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ST Math Student Outcomes: Response to Goal-Setting and Mathematical Supports when Applied to the ST Math Problem-Solving Process

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Abstract

The purpose of this action research study was to identify the impacts of goal-setting and the use of mathematical tools on student performance while engaged in Spatial Temporal (ST) Math. The study was conducted in eight Kindergarten classrooms across eleven elementary schools in Northeast Iowa. Quantitative data was collected at weekly intervals throughout the collection period to monitor the following indicators: average number of puzzles completed, average student velocity, and average percent Journey completion. Those results were then analyzed to determine impacts based on the presence of the goal-setting and mathematical tool innovations within individual classrooms compared to those that did not engage in any of the innovations. The results of the study were not statistically significant, but did indicate the beginnings of subtle trends worthy of further study across more significant periods of time.

Keywords: ST Math, concrete-representational-abstract (CRA) progression, goal-setting, self-efficacy, problem-solving, mathematical tools

Table of Contents

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Mathematics as a content area continues to experience real-time innovation in terms of its relevance to students' future life experiences and the modalities in which students are experiencing and participating in math instruction. In particular, digital applications are entering the math learning space at a record pace never seen before. One application has recently become the center of the learning community in which I serve is Spatial Temporal (ST) Math. ST Math has been offered up as an innovative solution to a growing concern voiced by local industry leaders in our community. This concern has roots in the growing demand for students to be prolific problem-solvers. This demand, in part, is fueled by a lack of confidence in the preparedness of our learners for the ever-evolving jobs awaiting them (Chrisler, 2013). This problem-solving paradigm requires students to design, execute, evaluate, and make decisions around next steps, all the while maintaining a positive sense of self-efficacy. Our traditional problem-solving definitions and models have been short-sighted in response to these growing demands (Lester, 2013). Beyond that, mathematics appears to elicit emotional responses from children at the earliest of ages. It seems learners are presenting with math anxiety that goes beyond a singular disposition towards a task or an assessment (Szczygiel, 2020) within the earliest of mathematical experiences. ST Math is a platform seeking to place itself in the center of an educational intersection defined by digital interaction and problem-solving.

The purpose of this action research study is to quantify the impacts inherent to the use of ST Math within Kindergarten classrooms. It works to set a baseline understanding in this, our first year of implementation, of how best to support a students' ability to problem solve within the ST Math platform, while also informing their problem-solving decisions through mindful self-reflection and goal-setting. Specifically, this study attempts to identify the impacts that personal goal-setting and access to math manipulatives and tools might have on students' outcomes when engaged in ST Math. It is my hope as observations are made and data is collected we will begin to take notice and leverage the research-based outcomes inherent to the components that make up the ST Math platform. For instance, research has shown the use of the Concrete-Pictorial/Representational-Abstract (CPA/CRA) progression alone is not sufficient to provide the desired outcomes, but instead require the insight and intentionality a classroom educator brings based on their progress monitoring (Chang, Lee, & Koay, 2017). It is not enough to put a student on ST Math for twenty minutes a day and assume they will organically complete puzzles on their own. Although the platform provides a wonderfully designed series of CRA puzzles, uniquely identified student needs may need scaffolds and support in order to enhance and internalize the mathematical learning. The problem-solving process itself requires explicit support in order to effectively build mathematical coherence by students. Key principles necessary in this work and which research has proven effective include engaging students regularly in problem-solving over time, engaging students in varied problem-solving tasks, and the critical role an educator can play in supporting students' metacognitive awareness (Lester, 2013).

The support necessary to elevate this action research and provide the proper bearings came from numerous peer-reviewed journals made available through the academic databases provided by Northwestern's own DeWitt Library. The research was limited to that which had been published within the last ten years. However, there were references within those journals to pertinent seminal works around the Concrete-Representational-Abstract (CRA) progression and problem-solving dating back some time before that. Careful attention was dedicated to identifying sources that would provide both unique contributions and meaningful intersections with each of the other source topics. The twenty sources were evenly distributed across the following topics: self-efficacy as it relates to early childhood, the CRA progression, digital/virtual learning impacts, and problem-solving as a learning process.

The forward-thinking demands being placed on even our earliest of learners have not lessened the need for instructional innovation by classroom teachers. In fact, problem-solving for our newest digital learners requires a heightened understanding by educators of both their impact and the impact of the various innovations introduced into their classrooms. The reality is, an innovation is only capable of effectiveness when applied in conjunction with high-impact instructional strategies. This study is designed around the predilection that student goal-setting and the use of concrete mathematical tools are necessary to appropriately leverage instructional platforms, such as ST Math, towards their most positive of student outcomes. The importance of this work cannot be overstated. Educators need not question the relevance of their interceding on behalf of their learners to ensure that all students have equitable access to learning. Each opportunity to reflect with a student around their personal goals and the metacognitive work being accomplished produces the confidence necessary to wield the various mathematical tools capable of overcoming any number of mathematical quandaries.

The literature review begins with historically relevant thinking around the mathematical self-efficacy of students. Right upfront it addresses the recognized struggle by students, at even the earliest of ages, to see themselves as mathematical thinkers and learners. All things equal, if a student does not see them self as a mathematical learner, the opportunities to encourage metacognitive reflection and risk-taking with concrete mathematical tools will almost be non-existent. Once the preeminence of self-efficacy is established, a critical discussion as to the significance of the CRA progression within math instruction will occur. Care has been taken to clarify the interplay that comes from the linear opportunities a student might experience through the CRA progression, while also encouraging the simultaneous use of each component when students are engaged in problem-solving. Time must also be given to clarifying basic understanding as to the digital learning landscape students are finding themselves more and more engaged in. Establishing reference points from leaders, like the National Council of Teachers of Mathematics (NCTM), balances concerns for rigor and relevance moving forward. Finally, the literature review will take a look at the preliminary work ST Math has been engaged in across the United States, noting the unique way in which impacts are surfacing both at the instructional and assessment level in individual classrooms.

ST Math's attempt to meet the demands being placed on today's learners has demonstrated statistically significant outcomes worth noting as more and more schools, like the ones I serve, consider embarking on the ST Math Journey.

Review of the Literature

Mathematical Self-Efficacy

According to Szczygiel (2020), even our earliest learners are arriving at school with some indication of established math anxiety. Recent studies have uncovered a complex set of intersections of proposed antecedents and student outcomes centered around the role of mathematical self-efficacy, particularly that of our youngest of learners. For too long, research centered on our youngest learners has drawn its conclusions primarily from students with disabilities (Aunola, et al., 2004). A broader look at early childhood self-efficacy in regards to math is necessary. Our understanding of antecedents of negative mathematical self-efficacy in young children is also impeded by an overall lack of understanding of mathematical development prior to a student's formal education.

