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The Effects of Constructs Related to Mathematical Persistence
on Student Performance during Problem Solving

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Abstract

The common core state standards in mathematics support the importance of persistence to mathematical problem solving calling it a 21st century skill (Common Core Initiative, 2010). The nature of true problem solving as outlined by Schoenfeld (1992) requires this element of persistence in mathematics. However, new research (Duckworth et al, 2007; US Department of Education, 2013) has identified multiple ways to be able to measure these non-cognitive skills, such as persistence, using a variety of methods. The purpose of this study is to use these methods to be able to determine whether mathematical persistence is predictive of mathematical performance in problem solving. A 6th grade class, in an urban setting was used to administer a persistence survey constructed from research (Kloosterman & Stage, 1992) and a mathematical problem derived to require a high amount of persistence. We use a variety of constructs rooted in the persistence survey developed by Kloosterman & Stage (1992) and time spent on a task to determine the predictability of these constructs to actual mathematical performance measures including academic performance on a task and standardized measures. It was seen that the time spent on a mathematical task was predictive of positive mathematical performance on that task. With limitations, this research is used to discuss the importance of developing persistence in students in a mathematical classroom.

The purpose of this research was to investigate persistence and its effect on mathematical performance during problem solving. Schoenfeld (1992) defined problem solving as a question that is “perplexing, but difficult.” (p. 337). Commonly, people confuse problem solving with answering a problem. Schoenfeld (1992) describes problem solving as much more than answering a question that was previously not known. True problem solving requires students to think deeply about their method used towards arriving at a solution. It also requires an evaluation of the results. Problem Solving is one of the important elements of the Common Core State Standards in Mathematics (Common Core Initiative, 2010). To promote problem solving, as Schoenfeld (1992) outlined, requires problem solving opportunities that require persistence throughout the task. Merriam-Webster dictionary (2014) defines persistence as the quality that allows someone to keep doing something even if it is difficult. The nature of the Common Core Initiative (2010) highlights the importance of promoting persistence during problem solving in mathematics.

Even though non-cognitive factors, such as persistence, are important in the new Common Core standards, until recently little has been known about how to measure such skills. Such research is important towards understanding how to accurately measure persistence since persistence is required by students if they are to be college and career ready (Common Core Initiative, 2010) and research in the field (US Department of Education, 2013), has shown the importance in students to make them ‘college and career ready’.

Literature Review

Schnick Neale, Pugalee, & Cifarelli (2008) stated:

Mathematics = Underground Sewer System. It's huge, seemingly never ending, ___ with so many different ways to go. It's dark and uncomfortable, and unless someone else is leading me, I can never see much further than my small flashlight _beam in front of me.

[...] I know that it is all joined together and everything works _____ together as one giant system. (p. 328).

As the aforementioned quotation describes, Mathematics can be seen as an 'uncomfortable', 'never ending' system with many places to go and an unclear path to take. This metaphor categorized by Schinck et al., (2008) alludes to the importance of the connection of mathematical problem solving to persistence. In their study, 91% of student metaphors about mathematics contained an element of perseverance. Merriam-Webster dictionary (2014) defined perseverance as the quality that allowed someone to continue trying to do something even though it is difficult. Such non-cognitive factors often include grit, and persistence. If the definitions of persistence and perseverance are compared, they can be considered synonyms under the context of mathematical problem solving. According to Schinck et al., (2008), students demonstrated an important connections through metaphores to the importance of perseverance to mathematical problem solving.

