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DESIGNING FOR CONSISTENT IMPLEMENTATION OF A 5TH GRADE DIGITAL MATH CURRICULUM

Jeremy Roschelle[1], Steven Gaudino[2], & Samantha Darling[2]
[1]*SRI International;* [2]*Reasoning Mind*

Reasoning Mind products are used by over 100,000 students a year and have shown positive outcomes. In this design case we focus on implementation: how Reasoning Mind's approach evolved to tackle the challenge of achieving consistently high-quality implementations with many different schools, teachers, and students. Key insights include the definition of the Implementation Coordinator role and how that role is managed, the design and refinement of specific tools to support the implementation improvement process, and how Reasoning Mind's understanding of its organizational values in relationship to its approach to implementation evolved over time. Based on a study in which 23 schools in West Virginia are newly adopting Reasoning Mind, we also reflect on how the design insights are playing out in a large-scale implementation.

Jeremy Roschelle serves as a co-director of the Center for Technology in Learning at SRI International. His expertise is in design and evaluation of digital mathematics systems. He is the principal investigator of the current evaluation of Reasoning Mind.

Steven Gaudino is Vice President of Program for Reasoning Mind, overseeing implementation, professional development, and online tutoring. Steven has been at Reasoning Mind since 2004 and has been involved in implementation design throughout his tenure.

Samantha Darling leads the present implementation of Reasoning Mind in West Virginia, overseeing the team of Implementation Coordinators who support teachers.

INTRODUCTION

Improving mathematics learning is a long-standing goal for the use of technology in education. Innovators have developed novel approaches, such as the use of intelligent tutoring systems to guide students' learning. More recently, digital curriculum products are replacing conventional paper textbooks as the major classroom resource that guides instruction in mathematics throughout the year. Although many innovative approaches achieve positive results when evaluated in just a few classrooms, variability in how the approach is used by teachers and schools can result in mixed results in larger evaluations.

For example, a prominent experiment evaluated the most promising products available at the time and found that the impacts of digital mathematics products on student learning averaged out to be close to zero (Dynarski et al., 2007). In some classrooms in this study, student outcomes increased; in others, student outcomes decreased. Given the variability, a positive overall effect was not detected.

Even when the research basis for an innovative approach is exceptionally strong, implementation issues can interfere with student learning impacts. For example, Cognitive Tutor Geometry has a strong research-backed design, but one large scale trial found that students assigned to use the tutor scored 19% of a standard deviation lower than students in control classrooms (Pane, McCaffrey, Slaughter, Steele, & Ikemoto, 2010). Researchers attributed the drop to implementation stating: "data suggest that many teachers had difficulty implementing the treatment curriculum's learner-centered pedagogy" (Pane et al., 2010, p. 254). The challenge of achieving a consistent implementation has also been noted for the Khan Academy (Murphy, Gallager, Krumm, Mislevy, & Hafter, 2014) and other newer designs for blended learning (Murphy, Snow et al., 2014).

Conversely, when evaluations of technologies for mathematics learning have found stable positive effects, attention to the quality of implementation has often been a notable design feature. *T*echnology-enhanced, *R*esearch-based, *I*nstruction, *A*ssessment, and professional *D*evelopment (TRIAD), a digital mathematics curriculum for early mathematics learning, has strong evidence of efficacy and features a strong professional development component (Clements & Sarama, 2011). An evaluation of networked graphing calculators found positive effects on students' algebra learning and noted the extensive focus in the implementation on improving teachers' formative assessment practices (Pape et al., 2012). In another evaluation that found positive effects on mathematics learning, the approach to learning mathematics featured a "curricular activity system" approach which defines and supports the alignment and integration of curriculum, technology, and teacher professional development (Roschelle et al., 2010). Overall, there is now broad recognition that designing the implementation of a technology is a distinct phase of design from designing how the technology directly supports mathematics learning, and that specific design processes are appropriate to creating powerful supports for consistently high quality implementation (Penuel, Fishman, Cheng, & Sabelli, 2011).

In this design case, we focus on how Reasoning Mind's approach to implementation has evolved over time. Reasoning Mind is presently in use by over 100,000 students each year. When working at this scale, implementation issues become more salient than they are when testing earlier stage designs with just a few teachers or schools. In this article, we discuss why and how Reasoning Mind tackled implementation challenges with novel designs at the implementation level, building on prior design layers.

THREE PERSPECTIVES ON IMPLEMENTATION

The three authors of his article are working together on the West Virginia study.

The lead author, Jeremy Roschelle, has been involved in many evaluation studies of digital mathematics products that have been conducted by SRI over the past decade. Across these studies, he has seen many implementation issues that occur across products. Sometimes products are purchased by schools but are not used in classrooms as intended, or are used too little to make a difference. Sometimes, the product is used in classrooms, but the teachers' role is unclear or unsupported, and the teachers' contribution to student learning declines. A key challenge to successful "blended" learning approaches is balancing and integrating the roles of teachers and technology in supporting student learning. SRI has also seen digital mathematics products benefit from professional development support to teachers over at least one year (and often two years), not just introductory workshops. If teachers are to use data to adapt instruction, SRI has found that merely providing data is rarely enough; specific design must go into supporting teacher interpretation of the data and adaptation of their instruction. As a consequence of the profound role that implementation plays in mediating the outcomes that SRI seeks to measure in its studies, SRI now designs its studies with considerable attention to (a) allowing time to adaptively improve implementation before outcomes are measured and (b) measuring implementation through multiple instruments, including interviews, observations, teacher logs, and system data.

The second author, Steven Gaudino joined Reasoning Mind as a math curriculum developer in 2004. In 2005–2006, he recruited and led a team of editors and testers in ensuring the correctness and proper functioning of online educational content. Also in this period, he organized and ran one of Reasoning Mind's first pilot projects, using the curriculum he had helped develop. In 2007, Gaudino became Reasoning Mind's first Director of Implementation. In this role, he oversaw a massive expansion of the Implementation Department. Gaudino led the development of a large number of standard processes and supports, ensuring that the fidelity of implementations of Reasoning Mind was maintained—and even improved—throughout this period of rapid expansion.

The third author, Samantha Darling, was a classroom teacher who was energized when she learned how Reasoning Mind taught mathematics. She joined Reasoning Mind to take on the newly defined Implementation Coordinator role; an Implementation Coordinator works with schools and teachers throughout initial training and during the school year to support their achievement of high quality implementations. Now Darling oversees a team of Implementation Coordinators. Her perspective is grounded in the realities of working with teachers and schools on a daily basis to resolve implementation challenges; she appreciates the role of standardized processes and supports in this respect, and also the ways in which implementation improvement must build on a foundation of strong mentoring relationships with teachers.

From the perspective of Reasoning Mind, the design lessons reported here are shaping plans to support the implementation of this product in other regions of the country and to support high quality implementation of products designed for other grade levels. From the perspective of SRI, a non-profit research firm, the design lessons can inform its consulting and evaluation practices with regard to how other education products, such as formative assessment systems in science or digital curricula in computer science, could be successfully implemented at scale. Design insights which have ongoing utility from one or both of these perspectives are marked with a "✪".