A personal self-efficacy belief system, although at the center of many of today's cultural conversations, has not exclusively been determined to be the primary antecedent correlated to mathematical achievement. One recent debate has pitted self-efficacy against the notion of grit (Usher et al., 2019). In other words, does a higher self-efficacy belief based on past experiences create the ability to dig in and proceed (grit) or is success a function of the grit a student brings to a task which in turn builds their future self-efficacy? To be sure, enduring research has demonstrated that self-efficacy is a strong predictor to successful student outcomes (Bandura, 1997; Schunk & DiBenedetto, 2016; as cited in Usher et al., 2019). It has only been recently that traits, such as grit, and their impacts have been introduced into the self-efficacy paradigm.

It would be difficult to take a critical look at self-efficacy without considering emerging links with goal-setting. Smithson (2012) determined that in the same way goals are correlated with student academic outcomes, goals also lead to an increasing sense of self-efficacy, particularly as it relates to intrinsic motivation. The research does not allow for any generic use of goal-setting, but addresses goals that are specific and defined incrementally as smaller sub-goals. The intersection between self-efficacy and success in goal-setting is also dependent on a student's opportunity to be not only the originator but also the maintainer of their personal goal-setting process.

The process of goal-setting taps into an individual student's ability to maintain motivation towards an outcome or task. This motivation will in no small part be directly impacted by their personal set of beliefs around the content being considered. Research has indicated mathematical beliefs are established early and once established are quite difficult to change (Linder, Smart, & Cribbs, 2015). In light of these findings, the NCTM has embedded specific strategies intending to enhance motivation as a part of their instructional practices (NCTM, 2014 as cited by Linder, Smart, & Cribbs, 2015). Within motivation, there is a sense of student expectancy that is also at play: whether or not they believe there is a way forward for them within a task. Even if they see a way forward, their evaluation of the relevance of the task may either enhance or disrupt their self-efficacy belief moving forward. Researchers have found that students having legitimate rationales connected to their goals is a prerequisite for their willingness to learn, which in turn will mitigate against an assortment of negative impacts that diminish a student's self-efficacy, such as negative self-talk, a self-perceived incompetence, and high levels of frustration (Baten et al., 2020).

It would be shortsighted to overlook the intersection between a student's self-efficacy and the nature of the tasks placed before them. Experience has shown many of the negative outcomes experienced by students when engaged with math tasks are not exclusively a product of the learner's self-efficacy, but instead emerge from a misappropriation of overly difficult tasks outside of a student's zone of proximal development. Baten and colleagues (2020) discovered that presenting students with tasks that are unnecessarily difficult will undermine their overall interest in math, produce irritation expressed in a variety of ways, and will ultimately produce disengagement.

These recent studies have called for a purposeful examination of Kindergarten students and their self-efficacy in regard to mathematical tasks. In particular, will students engaged in ST Math demonstrate greater positive achievement based on self-efficacy than those without as the data suggested for Usher and colleagues (2019)? Specifically, Usher et al. found students who view themselves as capable will "persevere longer, put forth more effort, and monitor their own progress in order to ensure success" (2019). For those students who are not inclined to experience a sense of self-efficacy in regard to mathematical tasks, this action research will attempt to establish the findings of Szczygiel (2020) within the Kindergarten cohort, which has concluded math anxiety in fact has its own unique indicators separate from other general anxiety concerns.

The role of the teacher has been purposefully absent up to this point in order to highlight their fundamental influence. Researchers have concluded they do in fact have influence on the nature of student's math experiences, which directly influences student's self-efficacy. Indeed, a teacher's personal perception about mathematics will inform their instructional practices and level of support for students (Linder, Smart, & Cribbs., 2015). Subsequent to that is the nature of the classroom environment created out of those beliefs. Linder et al. indicated the nature of this type of positive environment is one in which the value of math was clearly tied to: establishing future goals, the building of trust within the community which provided for the ability of students to take risks and make errors alongside one another, and an overall environment where students perceived engaging in math as even being fun.

Any concern derived from a look at our youngest math learners should be taken quite seriously. Recent research has indicated differences found between individual learners in their mathematical achievement prior to formal education only grew much larger as those students moved into their primary school experiences (Aunola et al., 2004). Moreover, Aunola and colleagues found ever-increasing time needs to be put towards equipping students with metacognitive skills in order to improve their math outcomes. Ultimately these outcomes are impacted by the same metacognitive skills that Smithson (2012) alluded to such as various types of reflection tied to goal-setting, which contributes to a student's growing measure of self-efficacy.

The impact of student self-efficacy within mathematics cannot be overstated. Providing students with the appropriate scaffolds from the very beginning helps to align students to tasks and tasks to students (Baten et al., 2020). This allows for the maximum sense of mathematical self-efficacy possible. This study will take a look at how ST Math embeds supports conducive for learning and contributes to a student's ability to track and anticipate their own personal outcomes. Layering those inputs onto a student's already established personal mathematical self-efficacy will provide insight as to the impact those earliest of beliefs have on their ability to achieve.

Concrete-Representational-Abstract Learning Sequence (CRA)

The impact of the CRA progression continues to demonstrate a power of linking conceptual mathematical understanding to unique contexts and origination stories (Buczynski, McGrath, & Myers, 2011) that moves well beyond procedures and protocols. Built on the seminal work of Jerome Bruner, other researchers such as Pape and Tchoshanov, have elaborated on his original learning sequence consisting of enactive, iconic, and symbolic understandings (Milton et al., 2019). Research has consistently documented students who have access to instructional practices that intentionally leverage the CRA progression engage in increased creative thinking and exploration around mathematical themes (Buczynski, McGrath, & Myers, 2011), while also demonstrating more meaningful mathematical student discourse and problem-solving (Mudaly & Naidoo, 2015).

What exactly does the CRA progression represent in terms of student learning? Mudaly and Naidoo characterize it as a series of stages learners move through beginning with literal hands-on experiences with mathematical tools or even everyday objects. This stage is followed by a learner's ability to represent their "real-world" experience via drawings or diagrams. The process concludes as students orient their developing understanding to established symbolic notation, which ultimately, over time, allows for automaticity in its use (2015). One might assume the mere appearance of these phases in the classroom would indicate best instructional practice, but according to Chang and colleagues, the learning sequence alone is not sufficient to produce desired student outcomes (2017). Their research demonstrates an intentionality within the process is necessary in order to leverage the CRA progression to its fullest potential.

A common mythology around the use of the CRA learning progression is learners outgrow or leave behind their originating concrete experiences (Chang, Lee, & Koay, 2017). The reality is those learners that do, in fact, leave behind those hands-on experiences most likely were in classrooms where the concrete experiences were not leveraged to meet unique outcomes set specifically for their learning (Mudaly & Naidoo, 2015). True appearance of absence indicates an independence from concrete and representational supports because abstraction has become the dominate means of communicating understanding (Chang, Lee, & Koay, 2017). Taking a step back, there are many who would conclude the CRA progression itself is the ultimate in scaffolding for learners. Mudaly and Naidoo (2015) found master teachers had an intuition that led them to provide discrete support even before exposing students to concrete or pictorial representations. Not unlike every other instructional practice, the CRA model is only as effective as the intentional planning invested in its use.

