



Strength of Research for Reasoning Mind

Technical Report - July 2015

SRI Education[™]
A DIVISION OF SRI INTERNATIONAL

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Acknowledgment

We thank Reasoning Mind for their support in producing this report under SRI project #21614 with a charge to seek the best evidence and report it clearly and fairly. Any opinions found within are those of the authors.

Suggested Citation

Roschelle, J., Bhanot, R. T., Patton, C., & Gallagher, L. (2015). *Strength of Research for Reasoning Mind*. Menlo Park, CA: SRI International.

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Executive Summary

SRI Education reviewed a series of studies about Reasoning Mind, from 2003 to 2014. We found strong evidence supporting the quality of product design relative to design characteristics that have been shown to be empirically important in prior research with other blended learning products. With regard to student and teacher attitudes, it is clear that students and teachers like using Reasoning Mind to learn mathematics and find the Genie character particularly compelling. Student engagement, observed in both behaviors and affect, also showed higher levels of concentration and on-task activity, underscoring the potential of Reasoning Mind as an online learning system that addresses these important predictors of student learning.

With regard to student achievement, we reviewed four studies that should meet What Works Clearinghouse standards with reservations. Each of the studies found positive and significant effects on student achievement. These four studies occurred in a range of states and used a variety of student achievement outcome measures. Testing a product in a variety of settings and with more than one outcome measure increases the generalizability of findings. The strongest type of research study, a randomized controlled experiment, is now in progress and will contribute additional evidence in 2016.

With regard to large-scale implementation, we reviewed the data from Dallas, where a Reasoning Mind implementation reached over 26,000 students. As with any digital learning product, achieving a high-quality implementation is important to obtaining results. Implementations must be planned, given adequate resources, and managed. Reasoning Mind provides clear guidelines, extensive resources, and implementation coordinators to support districts, schools, and teachers in achieving a strong implementation. The data from Dallas show that a large district can successfully implement Reasoning Mind, and the key factors in implementation include making sure students use Reasoning Mind for enough time, supporting students to progress through mathematical objectives, and helping students to obtain high accuracy in their mathematical work. School leaders should plan enough resources to support teachers in their own professional learning in order to achieve these and other specified characteristics of a high-quality implementation. The data from over 26,000 students in Dallas show that as intensity of use and quality of implementation increased, student outcomes also increased.

Introduction

Reasoning Mind integrates curriculum and technology to provide mathematics instruction, support student engagement, and facilitate teachers' work with students. Reasoning Mind also includes an extensive program of implementation support to help districts, schools, and teachers use its product well. Since its beginning in 2002, Reasoning Mind has engaged researchers in studying its approach in schools. SRI Education, a research division of the nonprofit institute SRI International, reviewed a comprehensive set of 12 research studies conducted over this time period and examined some of the underlying data. SRI's goals were to summarize what the research says and to understand the strength of the evidence. Because these individual research studies had different qualities, we discuss the studies as organized by the kinds of claims each study best supports.

Evidence Supporting Quality of Design

With regard to quality of design, we have had the opportunity to conduct research studies of many digital mathematics and blended learning products other than Reasoning Mind. Across those prior studies, we have reported design features that are important with the quality of such products. Our comparison of Reasoning Mind's design features (Khachatryan et al., 2014) with these research-based features finds concordance. We discuss these design features before moving on (in the next section) to evidence of impact on student achievement.

1. SRI's prior research has found that the **quality of the mathematics curriculum** underlying a digital approach is important to its effectiveness (Means & Roschelle, 2010; Roschelle, Shechtman, et al., 2010). Reasoning Mind's design is based on a curriculum approach with a strong international pedigree. We have had several opportunities to review the Reasoning Mind materials and have noted several aspects that fit with research on the nature of high-quality mathematics instructional materials such as the integration of theory (conceptual understanding) with opportunities to practice mathematical skills, the provision of worked examples, the use of visual models, and the emphasis on curricular focus and coherence.
2. SRI's prior research has found that digital blended learning approaches are more likely to have effects when the **curriculum is transformed to take advantage of the digital medium** (Means, Bakia, & Murphy, 2014) rather than reproducing textbook pages. Reasoning Mind's design reinterprets an established pedagogical approach to mathematics using artificial intelligence techniques so as to take unique advantage of the capabilities of technology (Khachatryan et al., 2014.). SRI has had the opportunity to observe students using Reasoning Mind materials, and we have seen aspects of their interaction that fit with research on effective digital approaches, such as the use of technology to provide rapid, targeted feedback and to display multiple representations.
3. SRI's prior research has found that digital blended learning approaches are more likely to have effects when **teacher professional development is provided throughout the year** and not just in a one-time summer workshop (Hoyles, Noss, Vahey, & Roschelle, 2013; Roschelle, Shechtman et al., 2010). Reasoning Mind provides an extensive program to support teachers throughout the year, with clear objectives, materials, and milestones. Further, SRI has generally failed to find effects for interventions conceived only in terms of technology but has found positive effects when teacher professional development, curriculum, and technology are integrated as they are in Reasoning Mind.

4. Much prior research, including research conducted by SRI, emphasizes the **importance of students doing high-quality mathematics tasks** (Roschelle, Knudsen, & Hegedus, 2010; Stein, Grover, & Henningsen, 1996). The amount of time students spend engaged in doing challenging mathematics tasks with accuracy is often a strong predictor of student achievement. In our informal observations, we have noted that Reasoning Mind organizes the classroom so that students spend most of the time doing mathematics relevant to the curriculum and appropriate to their level of skill. Researchers specializing in studying engagement (Baker et al., 2012; Baker & Ocumpaugh, 2014) have conducted systematic studies of engagement in Reasoning Mind classrooms and have found high levels of engagement relative to what they have seen in other traditional mathematics classrooms (Ocumpaugh, Baker, Gaudino, Labrum, & Dezendorf, 2013). Student engagement levels have been found to be high for on-task behaviors as well as for engaged concentration for both versions of Reasoning Mind (Genie 2 and Genie 3) (Mulqueeny, Kostyuk, Baker, & Ocumpaugh, in preparation).

