first during the day and used exclusively the explore-instruct pedagogical approach. My lessons planned each day for students working for 50-75% of the class time on the lesson activity/tasks. I walked around the room, listened, asked probing questions, and applied different pedagogical strategies. This was very different to me and why I chose only one class to focus my changes. I wanted to make sure of my own ability and student outcomes before I committed to all classes. My tasks aimed to promote reasoning, problem solving, and to support students' productive struggle while engaged in conceptual

Corresponding Author Email: jzelkowski@ua.edu

exploration. Students as I predicted, struggled early in the unit and some resisted for the first couple of days. I made strong efforts to talk with students in groups where I saw this happening, often stopping mid-exploration to ask the whole class for discussion about their struggles. It was challenging for my students and me the first week. However, after week-1, my students and I seemed to be moving well through each lesson. My lesson designs aimed for students to gain procedural fluency without focusing solely on probability procedures. I really wanted to understand if allowing students to explore conceptually on their own strengthened student learning in comparison to *giving* students knowledge of the concept with notes and then allow for exploration of concepts. This was my belief I aimed to reinforce based on the three articles influencing my change. To close lessons, notes were presented and students recorded them to finish the class period, which is how I normally start most of my classes. Students had between two and five minutes to ask questions usually. I hoped to learn if Class A improved their learning from my past experiences and I had a comparable class to help me understand differences occurring in this pedagogically shifted class. All my other classes, I continued to use my normal approach. Class B (20 students), my other grade level 7th grade class, I taught the unit as in preceding years where students take notes and see examples for the first half of the class followed by lesson activities or problems where they explore or problem solve. I varied my approach from previous years teaching this unit to Class B making changes as I normally have made year to year. Students in both classes completed the same activity/tasks/problems each day. An example of such an activity can be found in Appendix A.

Student Attitudes and Beliefs

At the start of the unit for Class A and B, I had students complete a self-made attitudes and beliefs survey as a Google® form with all items Likert scored (1-strongly disagree to 5-strongly agree). Students then completed the same survey on the final day of the unit after the unit test. See Appendix B for the unit calendar in each class. My pre-test and post-test were identical given on day 1 and the end of the unit to both classes. Modifications from previous years' unit test included changes in questions/tasks to balance the classification labels of memorization, procedures without and with connections (Stein & Smith, 1998). An example of such a task would be

> It is important that you show your work for each problem. To receive credit for a problem, you must both indicate the correct answer and show plausible work justifying your answer.
>
> 1. Determine whether the event is impossible, unlikely, as likely as not, likely, or certain. You roll two fair number cubes and get a total of 14.
> 2. Determine whether the event is impossible, unlikely, as likely as not, likely, or certain. Your teacher divides the class into two groups of the same size by picking names at random from the class, and you will be put in group 1.

Doing mathematics tasks were not included for time considerations on the unit assessment. For long-term learning, I used our school's winter, early January, and spring, early April, formative assessment [Global Scholar] data on the probability standards related to this unit.

Class A and Class B. My personal perceptions of students in Class A and Class B were balanced and relatively similar for the classes as a whole. Class A had one or two students I classified slightly stronger than the top students in Class B, as well as Class B having two or three students lesser in mathematical ability than Class A. Overall, most measures showed both classes were of comparable ability (see Table 1).

Table 1
Class A and B Comparisons

Measures	Class A	Class B
January Formative Assessment	2678	2681
Prior 9 unit assessment averages	82.7%	78.8%
Pre-test on unit	10%	10%

The attitudes pre-post survey for Class A and Class B revealed positive results for the unit that we had hoped to find by conducting this study. Given the small sizes of the data, we only found two statistically significant differences pre-post. Class A significantly improved their beliefs on the items "When I come to a math problem that I do not understand, I persevere and try to come up with a way to solve the problem" and "I know how to find probability". Class B significantly improved their beliefs on the items "I like finding probability" and "I know how to find probability". Of all the items on the survey (Table C1 in Appendix C), Class A improved their beliefs and attitudes on 15 of 24 items, staying the same on four, and dropping on five. Class B improved their beliefs and attitudes on 14 of 24 items, staying the same on one, and dropping on nine. Overall, a modest improvement for Class A over Class B considering descriptive statistics.

The post-test results indicated short-term learning improved in Class A more so than in Class B. Class A scored on average a 75% while Class B scored 66% on the unit test. Class A demonstrated greater long-term learning by two measures on the Global Scholar spring assessment. Overall, Class A increased their spring standardized formative assessment score to 2688 (+10) while Class B decreased to

2623 (-53). With respect to the probability standards of the unit, the subscores showed +33 for Class A and +16 for Class B, double the growth.