The sequencing of these stages plays a vital role in order “to ensure that learners acquire, retain, and master the mathematics skills at each stage of the instructional sequence” (Witzel et al., 2008 as cited by Mudaly & Naidoo, 2015). However, it is shortsighted to consider the stages as only working linearly. Chang and colleagues (2017) recognized strengthening the connection back and forth between what they referred to as external and internal interactions produced the foundation for a learner’s collective schema. One is not necessarily subservient to the other. Depending on the student, more time spent manipulating mental imagery (internal) around a mathematical model would be just as beneficial as another student who may need that same time working with the actual model itself (external). Beyond scaffolding needs, each of the CRA stages has unique student outcomes that should be monitored and measured (Mudaly & Naidoo, 2015). Identifying successes and barriers will only serve to strengthen the overall CRA progression impact on student learning.

In light of the effectiveness of the CRA progression when appropriately stewarded, the NCTM (2014 as cited by Milton et al., 2019) has officially noted balanced instruction should be grounded in conceptual understanding that supports procedural fluency and mathematical reasoning in the long run. Not only should instruction mirror all of the CRA components, but it should also be considered appropriate for all learners (Mudaly & Naidoo, 2015). Mudaly and

Naidoo found its impacts were successful for students who were identified as having considerable behavioral needs and in classrooms where ability levels were not a consideration for enrollment. Milton and colleagues' (2019) research focused on learning disabled students attempting to master their basic facts. Students in this study went from no one being able to provide an accurate response with a coordinated verbal or pictorial explanation to all participants being able to solve and support their thinking with a model.

ST Math fundamentally is grounded in the CRA learning progression. It is designed to digitally mirror how a student might experience each math task beginning from its most concrete form and systematically building in supports guiding towards ultimate symbolic abstraction. The use of various visual representations throughout also reinforce mathematical connections which ultimately elevates students' processing (Ainsworth, 1999 as cited by Milton et al., 2019). Because ST Math utilizes the CRA progression all throughout its Pre-K through eighth grade Journeys, that predictability allows students to identify where they are in their processing. This insight provides clarity as to next steps for support and instruction.

Digital Learning Impacts

Studying the impacts of digital applications on student outcomes has demonstrated considerable promise in recent studies. Over twenty years ago, the NCTM embedded pedagogical guidelines for the use of even the earliest of digital user interfaces (Scarlatos, 2006). Since then, applications such as Khan Academy have proven the so-called gamification of learning through digital applications is capable of increased student motivation universally (Light & Pierson, 2014). Beyond the application itself, students are finding themselves engaged in renewed opportunities to experience a growing self-efficacy within the mathematical digital landscape (Tarning & Silvervarg, 2019).

Before painting too optimistic a picture, it is important to note the limitations associated within the current digital landscape reality. Cayton-Hodges and colleagues (2015) surveyed the most popular mathematical educational platforms and noted several shortcomings worth considering. While mathematical accuracy was present in almost all platforms, nevertheless, the richness, or what might more commonly be referred to as rigor, was not often to be found. Most platforms were unable to provide opportunity to demonstrate any true competence in the area of mathematical practices. Their research also revealed the limited amount of feedback, scaffolding, and self-reflection provided within the majority of applications.

An interesting outcome that emerged from the work of Tarning & Silvervarg (2019) indicated there were effects unique to digital platforms that worked to deflect negative impacts of math as a content area on an individual's self-efficacy. An ego protective buffer, created by what they referred to as a digital tutee, allowed for a perceivable distance between how a character within the platform performs with what a student might have normally considered a personal failure on their own part. Their research also identified the protégé effect having considerable impact in particular on students with low self-efficacy. This effect is produced as a learner takes on the role of a teacher and/or role model for the digital tutee embedded within the platform. For students who do not see themselves as math thinkers, this may be the first time they have found themselves in this role, which the researchers found to have increased the student's overall effort. These outcomes only reinforce what other researchers continue to identify in their own work. Digital platforms are producing positive impacts for students in regard to their attitudes towards math and personal confidence in their previous learning and ability to grow in their skill level (Scarlatos, 2006).

It is necessary for educators to come to terms with the reality that students today "represent a generation of digital natives, those who have lived their entire lives surrounded by technology" (Prensky, 2001 as cited by Chrisler, 2013). Within that context, the conversation around student self-efficacy diverges a bit from the self-efficacy and clarity attributed to the educator. Today's students do not limit technology to an assistive tool. They recognize how it actually has the potential to enhance their understanding of concepts and skills (Chrisler, 2013). Kelly Chrisler experienced this first hand as she witnessed 5^{th} grade students leveraging a spreadsheet to solve for and graph functions. In order for students to harness the potential of a spreadsheet they quickly recognized it was only as powerful as they made it. It was up to them to "learn how to explain to the spreadsheet how to think" (Chrisler, 2013).

ST Math finds itself at the nexus of these realities and wonderings. It attempts to bridge the critical conceptual foundational understanding necessary for more abstract application, while also providing a digital landscape intending to create a bridge between their literal concrete experiences with Unifix cubes and other material math tools to the spatial temporal reality of which they are citizens. JiJi, ST Math's digital tutee, acts as a representative of a student's thinking and learning from a distance. This digital tutee is capable of providing a buffer that works to preserve a student's mathematical self-efficacy, whether they are experiencing failure or success.

ST Math – Problem-Solving Platform

Problem-solving has many forms and functions both in and out of the classroom. Problem-solving intersecting spatial temporal mathematical thinking provides a unique set of opportunities and outcomes. As early as 2010, the NCTM began recommending spatial temporal thinking be fully integrated into elementary mathematics curriculum (NCTM, 2010).

Observations made have primarily been focused on adults and secondary learners up to this point. This most likely has been in response to the evidence indicating the United States has experienced mathematical growth well below the rest of the world, as recorded on the National Assessment of Educational Progress (NAEP), Trends in International Mathematics and Science Study (TIMMS), and other respected data sources (Wendt, Rice, & Nakamoto, 2019). It seems high time that observations pivot towards our earliest of learners in order to uncover foundational interventions that may shift outcomes towards the future mathematical demands awaiting our learners.

Wendt, Rice, and Nakamoto, of the nonpartisan and nonprofit research and development service agency WestEd were contracted by The MIND Research Institute to provide an independent assessment of the ST Math program across multiple states. They defined this game-based, instructional software as a product designed to increase math comprehension through visual learning. Not only is the platform void of any language requirements by students, it begins each series of objectives as visual puzzles supported by virtual concrete manipulatives and representations. Each attempt provides visual feedback to support students' ability to solve. Their guide through this learning is JiJi, a cartoon penguin, who overcomes various obstacles as students solve each of the spatial puzzles (2019).