The alignment of these design features of Reasoning Mind with prior research on effective designs for digital mathematics contributes to its promise and justifies conducting rigorous empirical studies.

Evidence Supporting Increased Student Achievement

Most of the research studies about Reasoning Mind report something about student achievement, but we found that the quality of the research designs varied, as is typical with any group of research studies. We focused on the higher quality research designs. The studies (a) included a comparison group of students who did not use Reasoning Mind, (b) established baseline equivalence of Reasoning Mind and comparison groups, and (c) had an appropriate posttest measure of student achievement. With certain additional technical qualifications (e.g., regarding attrition), such studies can meet What Works Clearinghouse standards with reservations (U.S. Department of Education, 2013). Four studies meet these criteria. Table 1 provides an overview of the four studies, and each is discussed separately on the following pages.

Table 1. Four Studies with Evidence of Student Achievement

	Houston, Texas, Genie 1, TAAS & TAKS (Weber, 2003)	Beaumont, Texas, Genie 2, TAKS (Waxman & Houston, 2012)	West Virginia, Genie 2, Singapore Math (Mingle, Mulqueeny et al., in preparation)	Texas, Genie 3, STAAR & ITBS (Mingle, Khachatryan, et al., in preparation)
Design	Randomized controlled trial	Quasi-experimental study	Quasi-experimental study	Quasi-experimental study
Grade	7th	5th	5th	6th
Version of Genie	1	2	2	3
Meets WWC standards	Meets WWC standards with reservations	Meets WWC standards with reservations	Meets WWC standards with reservations	Meets WWC standards with reservations
Achievement test	Texas Assessment of Academic Skills (TAAS) Texas Assessment of Knowledge and Skills (TAKS)	Texas Assessment of Knowledge and Skills (TAKS)	Singapore math placement	State of Texas Assessments of Academic Readiness (STAAR) Iowa Test of Basic Skills (ITBS)

HOUSTON, TEXAS, GENIE 1, TAAS & TAKS (WEBER, 2003)

This earliest research study examined the Genie 1 version of Reasoning Mind, which has been superseded by later versions. It was a small randomized controlled trial, with only two classrooms of students. Further, the Reasoning Mind team was intimately involved in the classrooms that used Genie 1. The quality of this study appears sufficient to meet What Works Clearinghouse standards with reservations. The key reservation is that the combination of differential and overall attrition was high, although direct involvement of Reasoning Mind would also limit generalizability. The classrooms were in Houston, Texas. Students were randomly assigned to either the Genie 1 or a comparison classroom. The two groups had differences in pretest scores, but statistical adjustments made in the final outcome analysis met the WWC baseline equivalence requirement. Students in the Genie 1 classroom had greater achievement as measured by the TAAS (end of year 6th grade) and by the TAKS test (end of year, 7th grade). Because Genie 1 has been superseded by later development, these findings are mostly noteworthy for establishing that from the beginning, Reasoning Mind had evidence of effectiveness.

Table 2. Descriptive statistics (raw scores) for TAAS (pretest) and TAKS (posttest) across the two groups in the Houston, Texas, Genie 1 Study. Because of differences in the tests, the pretest score is higher than the posttest score for both groups.

	Treatment		Control	
	Pretest	Posttest	Pretest	Posttest
Mean	87.38	29.9	87.96	25.48
SD	4.35	7.96	2.3	6.46
N	29	29	25	25
Standard Error	0.81	1.48	0.46	1.29
95% CI	1.58	2.89	0.90	2.53

BEAUMONT, TEXAS, GENIE 2, TAKS (WAXMAN & HOUSTON, 2012)

In a quasi-experiment conducted in the Beaumont, Texas, school district, students in eight schools used the Genie 2 version of Reasoning Mind in fifth-grade mathematics instruction. Students in the other six schools in the district did not use Reasoning Mind and were considered to be the comparison group. The quality of this study appears sufficient to meet What Works Clearinghouse standards with reservations. The key reservation is that this was a quasi-experimental design, not a randomized experimental design. Students in the two groups had statistically equivalent pretest scores, but statistical adjustments made in the final outcome analysis met the WWC baseline equivalence requirement. On the posttest, students who used Reasoning Mind scored higher on TAKS, the Texas state test, and this finding was statistically significant.

Table 3. Descriptive statistics (raw scores) for 2010 TAKS (pretest) and 2011 TAKS (posttest) across the two groups in the Beaumont, Texas, Genie 2, TAKS study.

	Treatment		Control	
	Pretest	Posttest	Pretest	Posttest
Mean	659.68	704.75	653.73	682.84
SD	96.04	99.70	89.62	100.38
N	568	568	639	639
Standard Error	4.03	4.18	3.55	3.97
95% CI	7.90	8.20	6.95	7.78

WEST VIRGINIA, GENIE 2, SINGAPORE MATH (MINGLE, MULQUEENY, ET AL., IN PREPARATION)

In this quasi-experiment, six schools in an urban school district in West Virginia used the Genie 2 version of Reasoning Mind as the core curriculum in fifth grade. The comparison group consisted of the other four elementary schools in the same district, which did not use Reasoning Mind and continued to use their existing fifth-grade mathematics materials. The quality of this study appears sufficient to meet What Works Clearinghouse standards with reservations. The key reservation was that this is a quasi-experimental design, not a randomized experimental design. Singapore Math tests were used both for the pretest and for the posttest. Singapore Test 3a was used for the pretest, and Test 4a was used for the posttest. The groups were found to be statistically equivalent at pretest. Attrition of students out of the study was acceptably low. On the Singapore Math posttest, students who used Reasoning Mind scored higher, and this finding was statistically significant.

Table 4. Descriptive statistics (raw scores) for Singapore Test 3A (pretest) and Test 4A (posttest) across the two groups in the West Virginia, Genie 2, Singapore Math study. Because of differences in the tests, the pretest score is higher than the posttest score for both groups.