ABOUT REASONING MIND

The focus of the design case that will follow is on the design of the support for *implementation* of Reasoning Mind's 5th grade core curriculum—much of which relates to how teachers are supported as they use Reasoning Mind with students through a school year. Design cases could also be prepared on other layers of design that are important to the system, such as the curricular and pedagogical design and the user experience design. Each of these design layers has its own criteria and processes, and its own design history. We begin with some background details on other design layers below, but focus our design case thereafter on the implementation design.

Background: Instructional Program

Reasoning Mind, a nonprofit organization, offers digital mathematics products that can be used either as a supplement to conventional instruction or as the core instructional materials for a grade level. We focus on Reasoning Mind's core instructional program for 5th grade, as this is what we are studying in West Virginia. In addition, implementing a new core curriculum is more intensive for teachers than implementing a supplement.

The Reasoning Mind core program is a complete system for teaching 5th grade mathematics, intended to be used by teachers and students for 70-90 minutes a day. This scheduled time was chosen to ensure that students complete their assigned curriculum over the course of the year with students completing a lesson, on average, each day. The amount of time is reported here because it is contextually important to understanding the implementation design; when teachers use a product as a core curriculum (rather than as an optional supplement), implementation issues become more important to address.

In a classroom using this system, students begin working individually on mathematics at a computer when they arrive in class and continue working individually for most of the time. The teacher also has a computer, which provides control over what is going on in class as well as reports featuring data about students' progress. The teacher sometimes addresses the whole classroom for a short period of time to discuss mathematics, logistics, or issues of motivation (e.g., goals, incentives, celebrating successes). The teacher spends substantial time working with individual students or with small groups of students; sometimes students ask for support from the teacher and, at other times, the teacher can use data to decide which students to work with. In addition, the teacher can use data to orchestrate peer mentoring and collaboration by matching students on similar topics or by pairing advanced students with those in need of additional support. This can be done through intentional peer seating or by designating students to serve as teacher assistants on a given day.

Thus, the Reasoning Mind core program is a blended learning approach in which students' experience is of learning both from the technology and from interactions with their teacher and peers– and the technology and the teacher are helping the students with the same mathematical challenges.

Background: Curriculum Design

The Reasoning Mind curricular design was built through Instruction Modeling, the process of examining effective instruction and recreating it through technology. Khachatryan et al. (2014) provide a design case for the curricular design, which we summarize as follows: By studying the methods of expert Russian teachers in their traditional classroom settings, Reasoning Mind found that quality mathematics instruction relies on a range of factors including: (a) the coherence of the written curriculum, (b) the activities expected of students, (c) the adaptations of the teacher, (d) the culture of the classroom, and (e) the nature of interactions between teachers and students. To capture these practices, Reasoning Mind's team of expert Russian teachers provided detailed scripts that described the moment-by-moment actions of teachers and students in each lesson. Each script was then studied and elaborated upon through extensive interviews. The interviews targeted the motivation behind each teacher decision.

Once this was fully understood, Reasoning Mind's Knowledge Engineers developed a novel technology-based user experience that recreated the set of experiences a student would receive in the expert teacher's classroom. For example, a key curriculum principle is that students learn through visual models, such as using an area model for multiplication (see Figure 1). Many design decisions in Reasoning Mind follow in a straightforward way from an analysis of existing high quality curricula and teaching practices. Further, the way these decisions were made would be unlikely to generalize to most learning technology products, few of which are made by observing teaching in one culture and seeking to re-produce that teaching process in another culture. As such, these decisions are not the focus of our design case.

Background: User Experience

In a Reasoning Mind classroom, each student logs onto an individual account that continuously adjusts to the student's pace and level of mastery as he or she study the curriculum. Unlike technology programs that break from traditional instruction, the Reasoning Mind system uses an intelligent tutoring system to present and adapt in the ways expert teachers would. Unlike curricula divorced from their cultural context, the Reasoning Mind system attempts to preserve the pedagogical methods that originated along with its curriculum's tradition. The design intention in the user experience is to provide students with a consistent quality of instruction that maintains fidelity to the curriculum and the proper method of teaching it. The design approach builds on prior research in intelligent tutoring systems. For readers interested in the design issues relating to authoring

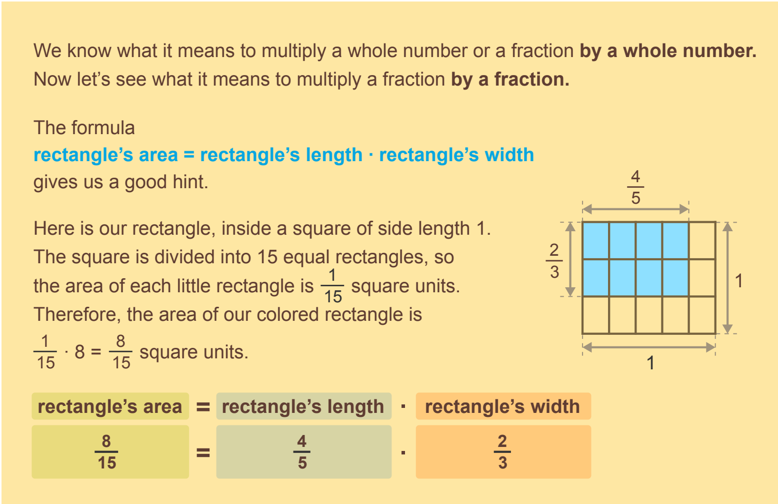

FIGURE 1. The Reasoning Mind curriculum takes advantage of international pedagogical practices such as using problems to drive content knowledge and integrating geometry to illustrate arithmetic concepts. In the screen shot above, area is used to motivate fraction multiplication. Students then develop an abstracted algorithm for this process through a series of guided questions. Based on each student response, the system provides tailored feedback and adjusts the content it delivers.

intelligent tutor systems more generally, a longstanding literature already exists (e.g., Murray, 1999). We focus on design of the implementation, for which not much literature is available.

Reasoning Mind also goes beyond the classic intelligent tutoring system by supporting peer learning in the classroom. As previously mentioned, the teacher can group students to work together in pairs or designate a student as a teaching assistant for the day. Also, teachers can use data reports to pair struggling students with those who demonstrated fluency. In addition, students are encouraged to work together on challenging problems in the Wall of Mastery. As with intelligent tutoring systems, there is already an extensive existing literature to guide design of collaborative learning (e.g., Kirschner & Erkens, 2013) for readers with further interest in the issues of designing for collaborative learning.

Background: Role of Teachers

Teachers need preparation, training, and support to use Reasoning Mind, as is the case with any core curriculum product. A new teacher's experience of Reasoning Mind begins with a "Qualification Course," which takes two to three days over the summer. The Qualification Course covers the things a new Reasoning Mind teacher needs to know to successfully launch the program with their students. Highlights include training on the student and teacher interfaces, data-driven intervention techniques, hands-on curriculum exploration, and best practices for managing a successful blended learning classroom. After the Qualification Course, teachers participate in ongoing professional development (PD) throughout the school year, which includes both PD modules and personalized coaching.