Field Notes Regarding Perseverance

Students from both classes were very apprehensive about taking the pre-test because they did not know much about probability. Many students did not even attempt more than half the items in both classes. On the winter Global Scholar formative assessment, students from both classes appeared to stop or quit on problems at the same frequency. The two class averages on the winter assessment essentially confirmed my field notes. As the unit began, students complained in Class A much more than Class B. Student quotes from Class A included: "I do not learn this way", "This stresses me out!", "You have not shown me how to do this", and "Oh Lord". By the end of the unit, comments in Class A were virtually absent from most students. Explore-instruct methods were more time consuming so students did not have as much time in class to do practice problems. As time progressed, students became less apprehensive to trying new kinds of problems and spent more time than previously.

During questioning in Class B, students would answer problems and finish activities faster than Class A. Students had more time to practice more problems since they did not have to take so long to discover concepts. Much more scaffolding was required for Class B to get started on activities than in Class A, and Class B gave up more easily on tasks requiring strong problem solving skills. Students in Class B almost exclusively relied on teacher notes on how to solve any problem. Students in Class B were able to answer questions generally faster than Class A, but student responses were not as in-depth as class A.

My Unproductive to Productive Belief Changes

When I became a teacher, I had many unproductive beliefs (National Council of Teachers of Mathematics, 2014). As the years have gone on through my own classroom observations, professional development participation, and now this project, my beliefs have become more productive about teaching and learning mathematics. I moved away from the belief that *students can learn to apply mathematics only after they have mastered the basic skills*. I thought my students must have basic skills and knowledge of a concept before they would be able to begin to explore a concept. For years, I thought *an effective teacher makes the mathematics easy for students by guiding them step by step through problem solving to ensure that they are not frustrated or confused*. I have always heard of teachers describe the best teachers as those who explain concepts so that students can understand them. Students have to be able to persevere in challenging situations in life so making it easy by guiding students through each step will not prepare them for their future. We have to teach them to persevere and to be able to rely on and to develop their own reasoning and problem solving skills.

Positive Changes in Student Attitudes and Beliefs

There were many positive findings in the survey data.

1. On the pre-survey, Class B had a higher opinion on item "I like to solve math problems that I have to solve on my own". After the unit, Class A had maintained their perception while Class B averaged one in three students dropping a full opinion point.

2. Class A's attitude on item "I do not like Math" improved by one full point on average for one in three students while Class B's attitude worsened by a full point on average for one in eight students.

3. On the survey item "math is hard to me", both classes had the same Likert scale belief (2.9-Neutral) on the pre-survey. After the unit assessment on the post-survey, Class A did not change while Class B now agreed (3.3) that math was hard to them. One in three students in Class B now thought math was harder.

4. Even more so, the survey item "I work hard in math class" strengthens this finding. Class A's agreement with this survey item dropped by a quarter-point, while Class B's agreement stayed the same.

5. Class A improved their perceptions on "Learning about Math" by a quarter-point while Class B dropped a tenth-point. Overall, Class A's attitude and self-belief improved while Class B did not.

6. The last important point links from attitude/beliefs to achievement. On the two items "I like finding probability" and "I know how to find probability", Class A improved pre-post 0.25 and 1.06 while Class B improved 0.65 and 1.10 respectively. However, the post-test and spring Global Scholar formative assessment scores indicate something different. Class A only improved slightly on their "like" of finding probability but their short- and long-term scores showed they could find probability much better than Class B who thought their ability to "find probability" was improved as much as Class A. This finding is likely because Class B had easier pathways to answers during the unit.

Post Unit Assessment

Class A dropped about three quarters of a letter grade while class B dropped well over one full letter grade. We did not interpret the lower mean scores as a negative outcome. Well documented in the research, probability is one of the more difficult mathematical content areas for students to master, particularly 7th graders given all the misconceptions students possess regarding recency effects, sample size, compound events, and representativeness (Kustos & Zelkowski, 2013; Shaughnessy, 1977). In fact, examining the last three years of our school-wide formative assessments on probability, this content area has historically always had the lowest scores. Class A scored higher by 75 points than all 14 of my other classes on the end of year assessment on probability.