Problem Solving

Schoenfeld (1992) defined problem solving as a question that was "perplexing, but difficult." (p. 337). He described problem solving as being able to solve a somewhat rigorous problem and evaluate the results on the effectiveness of the solution. Problem Solving is one of the important elements of the Common Core State Standards in Mathematics (Common Core Initiative, 2010). To promote problem solving requires opportunities for students to use and develop persistence (Schoenfeld, 1992). Students commonly feel different than educators, because they are driven by the solution to the problem rather than evaluating and reflecting on the process. Students feel that mathematics is about knowing the answer and being able to get to it as quickly as possible (Schoenfeld, 1992). Mathematics educators commonly embrace

problem solving as an inherent component of instruction, and is a major part of the CCSS as discussed above. However, real problem solve requires students to navigate a question that is mathematical in nature, using logical arguments both with appropriate mathematical language and symbols (Schoenfeld, 1992). True problem solving is not just following the teacher's lead, but navigating through mathematical tasks using mathematical language to hold your argument together. Beilock & DeCaro (2007) found that a student's working memory dictates the approach of different student's problem solving strategies. This approach can be altered in different situations of varying levels of stress. It was implicated that in situations of high stress, students were more apt to solve problems using simpler approaches due to their working memory constraints (Beilock et al., 2007). Overall, problem solving requires multiple processes, especially in stressful situations, which places a load on working memory.

Thom & Pirie (2002) defined perseverance in mathematical problem solving as students' ability (either led by intuition or experience) to know how to continue using a particular strategy and when to give up a strategy, after it is deemed ineffective. Through their study (2002), perseverance and control (defined as the students ability to set, evaluate, and revise goals throughout their problem solving process) were identified as two important factors to successful problem solving.

Ways to Measure Persistence

Even though these non-cognitive factors are important in the new Common Core standards, the US Department of Education (2013) has shown that we can measure persistence in four different ways. Measuring non-cognitive skills can be performed by having students fill out a self-report survey, having an informant (such as a parent, or teacher) fill out an additional survey for a student, using school records, and observing behavior from an in-class observation.

Each of these methods has benefits and trade-offs. Self-report systems ask students to evaluate their beliefs and skills related to the one particular topic. These surveys can be used to determine consistencies in student rankings and help make inferences about these students' dispositions. The trade-offs of self-report surveys is that the reliability of the student reflections can be compromised by inaccurate student reflections by either wanting to answer in a particular way, because of the contents of the study, or being very context specific in ways that can confuse the participants (US Department of Education, 2013).

Using informant reporting as a possible method to determine students' persistence can also have its benefits and trade-offs (US Department of Education, 2013). Informant reports can provide a secondary source in regards to student behavior. This is usually given by a teacher, or peer with first-hand knowledge. The observers can use specific rubrics that add a certain amount of objectivity to the results. In some cases, the same trade-offs to self-report surveys exist in informant report surveys. The information can contain bias from external perceptions. In some cases, it may be difficult for external observers to be able to accurately report on the mindset of students, as opposed to student actions (US Department of Education, 2013).

Using school records can also be a way of gathering information on students' non-cognitive skills (US Department of Education, 2013). School records like standardized test scores, homework completion, grades, and other benchmarks can provide additional information that could be tracked and collected over multiple years. This information can be used to really see trends in particular students. However, (US Department of Education (2013) says that this information can only broaden the indicators of persistence and make the results contain multiple measures of extraneous factors.

One of the newer methods is using behavior analysis as a method for determining students' ability to persevere (US Department of Education, 2013). This contains a wide variety of on demand observational data that detect and quantify specific physical indicators that can point to persistence. This method uses data on the process of learning rather than the end result and can be effectively used to really name the habits of different non-cognitive skills. This approach can sometimes be difficult because it requires diligent record keepers with assigned roles to track the behaviors. Commonly, technology can be used to help with this process, but this can be expensive and difficult to get for the purposes of research (US Department of Education, 2013). However, the standards (Common Core Initiative, 2010) and research in the field (US Department of Education, 2013), has shown the importance in accurately measuring persistence in students to make them 'college and career ready'.