	Treatment		Control	
	Pretest	Posttest	Pretest	Posttest
Mean	41.57	23.78	45.38	16.36
SD	23.49	13.5	24.14	14.5
N	119	119	92	92
Standard Error	2.15	1.24	2.52	1.51
95% CI	4.22	2.42	4.93	2.96

TEXAS, GENIE 3, STAAR & ITBS (MINGLE, KHACHATRYAN, ET AL., IN PREPARATION)

Two school districts participated in this quasi-experiment. In one district, one school used Reasoning Mind's newest Genie 3 version for sixth-grade mathematics instruction, and another similar school was identified to serve as a comparison group. In another district, one school volunteered and arbitrarily assigned half its students to Reasoning Mind or the comparison condition. The quality of this study appears sufficient to meet What Works Clearinghouse standards with reservations. The key reservation is that this was a quasi-experimental design, not a randomized experimental design. Using the Texas STAAR test the groups were found to be equivalent at pretest. The ITBS was used as a posttest; this test examines both mathematical skills and quantitative reasoning. On the posttest, the students who used Reasoning Mind had higher scores and this result was statistically significant. While this study was described as a pilot study, it is important because it provided evidence of effectiveness for the newest version of Reasoning Mind, Genie 3.

Table 5. Descriptive statistics using standardized z scores for STAAR (pretest) and ITBS (posttest) across the two groups in the Texas, Genie 3, ITBS study.

	Treatment		Control	
	Pretest	Posttest	Pretest	Posttest
Mean	-0.03	0.1	0.05	-0.11
SD	0.97	1.05	1.02	1.00
N	193	193	300	300
Standard Error	0.07	0.08	0.06	0.06
95% CI	0.14	0.15	0.12	0.11

OTHER NOTEWORTHY STUDIES

Two additional studies deserve mention. In a study conducted in the 2005-06 school year, Weber (2006) found no benefit for Reasoning Mind. This study attributed the finding to poor implementation. The team at Reasoning Mind widely views this study as a turning point for the product, as it led to considerable refinement of Reasoning Mind's approach to and support for implementation. In addition, SRI International is conducting a cluster randomized trial in West Virginia with the Genie 2 version of Reasoning Mind. This study is designed to meet What Works Clearinghouse standards in full but is not yet complete.

SUMMARY ACROSS STUDIES

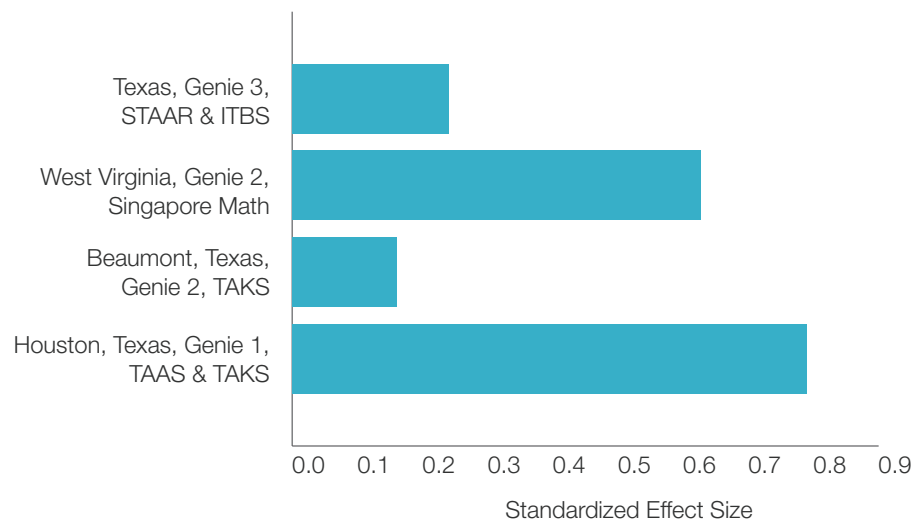
To summarize the studies, we looked at the effect sizes for the four studies described above. An effect size measures the magnitude of the difference observed between two groups, divided by the amount of variation observed in the groups. A helpful analogy can be the concept of signal and noise. The signal we are trying to detect in a study is the signal that shows a new approach was better than an alternative. But it can be hard to detect this signal

when there is a lot of variation, or noise, in the data. In general, schools, teachers, and students vary greatly, and therefore measuring learning gains in schools is subject to considerable noise. A large effect size indicates a relative advantage for the new approach that will stand out against the noise. A smaller effect size indicates a relative advantage for the new approach that could become lost in the noise (especially when only a small number of schools is considered). Larger effect sizes are rare in education research. And because larger effect sizes indicate ability to produce measurable results even with variation among schools, teachers, and students, larger effect sizes are considered more valuable.

In our examination, the effect sizes were 0.16, 0.24, 0.63 and 0.79 (Figure 1). All the studies were well designed and should meet What Works Clearinghouse Standards with reservations. It is noteworthy that the studies were conducted in two very different states, Texas and West Virginia, and used a variety of outcome measures, including Texas state assessments, ITBS, and Singapore Math. Achieving a positive effect in differing conditions and with a range of outcome measures is noteworthy.

The larger effect sizes—namely, 0.63 and 0.79—are rare in educational research.¹ Against the backdrop of other research SRI has conducted of related digital mathematics and blended learning products, these research designs are strong enough and these effect sizes are meaningful enough to provide a useful signal to schools about the likelihood of seeing student achievement gains when Reasoning Mind is implemented well. In addition, when the current SRI study in West Virginia is complete in 2016, results that fully meet What Works Clearinghouse standards will be available.

Figure 1: The standardized effect size of Reasoning Mind on student achievement varied by study but were positive and significant.



1. Educators often ask for a commonsense interpretation of how much impact a given effect size represents. Researchers debate whether this should be represented by categories (low, medium, high) or by estimated impact on a hypothetical “average” student or by amount of learning time saved. In our experience, educators do not find any of these ways to explain an effect size particularly useful. Given this lack of consensus, we think its best to stay close to the meaning of an effect size: A stronger effect size means that a difference due to the program can be measured even if there is a lot of variability among incoming students.

Evidence Regarding Student and Teacher Attitudes

We also examined 12 studies for reports on student and teacher attitudes. Four of the 12 studies examined students' attitudes toward math after using Reasoning Mind (Boriack, Wright, Stillisano, & Waxman, 2015; Waxman & Houston, 2008, 2012; Weber, 2003).