Discussion, Next Steps

Overall, the attitudes and beliefs survey, the short-term learning pre-post unit assessment, and the long-term learning standardized Global Scholar assessment scores support the pedagogical change for which I intend to begin using more regularly with all of my students. Research has linked student attitudes, beliefs, and self-efficacy to student achievement in mathematics (Popa & Voicu, 2015; Stylianides & Stylianides, 2014; Williams, 2014). Repeatedly since the work of Polya (1957) regarding problem solving to today, researchers and practitioners continue to understand these relationships in detail. Moving forward my next steps will be practice-oriented rather than focusing solely on *test score* improvement that was my typical practice. My graduate studies have helped me understand my pedagogical practices and beliefs. I needed to confirm for myself the importance of productive beliefs over unproductive beliefs about teaching and learning mathematics for my own students' attitudes and beliefs to be improved. It was clear to me after this unit; students did resist changes to my daily practice initially. Ultimately, student attitudes and beliefs about mathematics positively changed and achievement grew. It was a personal challenge to keep firm these changes in the face of student resistance. I look forward to these experiences with the rest of my classes though I expect it to be a difficult path.

References

Kustos, P., & Zelkowski, J. (2013). Grade-continuum trajectories of four known probabilistic misconceptions: What are students' perceptions of self-efficacy in completing probability tasks? *Journal of Mathematical Behavior*, *32*(3), 508-526. doi: 10.1016/j.jmathb.2013.06.003

Loehr, A. M., Fyfe, E. R., & Rittle-Johnson, B. (2014). Wait for it ... delaying instruction improves mathematics problem solving: A classroom study. *Journal of Problem Solving*, *7*(1), 36-49. Retrieved from `https://doi.org/10.7771/1932-6246.1166` doi: 10.7771/1932-6246.1166

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: Author.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards Mathematics*. Washington D.C.: Author. Retrieved from `http://www.corestandards.org`

Polya, G. (1957). *How to solve it; a new aspect of mathematical method*. Garden City, NY: Doubleday.

Popa, D., & Voicu, B. C. (2015). Motivational aspects engaged in performance of preadolescent students. *Procedia - Social and Behavioral Sciences*, *203*, 186-191. Retrieved from `https://doi.org/10.1016/j.sbspro.2015.08.280` doi: 10.1016/j.sbspro.2015.08.280

Richmond, A. S., Fleck, B., Heath, T., Broussard, K. A., & Skarda, B. (2015). Can inquiry-based instruction promote higher-level learning? *Scholarship of Teaching and Learning in Psychology*, *1*(3), 208-218. Retrieved from `https://doi.org/10.1037/stl0000032` doi: 10.1037/stl0000032

Shaughnessy, J. M. (1977). Misconceptions of probability: An experiment with a small-group, activity-based, model building approach to introductory probability at the college level. *Educational Studies in Mathematics*, *8*(3), 295-316.

Stein, M., & Smith, M. (1998). Mathematical tasks as a framework for reflection: From research to practice. *Mathematics Teaching in the Middle School*, *3*(4), 268-275.

Stylianides, A. J., & Stylianides, G. J. (2014). Impacting positively on students' mathematical problem solving beliefs: An instructional intervention of short duration. *Journal of Mathematical Behavior*, *33*(8), 8-29. doi: 10.1016/j.jmathb.2013.08.005

Westermann, K., & Rummel, N. (2012). Delaying instruction: evidence from a study in a university relearning setting. *Instructional Science*, *40*(4), 673-689.

Williams, G. (2014). Optimistic problem-solving activity: Enacting confidence, persistence, and perseverance. *ZDM*, *46*(3), 407-422.

Appendix A
Lesson

Probability: Games of Chance Assignment

Congratulations! Your class has been chosen to host a carnival to raise money for your school. Your task is to create a game of chance that will raise money for your school while demonstrating your understanding of probability. Your game should be fair and fun, but be designed to early money for the school. Therefore, the theoretical probability of your game needs to be in your favor. Your final assignment will be done in poster format and must include the following:

1. Name – Select a catchy name for your game (e.g. Crazy 7's). The name should appear at the top of your poster in big bold lettering.
2. Game Description/Rules of Play – Below your title describe your game. You may choose to use cards, dice, spinners, coins, dartboards, wheels, or other items for your game. Explain the rules of play. How do you play? What do you have to do to win? How do you lose?
3. Illustrations – Draw an illustration of your game. You may simply draw what it looks like or choose to create actual items for your game and paste them to your poster (e.g. spinners, dice, cards).
4. Outcomes – At the bottom of your poster, list all the outcomes for your game using either a tree diagram or organized list. Remember, the theoretical probability needs to be in your factor for you to make money!