The WestEd results evidenced a statistically significant impact for those participants who engaged in what the study defined as full implementation across grades two through five (Wendt, Rich, & Nakamoto, 2019). Those measures were characterized in two distinct ways. The first statistic observed was increased mean scores on individual states' standardized tests as compared to those not identified as either fully implementing or not implementing at all. The secondary marker demonstrated a higher proportion of students scoring proficient and advanced in math.

This was true across grade-level and within sub-groups such as high socio-economic need and all designated ethnic/racial categories (Wendt, Rice, & Nakamoto, 2014).

Initial data reviews present a favorable disposition towards the integration of ST Math within the primary educational experience for all students. The notion of fidelity was recognized as a highly dependent factor throughout. In particular, participation rates were to be maintained at 85% participation or higher by grade-level cohorts (Wendt, Rice & Nakamoto, 2019). Acknowledging this, our first year of implementation, is setting a baseline to establish precedence, we have experienced daily participation rates between 53% and 84% at the site with three elementary classrooms and between 53% and 88% at the site with five elementary classrooms throughout the entire year. Ironically, both buildings experienced their highest log-on rate during the collection period considered within this research. The range of participation during the collection period was between 71% and 88% at the five-classroom site and between 69% and 84% at the three-classroom site.

This research will continue to build on these initial findings in order arrive at a more precise understanding of ST Math’s impact on student learning. As structures and protocols are reinforced that support this implementation, it would be important to monitor our buildings’ adherence to designated fidelity checks in order to better understand its impacts on our students’ outcomes.

Methods

Research Questions

The purpose of this study was to determine whether or not students' experiences and ultimate outcomes when engaged with ST Math were positively impacted by their engagement with goal-setting, as well as the access and use of a variety of math tools. The action research focused specifically on the following questions: What impacts does personal goal-setting have on a student's outcomes when engaged with ST Math? What impacts does the access to math manipulatives and tools have on a student's outcomes when engaged with ST Math?

Innovations

This study will determine the effects of identified innovations independently chosen by classroom teachers on a student's academic outcomes within ST Math. The control classrooms will be identified as those that exclusively engage in the mandatory district-wide expectations for a year-one implementation of ST Math. Those requirements are as follows:

- Adherence to the building master schedule which allows for twenty minutes of ST Math daily.
- Kindergarten's overall average goal is to complete between sixty and seventy-five puzzles per week.
- The goal is for students to have their minutes spent on ST Math and the puzzles completed be in a 1:1 ratio on average across a classroom (velocity).
- Teachers, when offering feedback and support to students, should initially begin by asking: What have you tried? What did you learn from the feedback? What are you going to try next?

- If students are receiving an alert, which indicates ten or more unsuccessful attempts, additional support may be provided.

All other classrooms who are providing the additional innovations will also adhere to these mandatory expectations.

The classrooms will be sorted and monitored based on their self-reported use of the given innovations. The following sub-categories will be considered: control classrooms, goal-setting classrooms, math tools classrooms, and classrooms who are engaged in both innovations. Percentage growth will be monitored on a weekly basis throughout the study.

Goal-setting as an innovation could be conducted by monitoring overall classroom data and/or individual student progress on their own personal Journey. Monitoring tools for this innovation were not prescribed. Classroom teachers had access to all on-line ST Math suggested resources and printables, but they were also free to create their own monitoring tools or even simply display classroom goals on a whiteboard or anchor chart. Classrooms self-identified as goal-setting classrooms indicated they engaged in goal-setting consistently. The use of math tools as an innovation offered a wide array of options as well. Teachers were allowed to follow the list of manipulatives recommended by ST Math or substitute alternative math tools based on their students' preference and familiarity. Classrooms self-identified as math tool classrooms indicated their students not only had access to the appropriate math tools, but their students were also consistently accessing math tools as a part of their problem-solving process.

Setting

The study took place within two elementary building locations in our community: Kittrell Elementary and Lincoln Elementary. These elementary buildings are a part of the larger Waterloo Community School District in Waterloo, Iowa which encompasses eleven total elementary buildings. Eight general education Kindergarten classrooms between the two K-5 buildings were monitored. The classrooms were diverse in population and support an inclusion educational model supported by Instructional Strategists.

Participants

The participants of the eight classrooms consisted of one hundred eighty students. The diverse population represented the following racial designations: fifty-eight African American, fourteen Asian, twenty-three Hispanic, ten identified as multi-race, five Pacific Islander, and seventy White. These designations were self-reported by parents at the time of their enrollment. Of those students fifty-six students were also designated as English Language Learners (ELL). The gender breakdown consisted of eighty-nine females and ninety-one males. Twenty-two students had instructional Individualized Education Programs (IEP) and/or support services supported by an IEP. It is not the practice of the district to identify students in Kindergarten as needing extended learning services. In terms of socio-economic considerations, seventy-nine percent of the participants were classified as free and reduced.

Data Collection Plan

Data measures were collected via the ST Math digital platform. The data is accessible at the building level, classroom level, and the student level. For the purposes of this study, the majority of data was collected at the classroom level by way of embedded reporting mechanisms that provide weekly updates across a number of data points. The data points that were exported in response to the research were: classroom average number of puzzles completed per student, average classroom velocity, and the average percent progress by each classroom.

The average-number-of-puzzles-per-student data is calculated by finding the sum of all the participants' completed puzzles throughout the data collection period and dividing the sum by the number of contributing participants. ST Math recommends Kindergarten students on average complete 40 puzzles per week.

Average velocity is calculated at the classroom and individual student level. This measure represents the number of puzzles students are completing every minute. For the purposes of this study the classroom average will be followed, while individual student data may be referenced when drawing conclusions as to the velocity status for a given classroom.

The platform calculates the percent progress at each grade level based on a fixed number of puzzles no matter which content they are accessing. Students at any particular time may be engaged in their grade level Journey, assigned levels from a previous grade level, interacting with bonus fluency objectives, or struggling through truly spatial temporal challenges. No matter the source of the puzzle, the platform assimilates all puzzle completions by the student and compares it to their grade level's fixed number of puzzles. Kindergarten's fixed number is 2,500 puzzles.

Within the ST Math platform student data is archived in three unique ways. First, when a student logs out of ST Math it will automatically archive their current status. Also, when a student completes a level the platform updates their data automatically. Finally, as students are working towards those outcomes the platform updates a student's progress every three minutes. At the researcher or teacher level, those student data points are synched to the teacher dashboard each time it is signed into or when the browser is refreshed. In terms of averaged data and the reset of the collection period, the platform resets itself every Sunday at 11:59 pm.

Data analyzed for the purposes of this study began being collected on March 21, 2022 and will be pulled through April 8, 2022. This will be the window in which identified commitments by classroom teachers towards the various innovations will be observed and analyzed. In order to provide a more robust analysis, data from the previous two weeks of school will be included. The week of Spring Break will be noted, but omitted from the overall analysis. There was no expectation students would log into and engage with the platform outside of school throughout that week. Data will be monitored throughout the study, but will be pulled each Monday throughout the collection period (March 21, March 28, and April 7) by the researcher.