Duckworth et al (2007) studied the importance of perseverance (they referred to as grit) relating to education. In four specific studies, they used a self-report grit scale to determine the connection between someone's perseverance with their educational longevity and performance. Their study showed that students with a higher grit score tended to receive higher levels of education compared to participants with lesser grit scores (Duckworth et al., 2007). This was somewhat logical, because of the time and resources it requires to pursue higher levels of education. However, in another study within the same research article, Duckworth et al (2007) compared the grit score to undergraduate students in college to their high school Grade Point Average (GPA), which is a cumulative measure of academic performance, and the student's Scholastic Aptitude Test (SAT) scores (a measure of academic intelligence) it was found that more 'gritty students' preformed with higher high school GPAs and SAT scores their lesser 'gritty' peers. More importantly, it was found that in the sample of college students, those more

intelligent students were found to have lower grit scores other peers (Duckworth, 2007). Moutafi, Furnham, and Paltiel (2005) conclude, “That among relatively intelligent individuals, those who are less bright than their peers compensate by working harder and with more determination.” (Duckworth et al, 2007).

How to Promote Persistence

The US Department of Education (2013) identified three areas that promote the features of grit, tenacity, and perseverance as: (1) academic mindsets; (2) effortful control; and (3) strategies and tactics. They defined academic mindsets as the environment and their self-image of themselves as learners. It includes students’ personal beliefs and attitudes related to what they are learning. These self-perceptions can be indicators into the mindset of a student and allow teachers and researchers to determine a student’s ability to persist (US Department of Education, 2013). Additionally, they suggest promoting a growth mindset in terms of learning, rather than a fixed mindset. In a growth mindset, students are seen as life long learners, where their success is determined by their work ethic rather than intelligence. In contrast, a fixed mindset dictates a student’s perception to feeling bound by their intelligence and/or current intellectual abilities.

The effortful control element refers to a student intrinsic or extrinsic motivation. It is reasonable to conclude that a student’s motivation to complete the task is highly connected to the motivation that student has for the completion of the task (Thom & Pirie, 2002; Schwartz, 2005). However, effortful control also considers the student’s ability to have the will power and ability to block out distractions to be able to persist in the task (US Department of Education, 2013). This particular element is nested within the student’s ability to be able to handle the emotional stress and overcome it to demonstrate persistence.

The last element is strategies and tactics used during the task. The US Department of Education (2013) found that students are more likely to persevere within a task if they can specifically draw on a particular strategy/tactic during the task to help them self regulate throughout the task. These strategies can be specifically tied to the content (ie: graphic organizer for writing assignments, use of manipulatives to encourage students to play with mathematical concepts, ect.) or more broad to managing the task (checklist for managing the task, partner work, ect.). It should be noted that all three of the elements noted by the US Department of Education (2013), could be taught/developed by teachers in the design/implementation of lessons throughout the year.

Research Questions

There are three research questions. First, what is the relationship between persistence (measured as time spent) and performance (see the criteria to measure performance in the appendix) on a mathematical problem-solving task? Second, how do the constructs from persistence research correlate with outcomes from persistence and performance? Lastly, what constructs and variables are actually predictive of persistence during the problem-solving task?

Method

The method for this study was a quantitative method of data collection from a maximum sample of 32, 6th grade students at an urban charter school. These students were selected from a 6th grade class, in an urban educational setting, that has a wide diversity in student population. The data collection will contain elements from the four different methodologies reported by US Department of Education (2013) and synthesize their findings to increase the reliability and validity of the results. Each student will partake in a self-report survey about the student's

perceptions related to the use of persistence in mathematics. Schommer-Aikins, Duell, & Hutter (2005) used a questionnaire assessing students’ beliefs relating to mathematical problem solving using the Indiana Belief Scale (Kloosterman & Stage, 1992) and the usefulness of mathematics scale (Fennema & Sherman, 1976). Their research used factor loading to make 7 different categories (Effortful Math, Useful Math, Math Persistence, Math Confidence, Understanding Math Concepts, Word Problems, and Nonprescription Math). From these categories, 4 were specifically related to mathematical persistence, (Effortful Math, Math Persistence, Math Confidence, Understanding Math Concepts). From these 4 areas, the questions were used and randomized to create a 15-question survey that all students will complete. The survey containing the four factored groups that was modified from Schommer-Aikins, Duell, & Hutter (2005) can be seen in table 1.