The Reasoning Mind team believes that a strong quality of student learning will not occur without teachers who lead a high quality classroom implementation. A classroom environment that is not conducive to learning will dismantle any instructional approach. But even with strong classroom management, technology is not powerful enough to model all key practices, so the content must be supported by additional system components and coordinated teacher instruction. The practices that require special implementation focus include: (a) student mindset, (b) student practices, (c) classroom procedures, (d) instructional prioritization, and (e) conceptual discussion in small group settings. Reasoning Mind fosters these practices through its virtual mentorship, student interface, data tools for partners, and Implementation support as we describe next.

REASONING MIND FEATURES AND IMPLEMENTATION NEEDS

Building on a system that has previously established designs for its instructional, curriculum, user experience, and teacher components, Reasoning Mind addresses implementation holistically, as a new layer of design and not as a set of independent issues. Describing three important aspects of the Reasoning Mind approach is useful in clarifying how teacher implementation of Reasoning Mind matters to students' experience and learning.

The Genie Character

An animated character called *The Genie* guides the student through each lesson (see Figure 2). The Genie's primary function is to foster a productive mindset through its immediate feedback, solutions to problems, and words of encouragement. This consistent, positive presence can help students stay focused and persevere through challenging material.

To develop the student's connection to the Genie, Reasoning Mind employs a team of writers who respond to hundreds of student emails daily. For consistency, each writer responds according to a carefully constructed biography. Components of the Genie, such as its neutral gender and lack of voice, were intentionally designed to ensure that the character was equally relatable to all students.

Over time, Reasoning Mind refined the Genie's actions based on student and teacher feedback. Its reward response movements became more elaborate and varied, its emails

FIGURE 2. The Genie character guides students through each lesson.

to students drew from research on student mindset, and its solutions to incorrect problems became more interactive.

Though students respond positively to Genie, the teacher still sets the tone of the Reasoning Mind classroom, and student attitudes are modulated by the teacher's own mindset. This impact on the student experience means that teachers must have the tools and training needed for the program to have its intended effect.

Notebooks and Note Taking

Paper notebooks are also a prominent feature of Reasoning Mind's classrooms. Students are required to have notebooks and are guided to write specific mathematical definitions, procedures, and problem solutions in their notebooks. To develop productive note taking habits, the system labels key concepts with a "Write this Down" tag. At the end of the lesson, students are given a Notes Tests that serves as a review of the key concepts and a check of whether students recorded them in their notebooks. Students note taking habits are expected to develop throughout the year.

The purpose for the notebooks is to develop students' independent learning strategies—skills that enable students to learn mathematics effectively on their own. Teachers are critical to setting norms for notebook use, but also in guiding students to use their notebooks as a learning resource. For example, teachers help students to understand that they will have to keep notebooks that are clear and neat enough to be useful later. Further, teachers direct students to use notebooks as a primary learning resource when they are stuck. For example, many teachers implement a "3 before me" routine, where students must try to resolve their own challenge using their notebook, online resources, or a peer *before* asking the teacher for help. The importance of notebooks and of teachers' role in supporting note taking practice need to be reinforced throughout the training and coaching for Reasoning Mind teachers.

Data-Driven Decisions

Reasoning Mind collects data as each student solves mathematics problems and progresses through the system. This data is used by the system's algorithms to adapt to the students' needs—for example, a student who is achieving low accuracy on a set of problems may be directed to a diagnostic module and to additional learning resources for that topic. In addition, a key feature of Reasoning Mind's instructional module is that teachers are expected to use data to make classroom decisions.

The earliest reports provided insight into student performance, but they lacked the level of detail needed to pull small groups and provide intervention. For example, an overall percentage of problems solved correctly allowed teachers to know if students were being successful, but if the percentage was low, the teacher could not conveniently identify the particular areas of confusion. Through partner feedback, Reasoning Mind developed a set of features to support teachers in making instructional decisions. Teachers now can use an *objective spreadsheet report* to sort students by performance over any topic in order to form small groups for intervention or pair students for peer tutoring. To intervene, teachers need to see what problems the student got wrong and what incorrect solution was entered. The teacher can access this information for a particular student on a particular objective by clicking on the corresponding cell that shows the accuracy percentage. This opens the student's *activity logs* that contain the problems the student got wrong and what the student's answer was. The *new dataset* button generates similar problems to solve, so teachers can see a student's reasoning first-hand and then discuss the full solution together.

Teachers also get *status notifications* (see Figure 3). These notifications provide updates on student work in real time, which can give the teacher insight into whether students are spending their time productively. Learning these features takes time, and when teachers begin with Reasoning Mind, they typically have not previously used data as intensively to make real-time classroom decisions about which students to work with and what to work on. Thus an important concern for implementation fidelity is to help teachers incorporate Reasoning Mind's capabilities for data-driven decisions into the core of their teaching repertoire and daily practice. Similarly, the Genie and Note taking features can only realize their design intent though teacher support. As teachers become skilled on what to do incrementally, implementation support for teachers is critical to Reasoning Mind's approach.

RESEARCH AND REASONING MIND

Reasoning Mind has engaged external researchers in its work since its inception. SRI reviewed a series of prior research studies conducted by other investigators and found that effects on student learning were consistently positive

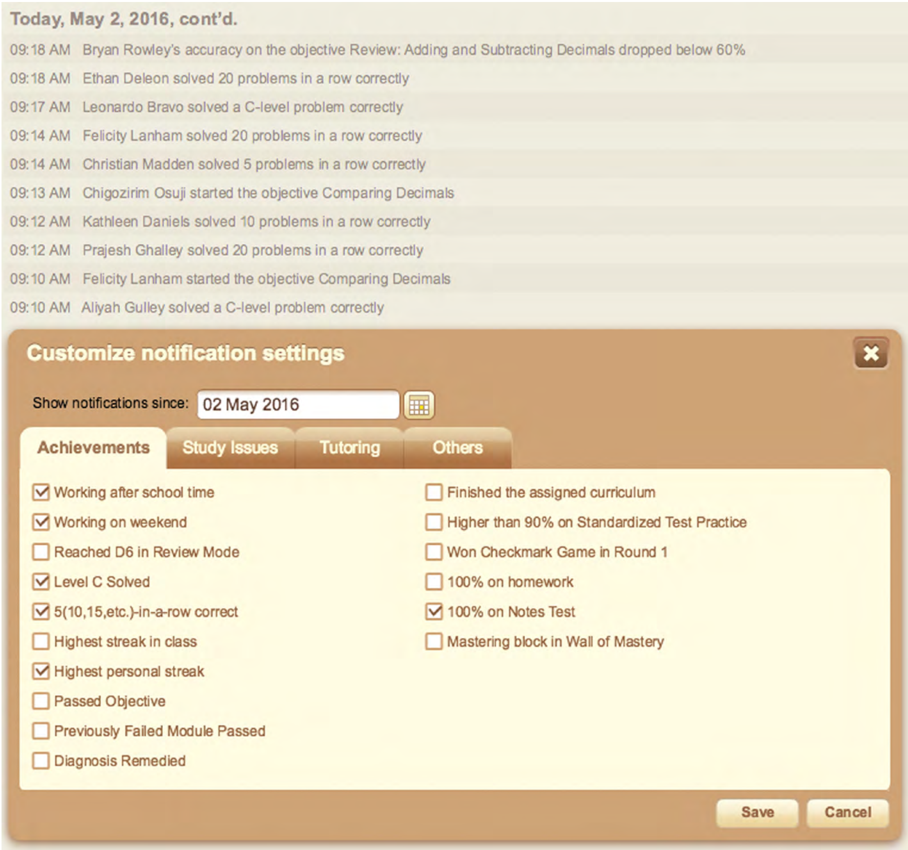

FIGURE 3. Teachers can customize their notifications.