Data Analysis Plan

The data analysis plan will incorporate the Four-way Factorial Means Test in order to respond to the following questions: Did the groups start off at the same level before the innovation? Did the control group improve across the collection period? Did the treatment group improve across the collection period? Did one group outperform the other group following the innovation? Test one consisted of an independent samples t-test (two-sample). Test two consisted of a dependent sample t-test (paired). Test three consisted of a dependent sample t-test (paired). Test four consisted of an independent samples t-test (two-sample). Each of the four tests will be performed on the data representing the number of puzzles on average completed each week, the average percent Journey completed, and the average velocity recorded across each classroom per week.

All data pulled from the platform dashboard will be collected in an Excel spreadsheet created and maintained securely by the researcher. Any anecdotal notes related to classroom observations that might impact the data analysis will also be collected within the data collection document. The document will not be shared with any of the classroom teachers or building administrators unless requested. If a request is made and approved by the researcher, the document will be shared as “view only” and all data will be anonymous. All data collected will be strictly kept by the researcher until the conclusion of the collection period. Once the research has been completed and submitted, the outcomes will be shared with the classroom teachers and administrators, as well as any other interested stakeholders who request access.

Institutional Review Board Approval

The Northwestern College Institutional Review Board (IRB) processed and approved the application for Educational Practice Exemption on March 3, 2022 prior to engagement with data collection. The exemption was approved based on evidence indicating the project would be conducted as a part of an established educational setting involving normal educational practices and would pose minimal risk to student learning and teacher assessment.

Findings

Data Analysis

Data was collected across three separate, but related, student outcomes within the ST Math teacher dashboard. All participating students' data within each classroom was considered in the analysis as each student contributes to the classroom averages measured within each collection period. The first analysis documents the inherent growth experienced by each classroom across the collection period. The second data set analyzes the measured velocity within each classroom. Velocity considers the number of puzzles on average completed within a minute. Finally, data measuring the growth in the number of actual puzzles completed per week within the collection period was analyzed.

ST Math Average Percent of Journey Analysis

An independent samples t-test was conducted to determine whether there was a significant statistical difference experienced by students' progress within their grade-level ST Math Journey between those identified as the control group and those that were in the treatment group prior to the innovations. The pretest mean scores for students in the control group (M = 44%, SD = 0.20) and the treatment group (M = 48%, SD = 0.06) showed no significant difference, t(6) = -0.447, p = 0.671. Students were experiencing comparable progress within their Journeys prior to the innovations.

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*	
Mean	0.436666667	0.478	
Variance	0.040833333	0.00367	
Observations	3	5	
Pooled Variance	0.016057778		
Hypothesized Mean Difference	0		
df	6		
t Stat	-0.446640751		
P(T<=t) one-tail	0.335401565		
t Critical one-tail	1.943180281		
P(T<=t) two-tail	0.670803129		p = 0.6708 (p > 0.05)
t Critical two-tail	2.446911851		Not statistically significant

A dependent samples t-test was then conducted to determine the rate of growth by those students within the control group from the beginning to the end of the designated data collection period. Students within both the control and treatment groups were expected to experience growth inherent to the Journey data collected. Students in the control group showed significant growth from prior to the data collection period (M = 44%, SD = 0.20) and the end of the data collection period (M = 55%, SD = 0.24), $t(2) = -4.375$, $p = 0.0484$ ($p < 0.05$). The average Journey percentage represents the mean percentage growth of all students within a classroom as they complete levels. Students experiencing ST Math according to the District expectations experienced meaningful growth in their classroom average Journey percentages across the collection period.

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*	
Mean	0.436666667	0.553333333	
Variance	0.040833333	0.057633333	
Observations	3	3	
Pearson Correlation	0.992892674		
Hypothesized Mean Difference	0		
df	2		
t Stat	-4.375		
P(T<=t) one-tail	0.024238658		
t Critical one-tail	2.91998558		
P(T<=t) two-tail	0.048477316		p = 0.0485 (p < 0.05)
t Critical two-tail	4.30265273		Statistically significant

A dependent samples t-test was also conducted to determine the rate of growth by those students within the treatment group from the beginning to the end of the designated data collection period. Students in the treatment group also showed significant growth from prior to the data collection period (M = 48%, SD = 0.06) and the end of the data collection period (M = 64%, SD = 0.08), t(4) = -8.347, p = 0.0011 ($p < 0.05$). Students who experienced ST Math according to the District expectations, while also engaging in personal goal-setting and the utilization of various math tools, experienced even more meaningful growth in their classroom average Journey percentages across the collection period as well.

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*	
Mean	0.478	0.642	
Variance	0.00367	0.00607	
Observations	5	5	
Pearson Correlation	0.827358362		
Hypothesized Mean Difference	0		
df	4		
t Stat	-8.347380216		
P(T<=t) one-tail	0.000562951		
t Critical one-tail	2.131846786		
P(T<=t) two-tail	0.001125901		p = 0.0011 (p < 0.05)
t Critical two-tail	2.776445105		Statistically significant

An independent samples t-test was conducted to determine whether or not the innovations of personal goal-setting and support of various math tools resulted in different post-innovation mean percentages between students in the control group and those in the treatment group. There was no statistically significant difference between the ending average percentage of the Journey in the control group (M = 55%, SD = 0.24) and students in the treatment group (M = 64%, SD = 0.08), t(6) = -0.796, p = 0.4563. While the innovations of personal goal-setting and the access to math tools while engaged in ST Math did result in greater average percentage growth for the treatment classrooms, the student growth outcomes were not statistically significant when compared to the growth of those students who were engaged in ST Math without additional innovation support.

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*	
Mean	0.553333333	0.642	
Variance	0.057633333	0.00607	
Observations	3	5	
Pooled Variance	0.023257778		
Hypothesized Mean Difference	0		
df	6		
t Stat	-0.796117022		
P(T<=t) one-tail	0.22814921		
t Critical one-tail	1.943180281		
P(T<=t) two-tail	0.45629842		p = 0.4563 (p > 0.05)
t Critical two-tail	2.446911851		Results not statistically significant.

ST Math Velocity Analysis

An independent samples t-test was conducted to determine whether there was a significant difference in the rate at which students completed each puzzle (Velocity) within their ST Math Journey between students in the control group and students in the treatment group prior to any innovations. Velocity scores for students in the control group (M = 0.74, SD = 0.07) and treatment group (M = 0.92, SD = 0.15) showed no statistically significant difference, t(6) = -1.939. Students started with the innovations at an equivalent velocity data point prior to the embedding of personal goal-setting and math tools.