Table 1:

Constructs Created from Factor Analysis showing the Item Number and the Survey Question.

Factor and Construct	Item Number	Survey Questions
1 Effortful Math (7 Items)	2	Ability in math increases when one studies hard.
	12	By trying harder, one can become smarter in math.
	8	I can get smarter in math if I try hard.
	11	Working can improve one’s ability in mathematics.
	4	I can get smarter in math by trying harder.
	15	Hard work can increase one’s ability to do math.
	9	I find I can do hard math problems if I just hang in there.
2 Math Persistence (2 Items)	5	If I can’t do a math problem in a few minutes, I can’t do it at all. (reverse scored)
	6	If I can’t solve a math problem quickly, I quit trying. (reverse scored)
3 Math Confidence (3 items)	7	I feel I can do math problems that take a long time to complete.
	10	Math problems that take a long time don’t bother me.
	1	I’m not very good at solving math problems that take a while to figure out. (reverse scored)

4 Understanding Math Concepts (3 items)	13	It's not important to understand why a mathematical procedure works as long as it gives the correct answer. (reverse scored)
	14	Getting the right answer in math is more important than understanding why the answer works. (reverse scored)
	3	It doesn't really matter if you understand a math problem if you can get the right answer. (reverse scored)

Each item given to students is on a Likert Scale from 1 to 5, where 1 is strongly disagree, 2 is disagree, 3 is neutral, 4 is agree, and 5 is strongly agree. This 15-question survey used in this study also contains some reverse scored items that would be tabulated in a similar manner, in reverse order. The original version of this survey had a Cronbach's alpha range from .54 to .84 demonstrating moderately high reliability (Schommer-Aikins, Duell, & Hutter, 2005) and validity is verified by Stage & Kloosterman (1995) in the predictive ability of this survey to determine student's success in college level mathematics.

In addition to the survey mentioned, students will also be actively engaged in a solving one mathematical problem. The problem is designed to be 'open' enough for anyone to try it, but still mathematically rigorous as outlined by Schoenfeld (1992). The research will consider two specific elements in this problem solving process, (1) the time that students actually spend solving the problem and (2) the accuracy of their problem solving. For (1) the time that students actually spend solving the problem, students will record the 'starting time' and flip their paper over when they are finished providing a detailed solution. The research staff will record the 'ending time' based on when the student flips the paper over. This time interval will serve to measure (1) of the problem solving process related to persistence. The problem is found below:

Sarah has a bottle of Pepsi. Kate has an equal bottle of Sprite. Sarah takes a teaspoon of Pepsi and puts it into the Sprite. Kate mixes the teaspoon of Pepsi/Sprite then takes a teaspoon

of the mixture and returns it to the Pepsi. Is there more Pepsi in the Sprite, or more Sprite in the Pepsi, or are they the same?

Construct a clear, mathematical argument for your answer using pictures/diagrams, equations/number sentences, expressions, and/or a written explanation of your logical reasoning using sentences.

Your work will be scored on the quality (completion of your argument), clarity (easy to follow), and accuracy (correctness) of your mathematical response.

In addition to the elapsed time, each student's response will be scored on a rubric to assess (2) as mathematical performance. Schommer-Aikins, Duell, & Hutter (2005) use a similar process by measuring academic performance on a six-point rubric. In this research study, four trained educators will measure each student's response as 0 = no response, 1 = inadequate response (contains major computation errors, focus entirely on the wrong mathematical idea or procedure, shows copied parts of the problem with no attempt at a solution), 3 = adequate response (omits parts or elements of the problem, contains computational errors, shows some deficiencies in understanding the problem) or 5 = superior response (clear and unambiguous, communicates effectively, shows mathematical understanding of the problem's ideas and requirements) with 2 and 4 as in the middle of those areas of performance. Four different educators will score each student's response after each teacher has received training on the context of the problem and rubric used for scoring. Every student response will receive 4 independent scores and the student's mean performance score will be the average of these four independent scores. The teacher scorers are a combination of certified teachers (both in the school and in neighboring school districts) and college faculty. The study will also use a combination of other performance indicators such as homework completion, and standardized testing as well as gender to determine the relationship between these variables and the main dependent variable of time/student performance. The combination of the student's time, mean

performance score, survey results, and other performance indicators will be evaluated and used to inform the purpose of this study.