(Roschelle, Bhanot, Patton, & Gallagher, 2015). Teacher and student attitudes, as reported by external evaluators, show high engagement and motivation. SRI's report also noted that Reasoning Mind has shown an ability to achieve a high quality implementation at scale, for example, with over 25,000 students in Dallas.

SRI is presently conducting a study of Reasoning Mind in West Virginia with funding from the U.S. Department of Education's Institute of Education Sciences. The study is designed to evaluate the impacts of Reasoning Mind's 5th grade core curriculum for mathematics on the state's end of year mathematics test, compared to impacts of business-as-usual approaches to teaching the same mathematics. Over 50 volunteer schools were recruited and randomly assigned to use Reasoning Mind either as a 5th grade core curriculum (the treatment condition) or to continue with their existing curriculum for 5th grade (the control condition). To date, the research team has had the opportunity to observe classrooms and survey teachers, and has been able to inspect the system log data that result from teachers' and students' use of Reasoning Mind. After describing Reasoning Mind's designs to support implementation, we will return to this study to reflect on how our observations in the first year of implementation in West Virginia relate to the designs, thus enriching the design case with observations from a large-scale implementation. Collecting and analyzing this data is also instrumental to SRI's role in communicating insights about how to address large-scale implementation challenges with broader audiences.

WHY AND HOW REASONING MIND TACKLED IMPLEMENTATION

A need for tackling implementation as its own design issue emerged as Reasoning Mind tested its early approach in classrooms. The first classroom test of Reasoning Mind occurred in the spring of 2003. The results were encouraging, but the test occurred in only one classroom and the inventors of the approach were able to directly engage with students in the classroom (Weber, 2003). Although this helped the team move forward, the team also realized that a product that relies on the presence of its inventors during implementation cannot scale.

In 2005-2006, teachers implemented the program with less involvement of the inventors, but during the first year of the program's expansion, support to teachers was minimal. Teachers were not taught the curriculum's pedagogy, so there was no context to guide the content of their small group sessions. New classroom practices were needed to support this new environment, but no best practices were available. Interfaces and reporting tools were neither intuitive nor thoroughly explained. As a result, an external evaluation found that the quality of the implementations was inconsistent and overall low (Weber, 2006).

To address these issues, Reasoning Mind began to design professional development and implementation support in the 2006-2007 academic year. A cross-functional team was assembled to design the processes and supports that would be provided to teachers. The team included Reasoning Mind's CEO, Director of Implementation, Principal Analyst, content specialists, and experienced Reasoning Mind partners.

The team had considerable data at its disposal, and they used the system metrics, classrooms observations, evaluator reports, and teacher focus groups to target the most important implementation issues. Later, when the designs below were tested in the field, new data was collected and analyzed to drive its evolution.

✪ The Implementation Coordinator Role

The cornerstone of Reasoning Mind's design for implementation has been the Implementation Coordinator role. At first, Implementation Coordinators were hired to provide trainings and guidance throughout the school year, and their role could be considered to be the same as a trainer or professional development leader. To anchor this effort, Reasoning Mind distilled the best practices common in its implementations and the recommendations of its expert teachers into a rubric used by teachers, administrators, and Implementation Coordinators. Therefore, expert modeling drove the direction of implementation design just as Instruction Modeling shaped the Reasoning Mind curriculum.

Initially, the role of Implementation Coordinator was similar to the role of providing PD. However, the difference in the title for the role came to have important meaning. Whereas the mission of professional development is usually to improve a teachers' knowledge or skill in particular way, the mission of an Implementation Coordinator is to achieve a defined quality of implementation. Unlike professional development leaders, Implementation Coordinators (ICs) do not only *deliver* PD. Rather, they do what it takes to achieve the desired quality of implementation in each classroom.

For example, ICs initially focused just on teachers. This kept classroom practices as a local effort rather than a district initiative, and it alienated administrators who lacked the knowledge to actively monitor their implementations. The team saw this as a problem to be resolved, and expected that by engaging administrators, ICs could create higher accountability to implementation fidelity and simultaneously lower the cost of implementation per student. Hence in a refined implementation approach, ICs now also work with school administrators. Likewise, ICs have responsibility to communicate needed system improvements back to the Reasoning Mind team. Further, ICs work as part of the whole team to find solutions to difficult school-specific challenges, which may have to do with how instruction is scheduled at a school or how students are assigned to teachers or classrooms. Thus ICs now broadly *coordinate* the approach to achieving high quality implementation.

Another difference is how ICs allocate their time and attention. In conventional professional development (PD), trainers spend roughly equal amounts of time with each teacher. ICs, however, have the freedom to spend more time with teachers who need more support to improve their implementation. Likewise, the program of support can be customized to work with the characteristics of a particular teacher or school.

✪ Tools for Coordinating Improvement

As the number of schools using Reasoning Mind expanded, the organization realized that it could not afford to be solely responsible for improvement. Instead, Reasoning Mind took the approach of engaging teachers and administrators as partners in improving implementation. To aid administrators and teachers in overseeing their implementations, Reasoning Mind created a website called the Reasoning Mind Community (see Figure 4).