Appendix B
Unit Calendar

Table B1
Sample Unit Calendar

Day 1	Day 2	Day 3	Day 4	Day 5
1. Survey 2. KWL 3. Pre-test 4. Pre-task	1. Journal 2. Vocab Intro 3. Practice	1. Warm-up 2. Review 3. Sandwich Options Activity 4. Sample Space Notes	1. Warm-up 2. Review 3. Let's Roll Activity 4. Family Fun Activity 5. Theoretical Probability Notes	1. Vocab review 2. Quiz 3. Theoretical and experimental probability investigation
Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
1. Warm-up 2. Guided prediction problems 3. Practice 4. Exit slip	1. Warm-up 2. Review 3. Videos 4. Practice	1. Warm-up 2. Review 3. Independent and dependent events web quest 4. Independent and dependent events notes	1. Warm-up 2. Review 3. Quiz	1. Warm-up 2. Review 3. Pizza Toppings Activity 4. Combinations notes
Day 11	**Day 12**	**Day 13**	**Day 14**	**Day 15**
1. Warm-up 2. Review 3. Dogs or Cats Activity 4. Permutations notes	1. Warm-up 2. Review 3. Practice 4. Word search	1. Warm-up 2. Review 3. Theoretical & experimental probability investigation 4. TenMarks Activities	1. Warm-up 2. Review 3. Bucket Activity 4. Match/ no match game	1. Warm-up 2. Review 3. Compound probability notes 4. Practice
Day 16	**Day 17**	**Day 18**	**Day 19**	
1. Warm-up 2. Review 3. Study Guide 4. TenMarks	1. Warm-up 2. KWL 3. Survey 4. Review 5. Kahoot	1. Post-test 2. Word search	1. Questionnaire 2. Post-task	

Appendix C
Survey Results

Table C1

Pre-Post Survey Results for Both Classes

Survey Item	Class A Pre (n=16)	Class A Post (n=16)	A Change	Class B Pre (n=20)	Class B Post (n=20)	B Change
I like to solve math problems that are challenging.	3.31	3.13	-0.19	3.10	2.85	-0.25
I like to solve math problems that are easy.	4.00	3.94	-0.06	3.85	3.90	0.05
I like to solve math problems that my teacher has given me steps on how to complete.	4.06	4.13	0.06	3.85	3.80	-0.05
I like to solve math problems that I have to solve on my own.	2.94	3.06	0.13	2.90	3.25	0.35
I like to solve math problems with other students.	3.81	3.50	-0.31	3.90	3.85	-0.05
I like math.	3.56	3.31	-0.25	3.60	3.50	-0.10
When I come to a math problem that I do not understand, I persevere and try to come up with a way to solve the problem.	3.19	2.69	-0.50	3.50	3.45	-0.05
When I come to a math problem that I do not understand, I give up before attempting the problem.	2.56	2.63	0.06	2.15	2.15	0.00
I do not like math.	2.31	2.69	0.38	2.45	2.35	-0.10
I like math activities that let me explore a math concept before my teacher teaches me the concept.	3.38	3.19	-0.19	3.25	3.00	-0.25
I like math activities that let me explore a math concept after my teacher teaches me the concept.	3.44	3.50	0.06	3.55	3.50	-0.05
I like hands on math activities.	4.00	4.00	0.00	4.10	4.05	-0.05
I do not like hands on math activities.	2.25	2.06	-0.19	2.00	1.80	-0.20
I work hard in math class.	3.56	3.81	0.25	3.65	3.70	0.05
Math is easy to me.	3.19	3.19	0.00	2.85	3.10	0.25
Math is hard to me.	2.88	2.88	0.00	3.20	2.85	-0.35
I like real-world math problems.	3.06	2.94	-0.13	3.75	3.60	-0.15
I like finding probability.	3.31	3.06	-0.25	3.70	3.05	-0.65
I know how to find probability.	3.94	2.88	-1.06	4.05	2.95	-1.10
Rate the following: Math	3.67	3.67	0.00	3.63	3.65	0.02
Rate the following: Problem solving	3.60	3.73	0.13	3.58	3.50	-0.08
Rate the following: Learning about math	3.53	3.27	-0.27	3.32	3.40	0.08
Rate the following: Math class	4.27	4.00	-0.27	3.84	3.85	0.01
Rate the following: Probability	3.60	2.87	-0.73	3.63	3.20	-0.43