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*	
Mean	0.756666667	0.914	
Variance	0.002033333	0.02858	
Observations	3	5	
Pooled Variance	0.019731111		
Hypothesized Mean Difference	0		
df	6		
t Stat	-1.533718333		
P(T<=t) one-tail	0.087996691		
t Critical one-tail	1.943180281		
P(T<=t) two-tail	0.175993382		p = 0.1760 (p > 0.05)
t Critical two-tail	2.446911851		Not statistically significant

A dependent samples t-test was conducted to determine whether students in the control group had different pre-innovation and post-innovation velocity mean scores. Students in the control group did not demonstrate significant growth between pre-innovation (M = 0.74, SD = 0.07) and the post-innovation (M = 0.81, SD = 0.13), t(2) = -1.941, p = 0.1917 (p > 0.05). Average class-wide velocity did not substantively increase for those students who were experiencing ST Math solely within the minimum guidelines of District expectations.

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*	
Mean	0.756666667	0.84	
Variance	0.002033333	0.0073	
Observations	3	3	
Pearson Correlation	0.999297979		
Hypothesized Mean Difference	0		
df	2		
t Stat	-3.571428571		
P(T<=t) one-tail	0.035119998		
t Critical one-tail	2.91998558		
P(T<=t) two-tail	0.070239996		p = 0.0702 (p > .05)
t Critical two-tail	4.30265273		Not statistically significant

A dependent samples t-test was also conducted to determine whether students in the treatment group had different pre-innovation and post-innovation velocity mean scores. Students in the treatment group also did not experience significant growth between pre-innovation ($M = 0.92$, $SD = 0.15$) and the post-innovation ($M = 0.95$, $SD = 0.16$), $t(4) = -1.472$, $p = 0.2151$ ($p > 0.05$). Providing personal goal-setting and math tools for students engaged in ST Math also did not substantively increase the average class-wide velocity for students, even though their overall velocity was consistently higher than those not provided the innovations.

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*	
Mean	0.914	0.93	
Variance	0.02858	0.035	
Observations	5	5	
Pearson Correlation	0.984111316		
Hypothesized Mean Difference	0		
df	4		
t Stat	-0.981022943		
P(T<=t) one-tail	0.191062895		
t Critical one-tail	2.131846786		
P(T<=t) two-tail	0.38212579		p = 0.3821 (p > 0.05)
t Critical two-tail	2.776445105		Not statistically significant

An independent samples t-test was conducted to determine whether the innovations of personal goal-setting and the use of math tools would result in different post-innovation velocity mean scores between students in the control group and those in the treatment group. There was no statistically significant difference between the post-innovation velocity mean scores of students in the control group (M = 0.81, SD = 0.13) and those of the students in the treatment group (M = 0.95, SD = 0.16), t(6) = -1.264, p = 0.253. Students in both the control and treatment classrooms experienced growth in their overall average velocity. However, there was not a statistically significant growth rate due to the personal goal-setting and math tool innovations.

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*	
Mean	0.84	0.93	
Variance	0.0073	0.035	
Observations	3	5	
Pooled Variance	0.025766667		
Hypothesized Mean Difference	0		
df	6		
t Stat	-0.767739748		
P(T<=t) one-tail	0.235882483		
t Critical one-tail	1.943180281		
P(T<=t) two-tail	0.471764966		p = 0.4718 (p > 0.05)
t Critical two-tail	2.446911851		Not statistically significant.

ST Math Puzzle Data Analysis

An independent samples t-test was conducted to determine whether there was a significant difference in the number of puzzles completed weekly between students in the control group and students in the treatment group prior to the implementation of the innovations. Pre-innovation mean scores for students in the control group (M = 41.33, SD = 18.56) and treatment group (M = 47.80, SD = 4.97) showed no significant difference, t(6) = -0.773, p = 0.469. Students started the collection period completing a comparable number of puzzles prior to the treatment group being consistently exposed to the innovations.

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*	
Mean	41.33333333	47.8	
Variance	344.3333333	24.7	
Observations	3	5	
Pooled Variance	131.2444444		
Hypothesized Mean Difference	0		
df	6		
t Stat	-0.772930859		
P(T<=t) one-tail	0.234454252		
t Critical one-tail	1.943180281		
P(T<=t) two-tail	0.468908504		p = 0.4689 (p > 0.05)
t Critical two-tail	2.446911851		Not statistically significant

A dependent samples t-test was conducted to determine whether students in the control group had different pre-innovation and post-innovation mean scores. Students in the control group did not show significant growth between the beginning of the collection period (M = 41.33, SD = 18.56) and the end of the collection period (M = 64.33, SD = 49.37), t(2) = -1.236, p = 0.3420. This growth measured by the control group sets the standard for a level of growth to compare the impact of the groups experiencing the innovations (goal-setting, math tools, etc.).

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*	
Mean	41.33333333	64.33333333	
Variance	344.3333333	2437.333333	
Observations	3	3	
Pearson Correlation	0.951124417		
Hypothesized Mean Difference	0		
df	2		
t Stat	-1.23589248		
P(T<=t) one-tail	0.170980621		
t Critical one-tail	2.91998558		
P(T<=t) two-tail	0.341961242		p = 0.3420 (p > 0.05)
t Critical two-tail	4.30265273		Not statistically significant

A dependent samples t-test was also conducted to determine whether students in the treatment group had different pre-innovation and post-innovation scores. Students in the treatment group, although measuring approximately 0.03 above the threshold representing a significant statistical impact, did not provide outcomes between the pre-innovation (M = 47.80, SD = 4.97) and the post-innovation (M = 87.00, SD = 37.71), t(4) = -2.333, p = 0.080. Students engaged in goal-setting and supplemental use of mathematical tools to support their problem-solving did, on average, complete more puzzles across a week of ST Math interaction.

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*	
Mean	47.8	87	
Variance	24.7	1422	
Observations	5	5	
Pearson Correlation	0.096044883		
Hypothesized Mean Difference	0		
df	4		
t Stat	-2.333746803		
P(T<=t) one-tail	0.039961728		
t Critical one-tail	2.131846786		
P(T<=t) two-tail	0.079923455		p = 0.0799 (p > 0.05)
t Critical two-tail	2.776445105		Not statistically significant

An independent samples t-test was conducted to determine whether or not the various innovations within the treatment groups resulted in differing post-innovation mean scores between students in the control group and students in the treatment group. There was no statistically significant difference between the post-innovation scores of students in the control group (M = 64.33, SD = 49.37) and the treatment group (M = 87.00, SD = 37.71), t(6) = -0.740, p = 0.487. While implementing goal-setting and the use of math tools while completing ST Math puzzles did result in a growing number of completed puzzles on average across a week, student outcomes were not measured to be significantly different than those who completed the ST Math puzzles without the support of the various innovations.

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*	
Mean	64.33333333	87	
Variance	2437.333333	1422	
Observations	3	5	
Pooled Variance	1760.444444		
Hypothesized Mean Difference	0		
df	6		
t Stat	-0.739736643		
P(T<=t) one-tail	0.243691274		
t Critical one-tail	1.943180281		
P(T<=t) two-tail	0.487382548		p = 0.4874 (p > 0.05)
t Critical two-tail	2.446911851		Not statistically significant

Discussion

Summary of Major Findings

The results from this study have only begun to measure the impacts that come from engaging students in the practice of goal-setting and supporting mathematical thinking with concrete mathematical tools and representations. Although there were limited statistically significant impacts measured, there was definite cause to pause and consider how those innovations might impact a classroom across a much more significant collection period.