Results

The mean performance score from the 4 independent scorers, the student responses on the survey (separated into factors by Schommer-Aikins, Duell, & Hutter (2005) and labeled as constructs) and the time were analyzed into table 2.

Table 2

Correlation Table Showing the Mean Performance Score, Time, and the Four Constructs of the Persistence Survey

	Mean Performance Score	Math Confidence Construct	Effortful Math Construct	Understanding Math Concepts Construct	Math Persistence Construct	Time
Mean Performance Score	1	-0.046	-0.148	0.009	0.042	0.436***
Math Confidence Construct	-0.046	1	0.338**	0.470***	0.717***	0.121
Effortful Math Construct	-0.148	0.338**	1	0.377**	0.125	0.385**
Understanding Math Concepts Construct	0.009	0.470***	0.377**	1	0.460***	0.229*
Math Persistence Construct	0.042	0.717***	0.125	0.460***	1	0.120
Time	0.436***	0.121	0.385**	0.229*	0.120	1

0.40 to 0.69 Strong positive relationship***; 0.30 to 0.39 Moderate positive relationship **; 0.20 to 0.29 weak positive relationship *

According to the analysis in table 2, there are multiple strong relationships determined in the data. Interestingly, the strongest positive correlation in table 2 is between the survey’s constructs of math persistence and math confidence. This is meaningful, because it shows there

is a connection between a student's confidence in mathematics and their ability to persist through a mathematical task. This seems to hold merit and can be an important finding related to mathematical persistence. In addition, the survey constructs of effortful math and math confidence, understanding math concepts and effortful math, and understanding math concepts and math confidence has moderately positive to strongly positive relationships. This helps support the reliability in the survey found by Schommer-Aikins, Duell, & Hutter (2005).

Regarding the purpose of this study, there is a strong positive correlation (0.436) between a student's time spent on the task and the student's performance on that task. In addition, three of the survey's constructs have positive correlations with time. Effortful math and time has a moderately positive correlation (0.385) and understanding math concepts and time has a weak positive relationship (0.229). So, the student beliefs of the importance of effort are positively correlated to how much time that student spends on the task. Similarly, the student's understanding of math concepts are positively correlated to how much time the student spends on the task. These findings seem to hold merit and can play an important role in the discussion.

Table 2 shows the positive correlation between the survey constructs, mathematical performance, and time spent for students. However, it is still yet to be determined whether any of these factors can predict mathematical persistence and/or performance. In order to determine the predicative nature of these qualities in this study, we introduce several control variables to establish any effects they may have towards persistence and performance. As a part of our method, we collected data on (1) homework completion percentage, (2) gender, and a (3) standardized assessment as other performance indicators. (1) Homework completion is determined by the total homework assignments handed in compared to total homework assignments assigned, as a ratio, over a 3-month interval prior to the study. (2) Gender is

tabulated as male=1 and female=0. The (3) standardized assessment is known as MAP (Measure of Academic Progress). The MAP testing is a computerized adaptive assessment that is customized to students’ specific academic levels (Northwest Evaluation Association, 2012). In this assessment, students answer questions on a computer, and as they answer the questions accurately or inaccurately the adaptive test responds with harder or easier questions, respectively. Northwest Evaluation Association (2004) specifies that the 6th grade MAP assessment for mathematics has an internal test-retest reliability between .91 and .94 (n = 23,389). It also shows concurrent validity between .80 and .87 (n=2,911) with the Indiana Statewide Testing for Educational Progress-Plus and the NWEA Achievement Level Test. Both of these tests are standardized measures of mathematical performance.