Students' attitudes toward math (e.g., liking math) were captured at the end of the intervention across these four studies. Overall, students reported liking math more after learning with Reasoning Mind. The percentages of students who agreed with the question "Do you like math?" ranged from 57% to 86% across the four studies. Although we do not know students' attitudes before their experience with Reasoning Mind, the overall trend is encouraging because it shows that after learning math with Reasoning Mind, more than half of students had positive attitudes toward math. We also observed that studies of later versions of Reasoning Mind reported higher percentages of student agreement with "liking learning math with Reasoning Mind" than studies of earlier versions. We discuss this in more detail in the section about Implementation.

With regard to students' experience in the system, the animated character called Genie was consistently voted by students as their favorite part of the experience. Genie was described as being encouraging, tutoring students and showing them the solution to a given problem when it was challenging for them. In addition, the students valued the gaming context of the learning experience, as well as the extrinsic reward associated with the game, such as "winning prizes and awards" (Weber, 2003, p., 30). Several students also appreciated being shown how to solve for the solution so they understood the rationale and method better. The students' comments provided in the studies suggested that at least for some the value of the learning game was evident: "It made you think," "[you] learn more than one topic in just a day" (Waxman & Houston, 2012, p. 15).

Five studies examined teachers' attitudes toward Reasoning Mind and teachers' perception of benefit for their students. The teacher surveys were also administered using a treatment group post-only design, which limits the strength of conclusions that can be drawn. In particular, the studies did not reveal teachers' attitudes before they used Reasoning Mind or what teachers' attitudes toward alternative products might have been.

Overall, teachers perceived Reasoning Mind to be beneficial for students. In responses to open-ended survey questions, teachers wrote about how Reasoning Mind allows students to master gaps in their content knowledge, to receive immediate feedback, and to learn problem-solving skills (Khachatryan et al., 2014; Waxman & Houston, 2008). Other teachers noted that Reasoning Mind improved students' math confidence and independence in learning (Boriack et al., 2015; Bush & Kim, 2013) and that students overall enjoyed math more (Waxman & Houston, 2012). Teachers liked the implementation and professional development they received through support from the implementation coordinator and their participation in best practices workshops.

Evidence About Large-Scale Implementation

In its evaluations of blending learning approaches, SRI generally finds that achieving student gains requires close attention to quality of implementation, especially as a program scales up across many schools and districts. Reasoning Mind provides clear guidelines, resources, and implementation coordinators to help districts achieve the necessary quality of implementation. More than most products we have had the opportunity to investigate, Reasoning Mind has created a clear system to support districts in achieving a high-quality implementation.

A study conducted in Dallas Independent School District, a large, diverse, low socioeconomic status school district, with approximately 26,000 students offered insights into how Reasoning Mind scales up to large-scale deployments. As primary source for this section, we draw on a report written by representatives of the district itself (Bush & Kim, 2013). Reasoning Mind was adopted in Dallas as a supplementary math program for all students in the second and third grade. The district purchased Reasoning Mind for \$35 per student. Some teachers were closely supported in their implementation of Reasoning Mind, at a cost of \$3,500 per teacher. Other teachers were “unsupported” but encouraged to access online Reasoning Mind teacher materials. The researchers tracked Reasoning Mind usage, examined student end-of-year test results on the Texas STAAR assessment, and conducted surveys of students, teachers, and administrators. Overall, the report made clear that Dallas was pleased with the performance of Reasoning Mind.

Students varied in how much they used Reasoning Mind in Dallas. Reasoning Mind initially recommended 30 hours of supplementary use per semester. In this initial study, the data showed students generally spent less time than the recommended 30 hours per semester, with substantial variation in how much individual students and schools used Reasoning Mind. In the fall semester, students on average used Reasoning Mind for about 19 hours. In the spring semester, use increased on average to about 32 hours. In subsequent school years, this pattern of usage growth continued. Similarly, there was variation in how many objectives (topics within Reasoning Mind) the students covered. For example, in the spring 33% of second-grade students completed 10 or fewer objectives, 50% completed 11-20 objectives, and 17% completed 21 or more objectives. Another important variable was students’ accuracy rate in completing the easier A-level problems. The Dallas study found that students who completed more objectives and who achieved higher levels of accuracy in Reasoning Mind had better test outcomes on the end-of-the-year examination. The data showed that realistic large-scale implementations are likely to ramp up in intensity of use from fall to spring, that students need the opportunity to spend enough time on the system to complete a substantial number of objectives, and that it is important to support students to achieve high accuracy on the work they do in Reasoning Mind—not just race through as many math problems as possible.

The administrator survey revealed some issues that may have prevented students from having enough time to use Reasoning Mind. The top issues cited were generic to any technology: poor wireless connectivity and lack of availability of laptop carts. The only issue specific to Reasoning Mind was ease of student log in, which most likely can be readily addressed by Reasoning Mind going forward. Overall, administrators were satisfied with Reasoning Mind.

Two groups of teachers participated in this project. “Supported” teachers had ongoing help from Reasoning Mind implementation coordinators. “Unsupported” teachers attended the Reasoning Mind Qualification Course along with the supported teachers, and learned about the basics of the Reasoning Mind curriculum and implementation practices, and completed an end-of-course assessment. Both groups of teachers responded positively (*agree* or *strongly agree*) to seven of nine teacher satisfaction questions. Teachers did not feel that other teachers in their building were positive or that they had enough district technology support. Student performance was not different depending on whether they had a supported or unsupported teacher, indicating that costs can potentially be reduced by implementing a mix of support levels. However, supported teachers were more satisfied with the support they received from Reasoning Mind and reported working more closely together. Further, Reasoning Mind representatives observed supported teachers throughout the year and found that teachers demonstrated expected growth in such areas as data-driven decision making, lesson planning, incentive systems, support for students’ independent learning, and others. It is likely to be

important for a district to have enough supported teachers to create a self-sustaining teacher community of practice to help all teachers achieve this type of pedagogical growth.