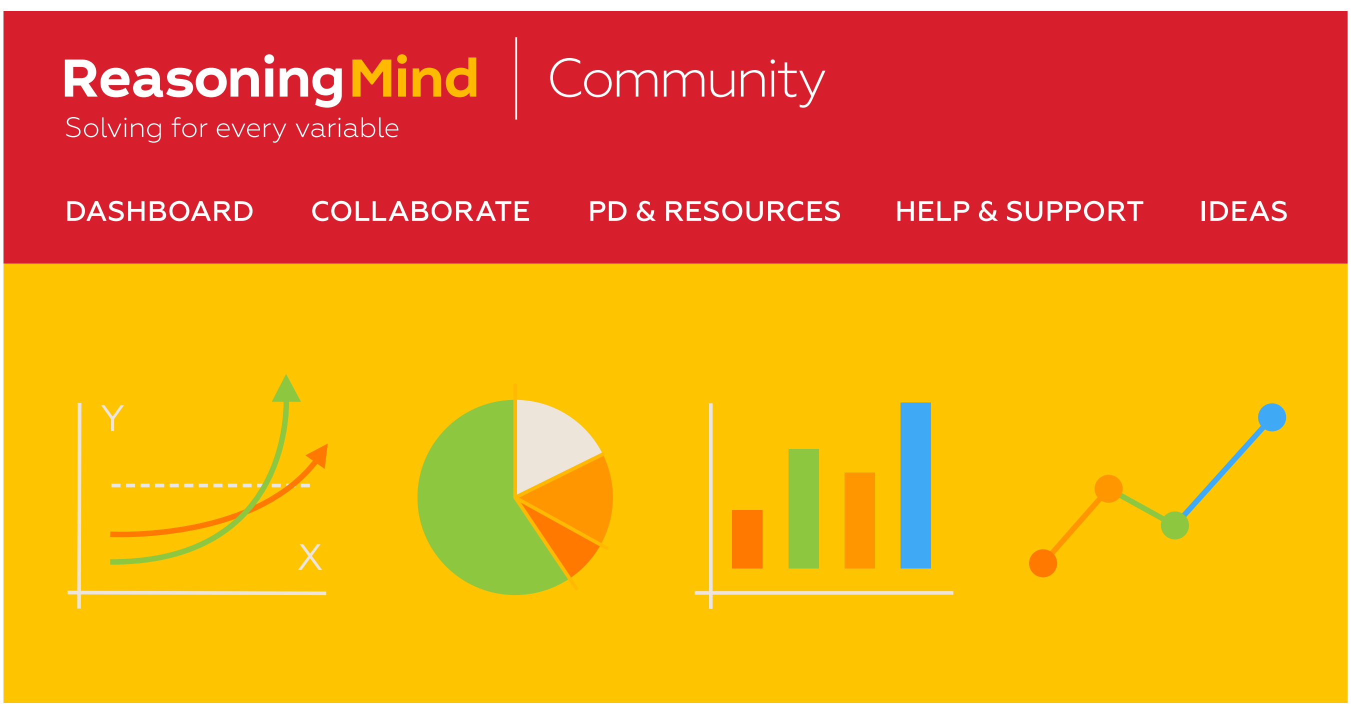

FIGURE 4. Part of the Reasoning Mind Community site.

Key elements of the site include:

- **DASHBOARD** The community dashboard integrates student metrics with recommendations generated from observation data. Therefore, an administrator who uses the Reasoning Mind observation application can have implementation quality automatically analyzed and recommendations to support instruction immediately prepared.
- **PD & RESOURCES** After reviewing the dashboard's recommendations, the PD & Resources tab enables partners to download or sign up for the help they need. For convenience, professional development is delivered in person, remotely, and online. Its courses are designed in collaboration with the curriculum team to ensure fidelity to the program's pedagogy and include a variety of best practice workshops, pedagogical trainings, and curriculum tutorials.
- **COLLABORATE** This moderated forum enables partners to interact with one another over targeted topics. Partners use this opportunity to exchange ideas and connect with a large network that fosters their growth. This peer support creates a culture around a common experience of using Reasoning Mind.
- **HELP & SUPPORT** For technical questions and help, partners can download guides or submit questions to the Partner Support Team through email and instant chat.
- **IDEAS** Teachers and administrators use this space to submit ideas for technical improvements, new functionality, and classroom resources. Teachers are also able to vote on ideas of others that would improve their experience.

By connecting partners to resources and each other, the design team created a Reasoning Mind Community that could serve as an integrated hub for administrator and teacher support. Related research shows that without this cultural support, educators are likely to revert to scripts of habit rather than adopt new pedagogical methods (Stigler & Hiebert, 2009).

✪ Defining Guidelines and Practices

Teachers require time to achieve high quality implementations. For example, the current study in West Virginia was designed so that teachers have an entire school year to improve their implementation of Reasoning Mind. Student learning results will be measured in a second school year, with a second cohort of students. Although this may seem like a long time, observations in West Virginia supported the need for a long developmental period. For example, some teachers reported a difficulty in the first semester with Reasoning Mind because it required so many changes from their traditional teaching style. However, by the end of the second semester, teachers were more positive, as we will discuss in further detail.

To support teachers' developmental trajectory, the Reasoning Mind team responsible for designing for implementation developed and refined clear guidelines and practices to drive its professional development, support, and resources. These guidelines and practices underwent multiple iterations over time.

The first iteration was an implementation rubric with three levels of implementation quality: *established*, *proficient*, and *advanced*. The expectation was that an individual teacher could have different quality ratings for different areas of their implementation. For example, a teacher could be advanced in terms of incentives, but only established in terms of data-driven decision making. From 2010 to 2014, ICs used this rubric to observe teachers. Its one-page, color-coded format was important to ease of use by ICs (see Appendix A).

The design of the implementation rubric evolved as more was learned from the implementations it served. At first, the implementation rubric was a distillation of effective teacher practices. In addition to supporting teachers with this rubric, Implementation Coordinators observed classrooms to inform their recommendations. As a result, a massive amount of Implementation data was collected.

Evaluations also contributed to the improvement of the rubric. For example, analysis of classroom observation and student performance data indicated that higher levels of implementation fidelity were correlated to stronger student outcomes in Reasoning Mind. This was encouraging, as it confirmed that many of the practices identified may support student success. The graph in Figure 5 shows the correlation between implementation fidelity and student problem solving accuracy (percentage correct) for the most difficult problems in Reasoning Mind's curriculum, level C problems. Similar correlations exist for level A and level B problems, which are not as hard.

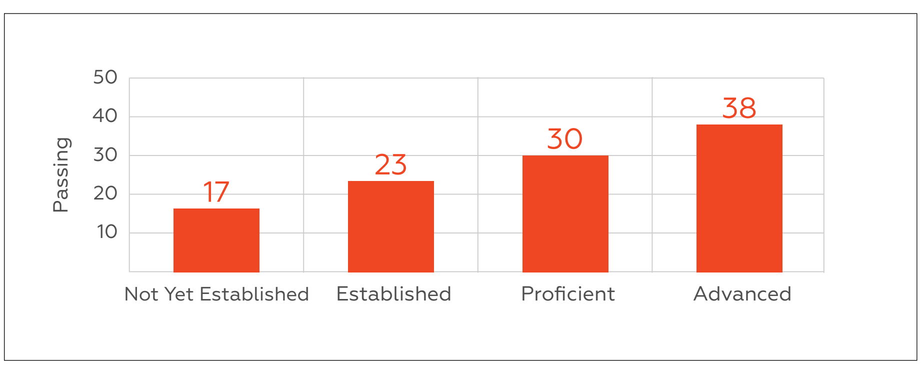

FIGURE 5. In classrooms with higher quality implementation, students get a higher percentage of difficult problems correct.

However, after many years of using version of rubrics to guide ICs in the work of improving implementations, Reasoning Mind came to realize that the rubric-based approach had both a key benefit and a key flaw. The key benefit was that the rubric recognizes areas in which implementation is improving without setting the expectation that all classrooms will improve at the same rate or in the same ways. The key flaw was that the rubric started to breed an orientation to compliance. Some ICs, teachers, and schools aimed for high marks on the rubric, while still not achieving strong student results. Other ICs, teachers and schools were inventing new best practices, but the practices were not spreading because they did not fit the rubric. This realization led to discarding the rubric format (i.e., the matrix of implementation characteristics and implementation levels) and re-focusing on the desired quality indicators.