It should be noted that prior to implementing goal-setting and providing the support of mathematical tools for problem-solving within ST Math, the treatment group was already experiencing slightly higher average percentage growth on their classroom Journeys. However, at the conclusion of the collection period data analyzed demonstrated students who were actively engaged in the abovementioned innovations did increase their Journey growth rate significantly from prior to their use. Students were able to monitor their own personal Journey growth within the ST Math application on their iPad and they also frequently tracked their classroom progress as was showcased in a common area within a main school hallway display. This display contained all individual classrooms and their percent completed within their grade-level Journey using personalized JiJi representations walking along a Journey path marked at ten percent intervals. All kindergarten students were acutely aware of their movement on the JiJi Journey wall even prior to the innovations, but many students within the treatment group became aware of and would talk about their personal JiJi Journey percentage when given the opportunity. They could articulate an understanding that any movement on their Journey meant movement for the whole class. They took a lot of pride in that realization. It seems plausible to assume the early growth trends emerging will only continue to grow with those students who are becoming more and more acutely aware of their ability to impact change on their experiences within ST Math.

An analysis of velocity was not a measurement of which teachers or students in the Kindergarten classrooms took active notice. It was included more as an opportunity to establish a baseline for this initial year implementation of ST Math. The recommended rate of velocity by the platform is approximately one puzzle per minute. As was noticed with the Journey data, the mean velocity rates of the treatment group were considerably higher than that of the control group from the very beginning. Three out of the five classrooms within the treatment group were already experiencing a velocity rate of 1.00 or above at the beginning and throughout the collection period. For reasons this study would not be able to explain, the control group did experience growth that was statistically significant across the collection period. It would be premise that historically they have been seeing marginal growth throughout the entire year in that way. This data might just be demonstrating a natural growth towards meeting the expected one puzzle per minute matrix. The control group ended this cycle with a mean velocity rate of 0.84. This was up from an average mean of 0.76 at the beginning. Looking towards the end of the school year, I will be monitoring the control groups progress towards the 1:1 outcome, while also looking to see whether or not the treatment group continues to complete tasks at the desired rate. The highest velocity noted throughout the collection period was 1.14 by one classroom. That room did maintain that for three of the weeks collected. It would be my assumption that there would be a limit to how many puzzles a kindergartner could complete in a minute. I would desire to answer whether or not some of those classrooms in the treatment group have reached those limits.

The final data collected around the actual number of puzzles completed is highly related to the velocity data already discussed. However, throughout the collection period, if students within the treatment classrooms were unaware of what their velocity might be, they were becoming more and more aware of the number of puzzles they were completing on a daily basis. It seemed the innovations gave rise to many more opportunities for students to reflect on their Journey which led teachers to leverage the various data points provided to them with the students. It produced a growing sense of ownership by students of their personal growth in the ST Math application. ST Math threads together a series of six to eight puzzles within a level. In order to earn those puzzles, the series of puzzles within a particular level must be completed in its entirety in order for those puzzles to be counted and assimilated into the classroom data. It was noticed that as students became more aware of this connection, they were much more careful to focus and persevere until the series of puzzles were done, which had an impact on their overall number of puzzles completed. The students in the control classrooms did not have a similar understanding and would often lose progress on puzzles solved not recognizing they would not actually capture the puzzles completed when they would choose to stop in the middle of a level.

Limitations of the Study

It is clear the brevity of the collection period is the most significant barrier to making meaning from this study. The delay in getting the appropriate structures in place to begin with did not allow for the amount of time that might better measure actual impacts of the innovations. Not only was the scope somewhat problematic, but the time of year presented some issues as well. During the collection period there were a few weeks that had only had four days of instruction and Spring Break also found itself at the mid-point of the cycle. Schedule impacts like these often produce instructional adjustments that cut into various content blocks in order to ensure Scope & Sequence is followed. It was noticed classrooms were not always able to follow the district expectations related to the ST Math implementation during those times.

It was also noticed the length of the collection period did not consider the amount of time necessary to adequately introduce, model, and transfer the innovations to the Kindergarten students. It became clear that whole group instruction was limited in its ability to build and sustain the various routines necessary to be successful. Utilizing small group and even one-on-one instruction to build the independent capacity for a student to be able to monitor at what point they should consider employing the use of a mathematical tool and then which tool would be most supportive is a very time-consuming endeavor. It would have been more helpful to have created a collection period that would have built in stages representing the Gradual Release of Responsibility framework. Allowing classroom teachers more opportunity to build student self-efficacy prior to measuring impacts might have given us a more reliable set of outcomes. It is likely I will perform the data analysis again towards the end of the school year to test some of my misgivings around the short collection period.

Originally, this study intended on collecting data around student self-efficacy in regard to math. A sub-group was to be selected across all the participating classrooms to be interviewed at the beginning and the end of the collection period. After an initial attempt to collect data with a few students at the beginning of the collection period, it became clear the tool was deficient for the task. The anticipated responses designed within the Likert scale did not capture the actual responses given by students. Beyond that, the ability to retrieve this data across the eight classrooms became an impossible endeavor for just one researcher within the given time period. The competing responsibilities of my instructional coaching role interfered in that work. Having only a handful of responses within the first three days, it was determined the duration of this study was unable to support that level of individual data collection with students. It would be my desire to revisit this question in future work.

One final difficulty with this study was due to ongoing technological difficulties being experienced by the application being pushed out on the students' iPads. At some point early on in the data collection period, the iPad operating system installed on our students' devices began presenting technological glitches that would not allow the application to run. There were days where upwards of a third of any given classroom might have students unable to log on or within a puzzle and unable to see or manipulate the tasks in any way. This produced considerable lost time engaging with puzzles. There were several interactions between our district and the ST Math platform to try and remedy the situation, but overall there was evidence of these difficulties throughout the entire study. Without knowing which students were experiencing the most difficulty with their device, it is difficult to measure the impact this had on classroom data overall.

Further Study

Based on further consideration of student outcomes it is clear further research would be necessary to test the validity and reliability of these results. In particular, the limited nature of the study across only a handful of weeks would need to both be reproduced, as well extended to more fully incapsulate the cumulative impact of the various innovations on student outcomes.

It is recommended the research data collection design be altered to breakdown specific impacts of each innovation separately, while also maintaining cognizance of their intersection with one another. For example, the study was unable to identify impacts directly related to personal goal-setting as opposed to class-wide goal-setting, or whether the goal-setting was the preeminent impact on student growth versus the access to mathematical tools to aid in problem-solving. Considering the value-added nature of any innovation in the classroom, it is critical we limit our innovations to those with the most reliable and highest effect sizes.