In a follow-up study in the next school year (Bush & Kim, 2014), the program in Dallas expanded to 35,000 students and included grade 4 along with grades 2 and 3. Results showed that students who used Reasoning Mind more often were more likely to meet or exceed standard on the ITBS. These results were similar for different groups of students, such as African American, Latino, and Asian students. Further, students who had used Reasoning Mind for more years in school were more likely to pass the Texas STAAR test. These results are all correlational, and cannot prove that Reasoning Mind caused student test scores to climb. Nonetheless, correlational results at this scale are encouraging.

In comparison, the four studies discussed in the section on student achievement had research designs better suited to evaluating the efficacy of Reasoning Mind, but all four were at a smaller scale. The Dallas studies, in contrast, are best suited to understanding what is important as Reasoning Mind is deployed at a much larger scale. Some key factors that emerge include the following:

- As with any technology-based product, the district's IT infrastructure must support the target use model for the product.
- Districts should attend to the recommended number of hours students use the program because students need enough time on the program to learn. Further, once students are using the program for enough time, it is important to support them in obtaining high accuracy rates and to progress through most of the objectives (topics), as accuracy and progress through objectives best predict eventual scores on end-of-year tests.
- Initially, districts should focus on providing the recommended professional development to all participating teachers. Yet as time goes by, it may become less important to give all teachers the same amount of ongoing professional development and more important to emphasize the growth of a teacher community. In a successful teacher community, teachers in schools would work together to continually improve their pedagogical skills with Reasoning Mind. When a strong teacher community exists, teachers can be supported less by external professional development and more by each other, while still continuing to improve their use of Reasoning Mind.

Overall, it is noteworthy that achieving a high-quality implementation of Reasoning Mind is within reach for large districts such as Dallas. Further, when a district achieves a high-quality implementation, it is reasonable to anticipate increased pass rates as teachers and students use Reasoning Mind appropriately. High-quality implementation will require planning, resources, and thoughtful management over time to make sure the system is used with sufficient intensity and to ensure that the teachers have the knowledge and comfort to support students in progressing through more mathematical objectives and to more difficult mathematical problems and to achieve high mathematical accuracy in their work.

Evidence Regarding Student Engagement

Reasoning Mind has been adopted as a platform for research studies by leading research teams, and it maintains an active engagement in scientific research communities. One important set of scientific studies is developing better ways to measure student motivation, engagement, emotions, and other factors as students use digital mathematics environments (Baker, D'Mello, Rodrigo, & Graesser, 2010; Baker et al., 2012). Researchers have been attracted to studying these factors in Reasoning Mind because student engagement is generally high and useful data sets are readily available. These collaborations with scientists may lead to advances in Reasoning Mind's technology in the years to come.

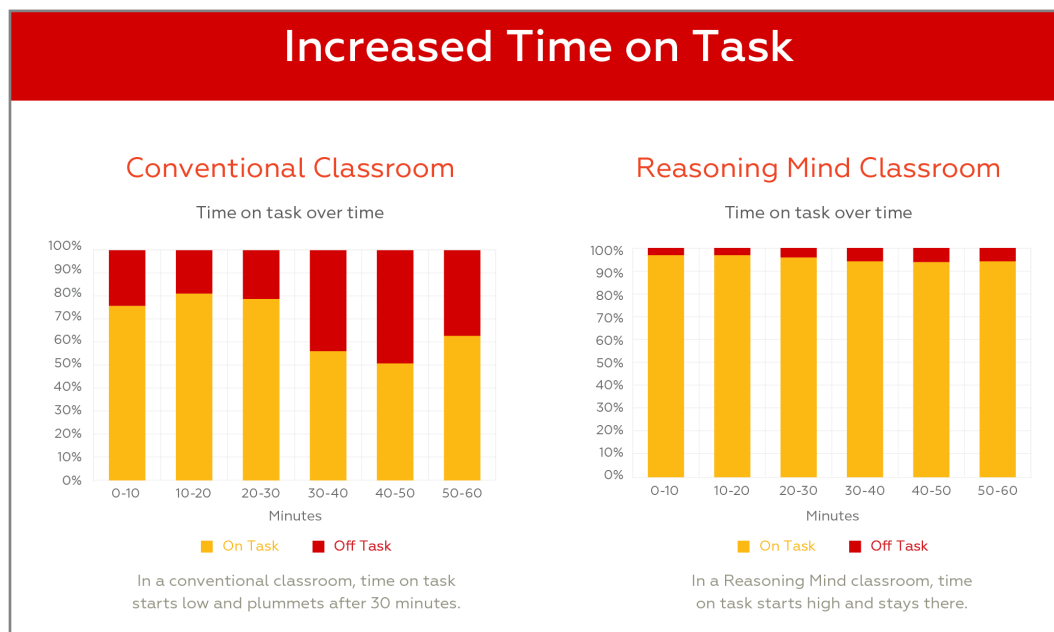
One of the studies we reviewed (Mulqueeny, et al., in press) illustrates this point well. This study examined student engagement in classrooms using Reasoning Mind compared with traditional math classrooms. Further, it examined how student engagement compared across the current version of Reasoning Mind (Genie 3) and the previous version of Reasoning Mind (Genie 2).

The first aspect of this study was conducted in a mostly urban and majority Latino school district in Texas among sixth-grade classrooms. A quasi-experimental study design was used. The results showed that students using the Genie 3 curriculum had higher rates of engaged concentration and time on task than students in traditional math classrooms. At the same time, Genie 3 students were less bored than their counterparts. However, the Genie 3 students engaged in less on-task conversation than students in traditional classes

In a second aspect of this study, students using Genie 3 were compared with students using the prior version, Genie 2. The students were drawn from a small school with a largely White student population, with one-third Latino students. Students in the Genie 3 group were observed to have higher levels of engaged concentration and more time on task when compared with students using Genie 2. The research report suggested that future development efforts in the Reasoning Mind system were likely to take these results into account in order to further improve the level of engagement.

Overall, these data underscore the benefit of research collaborations that can potentially advance the design of blended learning experiences for students. Studies using more rigorous research designs are also needed to keep in mind how student engagement changes from baseline levels. Nevertheless, the results for raising student engagement, both manifested in behavior and affect, are encouraging and in the positive direction.

Figure 2. Observed on-task behaviors were higher in classrooms using Reasoning Mind platforms compared with classrooms using traditional math curricula. Source: Mulqueeny et al., in preparation. (Reprinted with permission).