Achieving managed implementation required a clear definition of what high quality implementation looks like, but to avoid the issues with the leveled rubrics discussed earlier, the team wanted goals at the forefront, with the practices as examples of how to attain them. After Reasoning Mind's analysts studied the rubric variables that had the greatest impact on student performance, the Implementation team produced the Goals and Practices document (see Appendix B), placing a greater emphasis on the suite of Implementation components that made the greatest impact. This is reinforced by tailored Reasoning Mind reports and a mobile application that translates classroom observations into recommendations in the Reasoning Mind community.

✪ Regional Implementation Managers

Another important design change was in the management of implementations. Initially, ICs were managed centrally from Reasoning Mind's offices in Texas. As Reasoning Mind spread to other states, regional differences became noticeable. The ways in which schools are managed varies from state to state (for example, Texas tends to have very large school districts whereas West Virginia has very small ones). The culture of how teachers and administrators communicate is different. Also, some of the challenges schools face are similar within regions, but different across regions. In response, Reasoning Mind developed a new role for a regional IC manager, who works with a team of regional ICs to improve implementation.

The Implementation Manager (IM) coaches a team of ICs, each of whom is developing skills in supporting Reasoning Mind's implementations in schools and at a higher county level. Together, regional teams discuss emerging challenges in their area and seek common best practices and solutions that will address the challenges. The IM also coordinates with Reasoning Mind's central office to discuss improvements and developments to the system, Professional Development and materials, and overall support structures which are needed to ensure strong partner relationships and high quality classroom practices.

Within its regional strategy, Reasoning Mind is seeking to strike a balance between setting high standards for implementation quality everywhere, but also seeking to continue to innovate in how high quality implementation is defined and achieved. The goal is to capture what's working to enable students in every Reasoning Mind site to have a very high quality mathematics leaning experience, without over-emphasizing compliance to practices that are not universally necessary, and while retaining the flexibility to add emerging best practices into the mix.

WV IMPLEMENTATION REFLECTIONS

In West Virginia, the SRI team has been able to reflect on data from a first year of implementation improvement across 23 schools (in the 2014-15 school year). Reflecting on this data helps to inform the design issues discussed earlier and is important to SRI's process of developing reference cases that SRI can share with confidence across related implementation design challenges. Student learning outcomes, however, are not yet available and thus SRI is not yet able to report on the efficacy of the product.

Overall, we noted that all teachers were able to complete the required Reasoning Mind initial qualification course and began using Reasoning Mind. At the beginning of the school year, some teachers were slower to start using Reasoning Mind, in part due to technology issues. Some teachers complained about the system; they didn't like the changes to their teaching practices that were required, such as spending less time leading the whole classroom and more time working with individuals and small groups. Some teachers thought the content was too hard for the students. Overall, most teachers immediately engaged with Reasoning Mind as their core curriculum for 5th grade mathematics but teachers varied in their degree of commitment to the program.

Providing ongoing support to engage teachers with the Reasoning Mind curriculum and blended learning classroom strategies more fully are major roles of the Implementation Coordinators (ICs). Assigning each IC to specific first year 5th grade teachers allowed for personalized support in the initial training, launching of the program, and then ongoing support throughout the academic year. ICs are experts in Reasoning Mind's system components, student and teacher interface functionality, curriculum, and implementation best practices and served as coaches who provided direct feedback and guidance, as well as remote support. For first year teachers this included: (a) an in-person meeting after their training to develop an appropriate plan of action for introducing students to the Reasoning Mind program; (b) an in-person, on-site training directly after launch in which an IC visited a teacher during Reasoning Mind time to model best practice strategies; and (c) monthly observations with follow-up meetings to discuss best practices, goals, and growth.

Another role of the IC was to monitor system performance data and identify next steps for professional development on student and teacher actions. First year teachers received weekly data reports with reflections from ICs to help coach them in Reasoning Mind's data analysis and tutorial strategies. These reports also helped set goals for motivation and progress toward curriculum completion. For professional development, each first year teacher was encouraged to take advantage of six two-hour Reasoning Mind workshops, three in the fall and three in the spring. ICs helped teachers set goals on these workshops, monitored their progress, and suggested topics for study. For many teachers, Reasoning Mind was the first technology-based core curriculum they had taught, and this coaching aspect of the support is crucial for teacher commitment and fidelity. Because of this, teachers also had access to their IC through phone, email support, and the Reasoning Mind Community where they could find resources, get technical help on system reports or accounts, and collaborate with other teachers across the country.

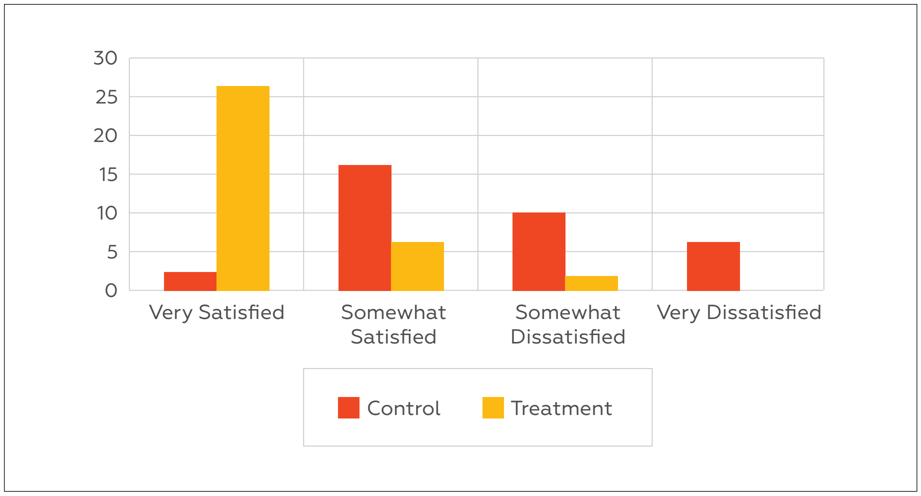

FIGURE 6. Reasoning Mind (Treatment) teachers were more satisfied with their math curriculum.

By the end of the year, key indicators reflected a quality of implementation that the aforementioned design features were intended to support. On average, schools were using Reasoning Mind for close to the target 70 minutes a day. System data showed that students on average were solving over 2,500 math problems per year in Reasoning Mind, and these problems included the desired range of problem difficulties (levels A, B, and C). Further, although student accuracy rates in solving the problems varied by school (and by classroom), all classrooms were within the range of expected accuracy rates. The system use data also shows that teachers in the treatment group were using the performance reports provided by Reasoning Mind regularly on a daily basis (over 5 times a day on average). The gradual movement of the indicators to appropriate levels re-affirmed our understanding that with well-designed support for implementation from ICs, all teachers can reach the target quality within a year and that some teachers reach these levels sooner than others.

In addition, teachers in both the Treatment group (using Reasoning Mind) and in the Control group (using their usual curriculum materials) took an end of year survey. Treatment teachers were notably more positive about their curriculum resource. For example, when asked "how satisfied were you with your curriculum this year", 26% of treatment teachers responded as "very satisfied" whereas less than 3% of control teachers chose this option. Six percent of control teachers expressed that there were "very dissatisfied" with their curriculum, while no treatment teachers responded so (see Figure 6).