The constructs of the persistence survey, the mean performance score from the mathematical task, and the three control variables, were entered as main effects of the dependent variable time and analyzed. After several iterations of the model, only two variables were shown to have any significant predictive value to the dependent variable of time. These results are in table 3.

Table 3

Multiple Regression Model 1 showing Mean Score and Effortful Math Construct as Main Effects, Dependent Variable is Time (n=20, r²=0.325).

Variable and Description Name	Parameter Estimate & Significance	Standard Error	Standardized Coefficients	Min	Max	Mean
Mean Performance Score	2.525*	0.966	0.498	1.5	4.5	3.45
Effortful Math Construct	2.566*	1.066	0.458	2.67	5	4.025

*p<0.05

In this table, the mean performance score is predictive of the time spent on the problem (n=20, r²=0.325). So, the higher your mathematical performance score is on the problem, the

more time you spent on it. In addition, the Effortful Math construct is predicative of the time spent on the problem ($n=20, r^2=0.325$). Namely, the higher Likert score on the Effortful Math construct, the more time you spend on the problem. These findings will be addressed in the discussion.

Similarly, a process was used to determine the effects of the constructs of the persistence survey, the time spent, and the control variables on the dependent variable of student mean mathematical performance on the problem-solving task. This analysis is shown in table 4.

Table 4

Multiple Regression Model 2 with Gender and Maps Score as Controls and Time entered as Main Effect, Dependent Variable is Mean Performance Score ($n=20, r^2=0.395$).

Variable and Description Name	Parameter Estimate & Significance	Standard Error	Standardized Coefficients	Min	Max	Mean
Gender	-0.958*	0.360	-0.493	0 (Female)	1 (Male)	-----
MAPS Score	0.025*	0.012	.405	195	253	227.65
Time (minutes)	0.099*	0.036	0.501	2	15	8.95

* $p < 0.05$

According to table 4, the gender of the student is predictive of student mean performance ($n=20, r^2=0.395$). Specifically, females tended to score almost a point higher than males in mean performance on the mathematical problem-solving task. In addition, the MAPS performance score is also predictive of student performance ($n=20, r^2=0.395$). This seems to hold merit, because the mathematical performance on the MAPS standardized test was consistent with the performance on the mathematical problem-solving task. This speaks to the reliability and validity of the mathematical problem-solving task with other standardized assessments. Lastly, the time spent on the problem is predictive to the student mean performance score. This means that the more time that a student spent on the mathematical problem solving task, the higher that student scored on average. These findings will be addressed in the discussion.

Limitations

In this study, there are multiple limitations that should be discussed. This study used a randomized sample of 20 students from one urban school. The sample size of 20 students is sufficient for these findings, but should be considered as one limiting factor in interpreting the results. In addition, there were far more female participants than male participants (17 female, 3 male) because of the school environment and logistical complications. This factor could lead to a minimal amount of experimental bias within the data and some statistical anomalies already described in the results.

Another interesting limitation with this study is the measure of mathematical performance on the problem-solving task. Four independent scorers scored each student's response and a mean performance score was determined and used to inform the purpose of this study. However, one question arose throughout the investigation and experimentation in this research study. How do we quantify mathematical performance on one specific mathematical problem-solving task? As Schoenfeld (1992) claimed that problem solving requires deep thinking, understanding, and evaluation of their findings. For this study, a rubric was used to evaluate student's computational accuracy, the correctness of their mathematical idea/procedure, and overall understanding of the constraints of the problem. For this task, students had to make a claim rooted in the mathematical problem and support this claim with logical, coherent evidence. However, it was clear from exit interviews with each scorer that the effectiveness of a mathematical argument doesn't exactly imply the correctness of their mathematical idea.