Conclusion

SRI Education reviewed a series of studies on Reasoning Mind, from 2003 to 2014. We found strong evidence supporting the quality of product design relative to design characteristics that have been shown to be empirically important in prior research with other blended learning products. With regard to student and teacher attitudes, it is clear that students and teachers like using Reasoning Mind to learn mathematics and find the Genie character particularly compelling. Studies have shown greater engagement among Reasoning Mind students, including both higher levels of concentrated effort and more on-task (and less off-task) behavior, thus underscoring the potential of Reasoning Mind as a digital learning system that also addresses these important predictors of student learning. With regard to student achievement, we reviewed four studies that should meet What Works Clearinghouse standards with reservations. Each of the studies found positive and significant effects on student achievement.

These four studies occurred in a range of states and used a variety of student achievement outcome measures. Testing a product in a variety of settings and with more than one outcome measure increases the generalizability of findings. The strongest type of research study, a randomized controlled experiment, is now in progress and will contribute additional evidence in 2016.

With regard to large-scale implementation, we reviewed the data from Dallas, where a Reasoning Mind implementation reached over 26,000 students. As with any digital learning product, achieving a high-quality implementation is important to obtaining results. Implementations must be planned, given adequate resources, and managed. Reasoning Mind provides clear guidelines, extensive resources, and implementation coordinators to support districts, schools, and teachers in achieving a strong implementation. The data from Dallas shows that a large district can successfully implement Reasoning Mind, and the key factors in implementation include making sure students use Reasoning Mind for enough time, supporting students to progress through mathematical objectives, and helping students to obtain high accuracy in their mathematical work. School leaders should plan enough resources to support teachers in their own professional learning in order to achieve these and other specified characteristics of a high-quality implementation. The data from over 26,000 students in Dallas showed that as intensity of use and quality of implementation increased, student outcomes also increased.

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Appendix: Annotated Bibliography

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Setting: Texas

Grade level: Grades 2 to 6

Product version and type of use (supplement or core): Genie 2 as supplementary curriculum

Study design: Non-quasi-experimental post-only single-group design (surveys) and pre-post design (achievement tests)

Summary:

This 1-year evaluation study examined the effectiveness of the Reasoning Mind program on students' math achievement outcomes, along with survey data on attitudes of various stakeholders. The intervention was a 2-year-long implementation of the Reasoning Mind Genie 2 platform in Grades 2 through 6 across Texas Education Agency-funded schools. The report took a small selected sample of schools. A pre-post design was used to assess students' scores on the State of Texas Assessments of Academic Readiness (STAAR). A post-only design was used to study students', teachers', and administrators' perceptions of the students' experiences with the Reasoning Mind curriculum. The percentage of students gaining satisfactory progress on the STAAR test rose 5% over the academic year. A more rigorous research design would have provided more compelling evidence of the impact of the Reasoning Mind curriculum on students' achievement outcomes. Teachers were satisfied with the Reasoning Mind program and how it prepared the students using it for the STAAR test. The professional development provided to teachers also received positive reviews from teachers and administrators. An overwhelming majority of students also liked math more than before (80%). Again, a more rigorous research design would have allowed for making pre-post comparisons with these data.

Bush, J., & Kim, M. (2013). *Evaluation of the Reasoning Mind mathematics program 2012-2013*. Dallas Independent School District: Dallas, TX.

Setting: Dallas, TX

Grade level: Grades 2 to 3

Product version and type of use (supplement or core): Genie 2 as supplementary curriculum

Study design: Non-quasi-experimental single-group design

Summary:

This 2-year evaluation study stood out among the 12 studies since it was (a) completed by the Dallas District staff and (b) the largest scale implementation of Reasoning Mind. The Reasoning Mind program was implemented in second- and third-grade classrooms in all elementary schools, except for two. It was used as

supplemental curriculum in these classrooms. The study had a non-quasi-experimental single-group design. Despite this limitation, this was an important study providing detailed accounts of how implementation success, or lack thereof, was associated with impacts on student outcomes.

Professional development (PD) is a key component of the Reasoning Mind intervention. During the study all elements of PD were incorporated for all teachers in these grades during the first year and then for one district-nominated teacher per campus in the second year. These teachers were referred to in the study as supported teachers, while non-supported teachers were those who participated in some of the PD courses on their own. Across the district, 92% of supported teachers met PD requirements that included participation in PD courses, observations, and visits by the program coordinator. These PD courses included a Reasoning Mind qualification course that teachers were required to pass before implementing Reasoning Mind in their classrooms. Supported teachers received six additional PD courses totaling 12 hours, three formal program coordinator observations, and periodic program coordinator visits. During classroom observations, teachers were observed on four-level criteria established in the following domains: data-driven decisions, lesson planning, instructional methods, learning modes, teacher engagement, procedures, incentive systems, notebooks, independent learning and student engagement. Non-supported teachers could avail themselves of advice and services from program coordinators.

The lack of implementation fidelity at the teacher level had ramifications for the impact on students. Limited time on Reasoning Mind meant students did not advance to the more challenging and potentially more impactful levels in Reasoning Mind: Wall of Mastery review mode math problems. Most students stayed within the easy levels of Reasoning Mind in the first year and advanced to no more than the medium-difficulty levels in the second year.

Students' ITBS and STAAR scores were collected for the study. Overall, second-grade students' ITBS scores decreased slightly between cohorts, while the STAAR scores for third-grade students increased slightly between cohorts. The magnitude of change in scores was very minimal in both years, and given the lack of control group or baseline measures, these changes could not be attributed to the Reasoning Mind system. All in all, the findings indicated that in consistently predicting improved ITBS and STAAR scores, students' mastery of the easy-level objectives, the number of objectives achieved, and the accuracy rates of the problems completed were more important than the time students spent in the Reasoning Mind system. This occurred for both second and third-grade students.

The Reasoning Mind team found important take-aways in this study, namely the need for setting implementation standards for both teachers and students, such as required PD hours and student time on Reasoning Mind.