Teachers' positive response to Reasoning Mind appears to be related to the features of implementation cited in this article. For example, 88% of teachers said the Genie character and Genie rules were somewhat or very useful. In addition, 97% of teachers were completely satisfied with implementation support; the remaining teachers were not dissatisfied with implementation support, but described support as a "minor" issue. The importance of Implementation Coordinators in change management also came through in the teachers' free responses:

> *"[IC] was always very helpful and supportive. She was quick with responses and very reassuring during classroom visits. She made our transition to using RM very easy."*

> *"[IC] is always helpful in all communication and feedback that I need to be successful. She makes me feel at ease and is quick to respond when I have questions."*

> *"[IC] was great to answer all questions that I had. She always responded to emails within a day and was always able to be reached. Her PD was also very useful. My students enjoyed seeing her when she came to my class."*

> *"[IC] was very dependable and helpful anytime I needed her. I contacted her several times with questions or concerns that I had. She even came to my class to model a lesson that I did not understand."*

On the basis of this data, Reasoning Mind plans to make the implementation design tested in West Virginia its standard operating procedure for each new region as it expands. Because the data relates the specifics of the design for implementation to the quality of implementation observed, SRI sees the data as providing empirical support for this design for implementation. Empirical support gives SRI confidence to use this approach to implementation challenges as a reference design in its ongoing work with providers of digital instructional materials for other curricular topics.

CONCLUSION

The Reasoning Mind design case is a case of a nonprofit organization focused on a comprehensive digital curriculum that observed a need to address implementation quality early on, and made steady improvements thereafter. Throughout the same time period, Reasoning Mind continued to improve its product, for example, adjusting the math content to fit new standards, improving the algorithms used to assign problems to students, adjusting the behavior of the Genie character, etc. Improvement of implementation was a distinctive layer of work, with its own challenges and its own designs. This layer of design for implementation became increasingly important to Reasoning Mind as the use of the curriculum reached a larger scale.

SRI frequently works in a design consulting or evaluation role with a range of educational technology materials that are in the process of going from smaller scale to broader use. In the transition to broader use, challenges of supporting high quality implementation by teachers often rise to the surface—and cannot be addressed merely by design processes related to curriculum or user experience. Implementation has its own challenges and needs its own design processes, as even high quality instructional designs can fail to yield intended effects if implementation challenges are not addressed.

One set of challenges addressed in this design case was in how to work with school staff on improvement issues, as a high quality implementation takes time to achieve. Reasoning Mind distinctively designed the role of Implementation Coordinator, which is different from the traditional role of Professional Development Leader. Reasoning Mind also realized a need to coordinate not only with teachers, but also with school administrative leaders. Later, Reasoning Mind shifted to a regional approach, defining the role of Regional Implementation Manager, to coordinate implementation work across a region.

Another set of challenges was in defining tools for this work. Reasoning Mind developed a community tool to coordinate the work of its staff with school staff as they engage in improvement work. Reasoning Mind also developed and used Implementation Rubrics to guide the improvement work. These went through multiple iterations of use and improvement, but ultimately were supplanted by an Implementation Goals and Practice document. Reasoning Mind had noted that the prior rubric was leading (in some instances) to a compliance culture that was diverging from its goals. The newer document was built on previous rounds of evaluation research to identify the variables which were most closely linked to student learning, while leaving more freedom in how teachers and schools achieved implementations to reach targets.

A third set of challenges has been in balancing between a desire for standardization and recognition of the value of continuous improvement. Early in the history of Reasoning Mind, implementation was not standardized at all, and this led to low overall results. In response, new roles and tools (as described earlier) were standardized. But Reasoning Mind also learned that standardizing the wrong things could lead to optimization of variables which don't matter and inability to share emerging best practices which were different but also highly successful. Over time, Reasoning Mind has come to realize that its key value is the quality of each student's mathematical learning experience, and that it should focus on those variables which contribute most directly to this value, while being less prescriptive about implementation variables which are less important to this value.

Overall, this design case revealed how we addressed these challenges through the intertwined evolution of these three elements: (a) the definition of key roles and processes, (b) the design of tools and structures to support those roles and processes, and (c) the clarification of the values of the organization in relationship to the specification of its approach to implementation improvement. Going forward, Reasoning Mind plans to continue using and improving its design for implementation as it expands its work to other regions of the country. SRI plans to incorporate this design case as an exemplar when it works with the providers of other instructional materials that are going to scale, and thus need to address challenges associated with supporting high quality implementation of digital materials across large numbers of classrooms.

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APPENDIX A

Reasoning Mind's Implementation Rubric

REASONING MIND: Implementation Rubric

CATEGORY	ESTABLISHED	PROFICIENT	ADVANCED
DATA DRIVEN DECISIONS	Teacher uses the home screen or reports to make instructional decisions.	Teacher uses metric analysis to make instructional decisions.	Teacher uses metric and problem analysis to make instructional decisions.
LESSON PLANNING	Teacher starts the class with a structured agenda that includes intervention time.	Teacher uses metric analysis to start the class with specific students chosen for intervention time.	Teacher starts the class with specific intervention plans for the chosen students, such as key problems or additional materials.
INSTRUCTIONAL METHODS	Teacher regularly conducts interventions during each class.	Teacher uses a variety of intervention methods to address student struggles.	Teacher uses methods to challenge high-achieving students and anticipates potential problems through pre-teaching.
LEARNING MODES	Class is generally logged into Reasoning Mind during scheduled time and regularly uses Review Mode or Wall of Mastery, as evidenced by metrics.	Class is logged into Reasoning Mind for a high percentage of scheduled time and frequently uses Review Mode or Wall of Mastery, as evidenced by metrics.	Class is logged into Reasoning Mind for nearly all of scheduled time and frequently uses Review Mode and Wall of Mastery, as evidenced by metrics.
TEACHER ENGAGEMENT	Teacher generally is directly engaged with students during class time.	Teacher is directly engaged with students for a high percentage of class time.	Teacher is directly engaged with students for nearly all of class time.
PROCEDURES	Teacher has procedural expectations in place and intervenes when necessary.	Teacher has procedures in place that run smoothly and require little intervention.	Teacher has procedures in place that run efficiently and do not require facilitation.
INCENTIVE SYSTEMS	Teacher has goals and rewards based on class or individual performance, and most students can identify them.	Teacher has goals and rewards both for class and individual performance; the teacher reinforces these goals during each class.	Teacher encourages students to take ownership of goals, and students are highly motivated by them.
NOTEBOOKS	Students have organized notebooks that appropriately include theory notes and student solutions.	Students' notebooks include additional learning aids, such as corrected solutions, accuracy tracking, and vocabulary.	Students use their notebooks to answer questions and help with problem solving.
INDEPENDENT LEARNING	Students know independent learning strategies, including the Genie's Rules, and are reminded to use them.	Students use independent learning strategies; these strategies are reinforced during each class.	Students adeptly use independent learning strategies without teacher facilitation.
STUDENT ENGAGEMENT	In general, students are directly engaged in learning during class time, and misbehaviors are often redirected.	Students are directly engaged in learning for a high percentage of class time, and misbehaviors are nearly always redirected.	Students are directly engaged in learning for nearly all of class time, without teacher redirection.