In this problem, a student came to a conclusion that was not the 'correct' answer for the problem, but supported their conclusion with correct logical evidence and models. Several

scorers gave this example the same score as a student that received the correct end result to the problem, but did not support their claim sufficiently. The rubric correctly was used, but the score on the rubric did not accurately depict the nuances within the solution of the mathematical problem. This is a really interesting limitation that will be discussed further in the discussion.

Another interesting limitation for this research is in the mathematical beliefs survey from Schommer-Aikins, Duell, & Hutter (2005). The survey asks students to report their beliefs regarding the importance of factors related to persistence to effectively being able to mathematically problem solve. This study from Schommer-Aikins, Duell, & Hutter (2005) describe the reliability and validity of using this survey. However, US Department of Education (2013) specifies that self-report surveys can sometimes be unreliable due to students' inability to honestly measure their own abilities. This is especially true with non-cognitive factors where students can generally self-report a higher level of agreement or disagreement because of their self-image or other external/internal environmental factors. With these limitations in mind, we should consider the contents of this study as a point to build on for further research in this area.

Implications and Discussion

The purpose of this study is to determine the effects of persistence on the mathematical performance of students while problem solving. As seen in the results, two important key findings are determined in this study that pertain to the research questions. First, the time spend on the performance task is predictive of mean student performance on that problem solving task. This seems to hold merit, but is no inconsequential finding. Regardless of other factors, the students that spent more time on the task performed better. In the educational perspective, this is a highly important finding. As math teachers, we should push our students to demonstrate persistence throughout a task as well as understanding the mathematical concepts/procedures.

One could conclude with certain limitations that this non-cognitive skill of persistence (as spending more time on the task) actually propels student performance for the better or worse. So instructionally speaking, teachers should develop curricular opportunities for students to demonstrate the non-cognitive skills of persistence regularly throughout their curriculum. This finding is consistent with the shift in the Common Core State Standards (Common Core Initiative, 2010). In addition to creating opportunities for students to demonstrate persistence, educators must also better scaffold students for developing the non-cognitive skill of persistence in a mathematical setting. Some specific and explicit strategies are given by the US Department of Education (2013) and were discussed in the literature review. This scaffolding (US Department of Education, 2013) will better set up students to be able to persist academically, which may translate to performance. This skill should not only be assessed, but also taught through curriculum. Explicitly teaching persistence in mathematics could be a possible area of further research. It is seen in this study, that students that demonstrate persistence as time spent on the activity, are predictive of positive mathematical performance.

Another interesting element of this research is the constructs within the survey's predictability of mathematical variable of time spent on the task. In this study, students that have a higher Likert score in the area of Effortful Mathematics are predictive of higher time spent on the mathematical problem. If we consider the items within the Effortful Mathematics Construct seen in table 1, they are all items that ask students to evaluate the importance of work ethic on mathematical performance. This particular construct is interesting, because it shows that students that value spending more time and working hard did actually spend more time on the problem. However, this construct was not predictive of their mathematical performance in a similar manner. This yields to a discussion about the importance of quantifying mathematical

performance in the context of problem solving. As you will recall, each problem was assessed on the accuracy and coherence of a mathematical argument. This cannot be graded in a similar manner to a math quiz or test. There are particular nuances that are important when asking students to problem solve. Mathematical educators that are truly asking students to problem solve should consider how to evaluate student's ability to accurately perform during the problem-solving task that is quantifiable with high reliability and validity. If educators want to measure and develop non-cognitive skills effectiveness on the performance, then we need an evaluation of problem solving that is equipped to accurately convey the nuances that each student exhibits throughout the process. More research can be done in this area, but a more longitudinal evaluation throughout the mathematical problem solving procedure, could increase the reliability of the mathematical performance during problem solving.