Khachatryan, G., Romashov, A. V., Khachatryan, A. R., Gaudino, S. J., Khachatryan, J. M., Guarian, K. R., & Yufa, N. V. (2014). Reasoning Mind Genie 2: An intelligent tutoring system as a vehicle for international transfer of instructional methods in mathematics. *International Journal of Artificial Intelligence*, 24, 333-382.

Setting: Rural and urban districts across California, Texas, Louisiana, West Virginia, and Oklahoma

Grade level: Grades 4 to 6

Product version and type of use (supplement or core): Genie 2

Study design: Non-quasi-experimental single-group design

Summary:

This article essentially describes the design and function of the second generation of the Reasoning Mind program (Genie 2) and how it is used in classrooms. Building on the cross-transplantation of curriculum and instructional methods from the Russian math education system, several principles for designing intelligent tutoring systems are outlined. As part of the appendix, survey data from several independent studies of the Genie 2 system that were conducted across various U.S. states are presented. These results should be interpreted keeping in mind that these studies used non-quasi-experimental single-group designs, which do not provide baseline survey responses or comparison group data from other online math learning product implementations. Moreover, since all these survey results are provided in descriptive ways only, it is difficult to draw conclusively from the data. Students' reports on whether they liked learning math in the Reasoning Mind program were mostly positive. They preferred learning math in the Reasoning Mind program as compared to their traditional math classrooms. It is, however, unclear whether students like math in general. Teachers give positive marks to several design aspects of the Reasoning Mind program, including the student progress reports, in-person support provided by the implementation team, and the overall interface of the curriculum.

Mingle, L. A., Khachatryan, G., & Kostyuk, V. (in preparation). *Blended learning as a tool for international transfer of instructional practices*.

Setting: Texas

Grade level: Grade 6

Product version and type of use (supplement or core): Genie 3 as primary curriculum

Study design: Quasi-experimental study

Summary:

One of the three studies providing results from the latest version of Reasoning Mind, Genie, this study was a quasi-experimental study conducted across two school districts. This study also used two different assessments for pretest and posttest. The State of Texas Assessments of Academic Readiness (STAAR) was used as a pretest among sixth-graders in both comparison and treatment conditions. No significant difference between the

two groups suggested baseline equivalence. The Iowa Test of Basic Skills (ITBS) was used for the posttest. Even after controlling for the STAAR test, the study found group membership was a significant predictor of students' posttest results in that receiving the Reasoning Mind intervention positively predicted posttest scores.

Mingle, L. A., Mulqueeny, K., Khachatryan, G., & Kostyuk, V. (in preparation). *Reasoning Mind students outperform comparison on Singapore Math Test.*

Setting: West Virginia

Grade level: Grade 5

Product version and type of use (supplement or core): Genie 2 as primary curriculum

Study design: Quasi-experimental study design (pre-post)

Summary:

This study adopted a quasi-experimental pre-post design among four schools in an urban district in West Virginia. The strength of the study was in the use of the Singapore Math Placement test, which has a higher instructional sensitivity than other standardized tests, such as TAKS or ITBS, used in the other Reasoning Mind studies. While Singapore Math tests were used both for the pretest and for the posttest, the tests were different in the content foci. The pretest used Singapore Math Placement Test 3a, focusing mostly on operations with natural numbers and algebraic reasoning. In contrast, the posttest used Test 4a of the Singapore Math Placement Test, which is a more comprehensive assessment of fractions. Controlling for pretest differences, the authors used linear regression and found students in the Reasoning Mind intervention outperformed students in the control group. One particular drawback was in the lack of diversity in the student populations, thus limiting the generalizability of these findings to schools in more urban centers.

Mulqueeny, K., & Mingle, L. A. (in preparation). *Improving mathematical vocabulary with blended learning.*

Setting: Texas

Grade level: Grade 6

Product version and type of use (supplement or core): Genie 3 as primary curriculum

Study design: Quasi-experimental study

Summary:

In this study the authors compared interview data from students using the Genie 3 curriculum with those from students in traditional math classrooms. The questions included two math problems that the students had to verbally answer, and their answers were coded by independent raters for the use of explanations, providing calculations, and correctly setting up the data table. The transcripts were also coded on three levels

(low, medium, high) for the use of basic, intermediate, and advanced math terms. The results demonstrated that students using Reasoning Mind included more math terms in their answers than their counterparts and provided more accurate math explanations. This innovative use of interview data to parse out the quality of math reasoning, ideas, and arguments provided very promising results that can be replicated at a larger scale in future studies.

Mulqueeny, K., Kostyuk, V., Baker, R. S., & Ocumpaugh, J. (in press). Improving engagement in an E-learning environment. To appear in *Proceedings of the 17th International Conference on Artificial Intelligence in Education*.

Setting: Texas

Grade level: Elementary grades

Product version and type of use (supplement or core): Genie 2 and 3 as primary curricula

Study design: Study 1: Non-quasi-experimental, single-group design; Studies 2 and 3: Quasi-experimental design

Summary:

This was a larger study that included three different studies comparing student engagement in classrooms using the traditional classroom instruction and those using the Genie 2 or Genie 3 platforms. The studies used a well-established field observation measure, the Baker Rodrigo Ocumpaugh Monitoring Protocol (or BROMP) (Ocumpaugh, Baker, & Rodrigo, 2012) to observe student behavior and affect. A mix of small to large schools spread across Texas were included in the study. For the most part the five schools had large minority populations, with only one school having a majority White student population. Across the three studies, much higher levels of student engagement were observed among students using the Reasoning Mind curriculum than those using the traditional math curricula. This high level of engagement was manifested in both on-task behavior (over 85%) and engaged concentration (65%). The results were slightly more mixed for other engagement indicators, such as boredom (in the case of Genie 2) and on-task conversations (in the case of Genie 3). Because of limitations posed by the lack of random assignment of groups and absence of baseline measures of student engagement, this study lacked rigor. Nonetheless, the results demonstrated high student engagement, both manifested in behavior and affect, and are encouraging and in the positive direction.

Ocuppaugh, J., Baker, R. J. d., Gaudino, S., Labrum, M., & Dezendorf, T. (2013). Field observations of engagement in Reasoning Mind. In H. C. Lane, K. Yacef, J. Mostow & P. Pavlik (Eds.), *Artificial intelligence in education* (Vol. 7926, pp. 624-627). Berlin, Germany: Springer Heidelberg.