APPENDIX B

Reasoning Mind's Implementation Goals and Practices Document

Reasoning Mind

Implementation Goals & Practices

OUR MISSION IS TO PROVIDE A FIRST-RATE MATH EDUCATION TO EVERY STUDENT.

STUDENT PERFORMANCE

A-level Accuracy	A-level accuracy meets standard for 75% of students.
B-level Accuracy	B-level accuracy meets standard for 75% of students.
C-level Accuracy	C-level accuracy meets standard for 75% of students.
Productivity	Productivity meets standard for 90% of students.

STUDENT PRACTICES

Notebooks — Students keep organized notebooks to facilitate learning.

Foundation

- ✓ Students have:
  - notebooks.
  - organized and legible notes.
  - consistent theory notes.
  - consistent full solutions.
- ✓ Students use their notes to solve problems.
- ✓ Classroom procedures support the effective use of notebooks.
- ✓ Incentive systems motivate students to meet notebook expectations.
- ✓ Students understand and remember their notes.

Mastery

- ✓ Student notebooks include additional learning aids when appropriate.
- ✓ All students achieve an average Notes Tests score of 90% of higher.

Independent Learning — Students appropriately employ independent learning strategies.

Foundation

- ✓ Independent learning strategies are regularly communicated.
- ✓ Students know independent learning strategies and when to use them.
- ✓ Students use strategies appropriately to progress independently.
- ✓ Students read and understand the theory.
- ✓ Students read and understand the Genie's Solution.
- ✓ Classroom procedures support independent learning.
- ✓ Incentive systems motivate students to learn independently.

Mastery

- ✓ Students employ personalized learning strategies.
- ✓ Students use the Genie's Solution to correct misunderstanding.

Focus — Students are focused on learning.

Foundation

- ✓ Students are:
  - on task.
  - redirected when off task.
  - not disrupting others.
- ✓ Classroom procedures allow for maximum time on task.
- ✓ Incentives systems motivate students to be engaged in their learning.

Mastery

- ✓ Students are intrinsically motivated and on task.
- ✓ Students help keep other students focused on learning.

TEACHER PRACTICES

Data Driven Decisions	Teacher uses data appropriately to make instructional decisions.
Foundation	✔ Notifications, reports, and activity logs are used to determine: • which students need coaching on independent learning. • which students need intervention or enrichment. • which objectives need pre-teaching or re-teaching. • the root of student misunderstanding.
Mastery	✔ Data trends are identified and used as context for instructional decisions. ✔ Student notebooks are used to identify needs and inform coaching.
Instruction	**Teacher provides individualized instruction to students.**
Foundation	✔ Instruction addresses the needs of struggling students. ✔ Instruction challenges high-achieving students. ✔ Instruction reinforces independent learning. ✔ Misconceptions are quickly addressed. ✔ Intervention plans are devised before class. ✔ Intervention plans target specific students, concepts, and skills. ✔ Individualized instruction comprises the majority of scheduled class time. ✔ All diagnoses are remedied. ✔ Teachers appropriately use Reasoning Mind assignments to support learning.
Mastery	✔ Instruction addresses anticipated struggles through pre-teaching. ✔ Intervention methods are selected to best suit the student and content. ✔ Intervention plans include specific and strategic problem sets. ✔ Instructional methods reinforce Reasoning Mind's pedagogy. ✔ Instruction teaches students to state rules and definitions precisely. ✔ Instruction teaches students to write full solutions. ✔ Instruction teaches students to articulate mathematical reasoning.

PROGRAM ACCESS

Technology	Technology is accessible and meets minimum requirements.
Foundation	✔ Technology issues do not block students from using Reasoning Mind. ✔ Technology accessibility is sufficient to meet minimum time requirements. ✔ Technology issues are identified and quickly addressed by district IT staff in collaboration with Reasoning Mind staff. ✔ Technology changes are proactively communicated to Reasoning Mind IT.
Scheduling	**Scheduled time is sufficient and well structured.**
Foundation	✔ Scheduled time is sufficient to meet the minimum time requirements. ✔ Class periods are sufficiently long for productive Reasoning Mind use.
Mastery	✔ Class schedules contain flexibility to make up for missed class periods. ✔ Schedule time is sufficient to exceed the minimum time requirements.
Time Online	**Students spend their scheduled time in the program.**
Foundation	✔ Students spend the scheduled amount of time in Reasoning Mind. ✔ Students spend the vast majority of their online time in learning modes. ✔ Students spend an appropriate amount of time in Review and Wall of Mastery. ✔ Teachers make up missed class periods.
Mastery	✔ Students exceed minimum time requirements through additional practice.

INVESTMENT	
Teacher Investment	Teachers are knowledgeable and invested.
Foundation	✓ Teachers know and pursue the Implementation Goals and Practices. ✓ Teachers take ownership over the success of Reasoning Mind. ✓ Teachers are knowledgeable about best practices by participating in Reasoning Mind workshops and collaborating with others. ✓ Teachers are knowledgeable about Reasoning Mind's curriculum and pedagogy through workshops, collaboration, and independent study. ✓ Teachers provide feedback to Reasoning Mind.
Mastery	✓ Teachers provide guidance to other Reasoning Mind teachers. ✓ Teachers share their Reasoning Mind experiences with others. ✓ Teachers are active in the Reasoning Mind community. ✓ Teachers seek out additional professional development.
School Administrator Investment	School administrators are knowledgeable and invested.
Foundation	✓ Administrators reinforce the Implementation Goals and Practices. ✓ Administrators take ownership over the success of Reasoning Mind. ✓ Administrators are knowledgeable about best practices through administrator workshops and collaborating with others. ✓ Administrators ensure a timely launch of their implementations by coordinating student access and teacher preparation. ✓ Administrators are proficient with Reasoning Mind Goals and Practices reports and monitor the progress of their implementations. ✓ Administrators conduct regular classroom walkthroughs to provide informed teacher feedback. ✓ Administrators coordinate their support with Reasoning Mind staff. ✓ Administrators quickly address issues that inhibit student learning. ✓ Administrators provide feedback to Reasoning Mind.
Mastery	✓ Administrators provide guidance to other Reasoning Mind educators. ✓ Administrators share their Reasoning Mind experiences with others. ✓ Administrators are active in the Reasoning Mind community. ✓ Administrators seek out additional professional development.
District Administrator Investment	District administrators are knowledgeable and invested.
Foundation	✓ Administrators reinforce the Implementation Goals and Practices. ✓ Administrators take ownership over the success of Reasoning Mind. ✓ Administrators are knowledgeable about Reasoning Mind and how to implement it effectively. ✓ Administrators are proficient with Reasoning Mind Goals and Practices reports and monitor the progress of their implementations. ✓ Administrators coordinate their support with Reasoning Mind staff. ✓ Administrators quickly address issues that inhibit student learning. ✓ Administrators facilitate the enrollment process, the launch of Reasoning Mind, its implementation, and research efforts. ✓ Administrators provide feedback to Reasoning Mind.
Mastery	✓ Administrators provide guidance to other Reasoning Mind educators. ✓ Administrators share their Reasoning Mind experiences with others. ✓ Administrators are active in the Reasoning Mind community. ✓ Administrators attend professional development with staff.