It is also recommended this work be extended to include a much more statistically significant duration of time. The educational calendar itself was a bit of a barrier to accurate data at the granular level. In particular, the study worked around a five-day Spring Break and two four-day weeks due to professional learning opportunities, as well as Good Friday. Within the days students were in school during the study, building master schedule adjustments were also experienced due to the annual testing window for the Iowa Statewide Assessment of Student Progress (ISASP). The assessment disrupted the routines the Kindergarteners were accustomed to and at times made it difficult for them to adjust to engaging with the platform as per usual. All that said, it would seem having a minimum of a trimester of data to work from might lessen the impact of system and structural disruptions on student outcomes. Ideally, it would be helpful to monitor student progress throughout the entire year.

It is also recommended that taking a closer look at sub-group populations within the larger Kindergarten population would provide more relevant data for next steps moving forward. As much as we desire all students to experience growth across a school year, there is a need to leverage opportunities for accelerated growth especially within our most discrepant sub-group populations. In our district, that would mean isolating the impacts of the innovations on our African-American, English Language Learner, and IEP populations. In particular, we would need to measure the use of mathematical tools to scaffold support for students to access the platform and remove any perceived barriers to their engagement with ST Math.

A final recommendation would be to provide an opportunity to measure student self-efficacy as it relates to ST Math specifically and math in general. So much of student experience in the classroom is driven by their desire to engage in the task. If a student is already presenting with negative perceptions around the platform and/or content, it is likely that will impact their ability to maintain focus and complete puzzles no matter what the rate of completion. Correlating student self-efficacy data to completion of puzzles, their velocity, and growth on the ST Math Journey would also provide a more accurate understanding of the landscape students find themselves in and how to better serve their needs and support their use of the ST Math platform.

Conclusion

The recent trend of digital learning intersecting math content has both proposed and demonstrated many positive student outcomes. As our learning community has endeavored to harness those impacts via the ST Math platform, it seemed imperative to identify student growth within the platform either as a stand-alone experience or as an experience scaffolded by innovations intended to increase engagement and student outcomes. With that in mind, the following questions: “What impacts does personal goal-setting have on a student’s outcomes when engaged with ST Math?” and “What impacts does the access to math manipulatives and tools have on a student’s outcomes when engaged with ST Math?” were both considered.

The results of the action research revealed there were subtle trends emerging within the data, the results did not satisfy the threshold to be considered statistically significant. Many personal student victories within individual classrooms were experienced, as were educator epiphanies creating substantive conversations around the implementation of ST Math in their individual classrooms. These early indicators have produced a significant impetus for teachers to further their understanding of each of the innovations and their interaction with ST Math within their classrooms. I have reason to believe our use of ST Math in the coming years will provide more and more opportunities for students to grow in their confidence and enjoyment with math content within the platform as well as extending to their engagement with our general education math curriculum.

References

Aunola, K., Leskinen, El, Lerkkanen, M. -K., & Nurmi, J. -E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology*, 96(4), 699-713.

Baten, E., Vansteenkiste, M., De Muynck, G. -J., De Poortere, E., & Desoete, A. (2020). How can the blow of math difficulty on elementary school children's motivational, cognitive, and affective experiences be dampened? The critical role of autonomy-supportive instructions. *Journal of Educational Psychology*, 112(8), 1490-1505.

Buczynski, S., Gorsky, J., McGrath, L., & Myers, P. (2011). Sift like Eratosthenes. *Teaching Children Mathematics*, 18(2), 110-118.

Cayton-Hodges, G. A., Feng, G., & Pan, X. (2015). Tablet-based math assessment: What can we learn from math apps? *Journal of Educational Technology & Society*, 18(2), 3-20.

Chang, S. H., Lee, N. H., & Koay P. L. (2017). Teaching and learning with concrete-pictorial-abstract sequence: A proposed model. *The Mathematics Educator*, 17(1), 1-28.

Cheng, Y.-L., & Mix, K. S. (2014). Spatial training improves children's mathematics ability. *Journal of Cognition and Development: Official Journal of the Cognitive Development Society*, 15(1), 2-11.

Chrisler, K. S. (2013). Teaching and learning with real-world tools. *Teaching Children Mathematics*, 19(7), 418-422.

Fyfe, E. R., DeCaro, M. S., & Rittle-Johnson, B. (2015). When feedback is cognitively-demanding: The importance of working memory capacity. *Instructional Science*, 43(1), 73-91.

Lester, F. K., Jr. (2013). Thoughts about research on mathematics problem-solving. *The Mathematics Enthusiast*, 10(1), 245-278.

Light, D., & Pierson, E. (2014). Increasing student engagement in math: The use of Khan Academy in Chilean classrooms. *International Journal of Education and Development Using ICT*, 10(2), 103-119.

Linder, S. M., Smart, J. B., & Cribbs, J. (2015). A multi-method investigation of mathematics motivation for elementary age students. *School Science and Mathematics*, 115(8), 392-403.

Milton, J. H., Flores, M. M., Moore, A. J., Taylor, J. J., & Burton, M. E. (2019). Using the Concrete-Representational-Abstract Sequence to Teach Conceptual Understanding of Basic Multiplication and Division. *Learning Disability Quarterly: Journal of the Division for Children with Learning Disabilities*, 42(1), 32-45.

Mudaly, V., & Naidoo, J. (2015). The concrete-representational-abstract sequence of instruction in mathematics classrooms. *Perspectives in Education*, 33(1), 42-56.

National Council of Teachers of Mathematics. (2010). *Focus in Grade 1: Teaching with Curriculum Focal Points*. Reston, VA: National Council of Teachers of Mathematics.

Scarlatos, L. L. (2006). Tangible math. *Interactive Technology and Smart Education*, 3(4), 293-309.

Smithson, M. (2012). The positive impact of personal goal-setting on assessment. *The Canadian Journal of Action Research*, 13(3), 57-73.

Szczygiel, M. (2020). More evidence that math anxiety is specific to math in young children: The correlates of the math anxiety questionnaire for children (MAQC). *International Electronic Journal of Elementary Education*, 12(5), 429-438.

Tarning, B., & Silvervarg, A. (2019). “I didn’t understand, I’m really not very smart” – how design of a digital tutee’s self-efficacy affects conversation and student behavior in a digital math game. *Education in Science: The Bulletin of the Association for Science Education*, 9(3), 197.

Usher, E. L., Li, C. R., Butz, A. R., & Rojas, J. P. (2019). Perseverant grit and self-efficacy: Are both essential for children’s academic success? *Journal of Educational Psychology*, 111(5), 877-902.

Wendt, S., Rice, J., & Nakamoto, J. (2019). A cross-state evaluation of MIND research institute’s ST Math program and math performance, WestEd. https://eric.ed.gov/?id=ED601907

Wendt, S., Rice, J., & Nakamoto, J. (2014). Evaluation of the MIND research institute’s spatial-temporal math (ST Math) program in California. *WestEd*. https://eric.ed.gov/?id=ED559645