One last item for discussion is the importance of confidence related to mathematical persistence. On the correlation table 1, it was noted that students that self-report high levels of mathematical persistence also reported high levels of mathematical confidence. This is no arbitrary finding. Research (Thom & Pirie, 2002; Schwartz, 2005) shows that persistence as well as other non-cognitive factors are propelled or condemned by the student's confidence in their abilities and motivation in the task. Developing mathematical confidence could be the main factor for students to demonstrate persistence throughout a mathematical task. This could be an area of future research and tie tightly to the instructional design teachers can use to help develop persistence.

This research study highlights many of the important aspects of assessing and validity of the claim that persistence does matter for student success. This claim is made by the implementation of the Common Core Standards (Common Core Initiative, 2010) and other

research in the field (Duckworth et al., 2007). It was seen in this study that persistence as depicted as time spent on the task is an important predictive factor to mathematical performance in problem solving. More research is needed on the extent to which persistence actually can benefit students' performance in mathematical problem solving, but it is seen that these non-cognitive factors do play a crucial role in student success.

References

- Beilock, S. L. & DeCaro, M. S. (2007). From poor performance to success under stress: working memory, strategy selection, and mathematical problem solving under pressure. *Journal of Experimental Psychology*. 33:6. 983-998.
- Common Core Initiative (2010). National Governors Association Center for Best Practices & Council of Chief State School Officers. *Common Core State Standards*. Washington, DC: Authors.
- Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: perseverance and passion for long-term goals. *Journal of Personality and Social Psychology*. 92:6, 1087-1101
- Fennema, E., & Sherman, J. (1976) *Fennema-Sherman mathematics attitudes scales: Instrument designed to measure attitude toward the learning of mathematics by females and males*. Madison: University of Wisconsin, Center for Educational Research.
- Kloosterman, P., & Stage, F. K. (1992) Measuring beliefs about mathematical problem solving. *School Science and Mathematics*. 92, 109-115.
- Moutafi, J., Furnham, A., & Paltiel, L. (2005). Can personality factors predict intelligence? *Personality and Individual Differences*, 38(5), 1021–1033.
- Northwest Evaluation Association (2004). *Reliability and validity estimates*. Retrieved from http://images.pcmac.org/Uploads/Jacksonville117/Jacksonville117/Sites/DocumentsCategories/Documents/Reliability_and_Velocity_Estimates.pdf
- Northwest Evaluation Association (2012). *Measures of academic progress: MAP basic overview*. Retrieved from http://legacysupport.nwea.org/sites/www.nwea.org/files/resources/MAPBasicsOverview_0.pdf
- Perseverance. 2014. In *Merriam-Webster.com*. Retrieved November 9, 2014, from <http://www.merriam-webster.com/dictionary/perseverance>
- Persistence. 2014. In *Merriam-Webster.com*. Retrieved November 9, 2014, from <http://www.merriam-webster.com/dictionary/persistence>

- Schinck, A. G., Neale, H. W. Jr., Pugalee, D. K., & Cifarelli, V. V. (2008) Using metaphors to unpack student beliefs about mathematics. *School of Science and Mathematics*. 108:7, 326 – 333
- Schoenfeld A. H. (1992). *Learning to think mathematically: problem solving, metacognition, and sense making in mathematics*. Handbook for Research on Mathematics Teaching and Learning. New York: Macmillan.
- Sparkman, L. A., Maulding, W. S., & Roberts, J. G.. (2012) "Non-cognitive predictors of student success in college." *College Student Journal* 46:3 (Sept. 2012) p642
- Schwartz, A. E (2005). Learning math takes attitude, perseverance and courage. *The Hispanic Outlook in Higher Education*. 16. 35-37. (November 21st, 2005)
- Stage, F. K., & Kloosterman, P. (1995). Gender, beliefs, and achievement in remedial college level mathematics. *Journal of Higher Education*. 66, 294-311
- Thom, J. S. & Pirie, S. E. B. (2002) Problems, perseverance, and mathematical. *Educational Studies in Mathematics*. 50:1. 1-28
- US Department of Education (2013). *Promoting grit, tenacity, and perseverance: critical factors for success in the 21st century*. Center of Technology in Learning. SRI International. (February, 2013)