Setting: Texas

Grade level: Grades 5 to 6

Product version and type of use (supplement or core): Genie 2 as supplementary curriculum

Study design: Non-quasi-experimental, single-group design

Summary:

The participants came from largely economic disadvantaged backgrounds, with two of the three schools having 57% to 96% student populations eligible for free or reduced-price lunch and large Hispanic and African American populations. The third school had a relatively large White population, with only 16% coming from economically disadvantaged backgrounds. The study used a well-established field observation measure, known as the Baker Rodrigo Ocuppaugh Monitoring Protocol (or BROMP) (Ocuppaugh, Baker, & Rodrigo, 2012) to observe student behavior and affect. Across this diverse sample, students were engaged in on-task behavior 82% of the time and engaged in on-task conversation an additional 7% of the time. On the other hand, off task behaviors, including gaming the system, were evident in 11% of the observations. Affect largely manifested in engaged concentration in 71% of the observations, while boredom was observed 10% of the time. The research design of the study can be improved in future studies using the BROMP method to examine student engagement by measuring it also at baseline levels as well as using both treatment and control groups.

Waxman, H. C., & Houston, W. R. (2008). *An evaluation of the 2006-2007 Reasoning Mind program*. College Station, TX.

Setting: Several cities across Texas

Grade level: Grade 5

Product version and type of use (supplement or core): Genie 2 as primary curriculum

Study design: Randomized controlled trial and quasi-experimental pre-post study designs

Summary:

In this study, three schools (elementary, middle, and K-12) implemented the Reasoning Mind program across fifth-grade classrooms. While two schools used a randomized pretest-posttest control group experimental design, the third school used a quasi-experimental study design. Student math scores were gathered from their TAKS math scores, in addition to surveys completed by teachers and students using the Reasoning Mind program. Results indicated no difference in the TAKS achievement scores for the treatment groups and control groups, suggesting that Reasoning Mind did not have a notable impact on students' performance on this standardized test.

However, the authors posited that these findings may be an artifact of the low content validity that TAKS has to the Reasoning Mind curriculum. Nevertheless, the teachers spoke highly of the Reasoning Mind program, emphasizing the opportunity it gave the students to review lesson material, use self-pacing, and receive real-time feedback on their performance and problem-solving. Teachers also noted benefits of the Reasoning Mind curriculum to their own teaching by way of teachers learning new material and new teaching strategies for lesson objectives as well as having immediate access to student progress reports. Positive reaction was also evident in students' survey responses as they enjoyed learning math using the Reasoning Mind program. Nevertheless, since the survey results were largely presented descriptively, the use of more inferential statistics for analyzing these data would have added more value to the study's findings. Similarly, a pretest-posttest research design is critical for future students to allow for any valuable inference from survey responses.

Waxman, H. C., & Houston, W. R. (2012). *Evaluation of the 2010-2011 Reasoning Mind program in Beaumont ISD*. College Station, TX.

Setting: Several cities across Texas

Grade level: Grade 5

Product version and type of use (supplement or core): Genie 2 as primary curriculum

Study design: Quasi-experimental study design (pre-post)

Summary:

This was a well-designed quasi-experimental study that also addressed the issue of diversity in the student population and controlled for demographic characteristics like SES, ethnicity, and gender in its outcome analysis. The use of TAKS as the outcome assessment was problematic given that it tends not to be an instructionally sensitive measure. Yet the positive impact of the implementation on the treatment group, even after controlling for demographic characteristics, was an encouraging result. The study design for the survey findings is weak given the study used a post-only design for the treatment group. The findings on students attitudes towards Reasoning Mind were mostly positive with over 80% reporting they liked learning math in Reasoning Mind, and over 60% students saying they like math more after using Reasoning Mind. However, the lack of a reference point or pretest for these attitudes makes these findings difficult to interpret. Nonetheless, the study suggested Reasoning Mind regards teachers' and students' evaluation important for the improvement of its implementation, including the professional development provided to teachers.

Weber, W. A. (2003). *An evaluation of the Reasoning Mind pilot program at Hogg Middle School*. University of Houston: Houston, TX.

Setting: Houston, TX

Grade level: Grade 7

Product version and type of use (supplement or core): Genie 1 as primary curriculum

Study design: Randomized controlled trial

Summary:

One of the first studies to document the impact of the Reasoning Mind intervention, this small randomized controlled trial found early evidence for the significant impact of the Reasoning Mind intervention on the treatment group. This report also provides a detailed account of the psychometrics of the Reasoning Mind Assessment developed and adopted across most of the studies documenting Reasoning Mind implementation efforts. In a similar vein, the study provides early data on students' relatively positive learning experiences in the Reasoning Mind system. The drawback of the study examining students' and teachers' attitudes is the post-only design. This typically limits the interpretation and comparison between the control and treatment groups. In this case, however, the authors were able to partly make up for this lack of rigor by asking relative experience questions, such as asking students to compare whether their Reasoning Mind class was harder than their typical math class or if they like it more.

Weber, W. A. (2006). *An evaluation of the 2005-2006 Reasoning Mind project*. University of Houston: Houston, TX.

Setting: Houston, TX

Grade level: Grades 5 to 8

Product version and type of use (supplement or core): Genie 1 and 2 as primary curricula

Study design: Quasi-experimental pre-post design

Summary:

This was the second evaluation report published on the implementation of the Reasoning Mind curriculum across 10 schools. Despite best intentions to provide a randomized controlled trial, the report outlined several challenges that resulted in the study having a less ideal quasi-experimental pre-post design. These included lack of randomization due to school administrator choice, student mobility, and lack of achievement data for students. Students' achievement data was gathered from the Texas Assessment of Knowledge and Skills (TAKS) or the math test from the Stanford Achievement Test Series (SATS). The results were largely mixed, with no significant difference between the performance of the comparison groups and the treatment group. Overall, the study drew several important implementation and curriculum development lessons to improve future implementation and research on the Reasoning Mind program and its effectiveness.

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