The Future of Math Inclusion: The Promise of Digital Math Tools for Universally Accessible Mathematics Instruction

Lauren Hickman McMahon, Stefani Pautz Stephenson, and Seth Corrigan[1]

April 2024

1 Authors are Digital Promise staff except Seth Corrigan (University of California - Irvine)

Acknowledgments

This research was supported by funding from Texthelp. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the funders. We thank our research partners at University of California, Irvine; our Teacher Research Partners for their content and context expertise; and our industry partners at Texthelp for their collaboration in conducting this Research-Practice-Industry Partnership. We also thank Barbara Pape, Alison Shell, and Jessica Jackson from Digital Promise's Learner Variability Project for their insights and expertise.

Contact Information

Email: lmcmahon@digitalpromise.org

Digital Promise:

Washington, D.C.:
1001 Connecticut Avenue NW, Suite 935
Washington, D.C. 20036

Website: https://digitalpromise.org/

Suggested Citation

McMahon, L. H., Pautz Stephenson, S., & Corrigan, S. (2024). *The future of math inclusion: The promise of digital math tools for universally accessible mathematics instruction [Project Report]*. Digital Promise. https://doi.org/10.51388/20.500.12265/211

Table of Contents

Executive Summary

In this report, we share insights from a Research-Practice-Industry Partnership (RPIP) that explored mathematics instructional practices with support of digital mathematics tools. RPIPs bring together researchers, practitioners, and product developers, with each party having an equal voice, in a rapid-cycle model for edtech research and development. All parties work towards a shared research goal, while also fulfilling their unique value propositions. Research becomes professional learning for educators, on both the product and associated pedagogical practices. Industry partners gain insight into product use and implications for adoption, scale, and outcomes. Researchers generate new insights into how people learn.

We framed this RPIP using the principles of Universal Design for Learning (UDL): provide multiple means of Engagement, Representation, and Action & Expression. These principles support learner variability, improve accessibility, and are closely aligned with mathematics education research, which highlights the multimodal nature of mathematics (O'Halloran, 2015) and the need to use and connect multiple representations to help students develop understanding of mathematics concepts (National Council of Teachers of Mathematics [NCTM], 2014).

Mathematics teachers can implement UDL instructional practices without the use of technology, but digital tools designed with UDL in mind are especially well suited for supporting inclusive instruction. Texthelp is the developer of Equatio, an advanced equation editor with a suite of features that enable communication of mathematical symbolism, tables, graphs, diagrams, and other representations in digital environments.

We partnered with Texthelp and nine Teacher Research Partners who teach mathematics in grades 4-12 to explore the following research questions:

1. For what purposes do teachers use Equatio?
2. How do teachers use Equatio to design instructional activities that support Engagement?
3. How does Equatio help students develop understanding of mathematical language, symbolism, and diagrams? (Representation)
4. How do teachers use Equatio to develop and communicate mathematical concepts? (Expression)

To explore these research questions, we conducted a series of interviews and focus groups with our nine teacher partners, as well as a larger-scale survey of Equatio users. Initial interviews with our partners allowed us to get a baseline understanding of what features they were using and for what purposes. Next, we conducted two focus groups, which were attended by teachers, researchers, and Equatio product experts. With the opportunity to hear from other practitioners as well as Equatio experts, the first focus group provided professional learning about features of Equatio and how those features could be leveraged to support UDL in practice. Teachers were asked to try out a new feature or way of using Equatio for 4 weeks. When we reconvened, they shared an artifact that illustrated what they tried, and the group engaged in a debrief discussion about UDL, their experience trying something new, and what resources and supports they used or would like to see.

We found that at the beginning of the study, teachers were mainly using the basic equation editor to create instructional materials and assessments. Some users were using more features of Equatio in more robust ways (e.g., designing and implementing assessments then having students complete those assessments with Equatio and using Equatio to provide feedback), but all teachers learned something new through our focus groups and professional learning. The instructional practices they reported at the end of the study indicated far more possibilities for supporting UDL with this tool.

The purposes for which teachers used Equatio, both at the beginning and end of the study, included a wide variety of teaching and learning tasks. This highlights the flexibility of this tool and its ability to support core practices of teaching and learning mathematics.

We heard many illustrative examples of UDL practices, especially at the end of the study. With respect to the UDL principle to provide multiple means of Engagement, teachers reported using Equatio to simplify their workflow for creating engaging instructional materials, remove distractions and barriers, provide students with choice and autonomy, and share mastery-oriented feedback. With respect to Representation, teachers used Equatio to create and connect multiple representations and decode mathematical notation. Regarding the UDL principle to provide multiple means of Action & Expression, teachers reported that Equatio could provide students multiple means of expression and a flexible space to develop and communicate their ideas.

These findings suggest several implications for practice, product development, and future research. They offer a model of what UDL can look like in practice with the support of digital tools like Equatio. Practitioners can use these examples for ideas about designing and implementing learning experiences that support accessibility and inclusion. Product developers can use the findings around teacher learning to design relevant resources and supports for both teachers and students, help teachers understand features and uses of their product, and create communities where practitioners can share resources, ideas, and templates. Future research can continue to leverage the synergies between UDL and mathematics learning to explore real classroom practice rather than relying on teacher reports, as well as to build upon CAST's research on how UDL-informed instruction supports outcomes for students, specifically in mathematics.

Introduction: The Future of Math Inclusion

A strong foundation in mathematical thinking and practices prepares students for futures not just in mathematics, but also in sciences, technology, trades, and other postsecondary credentials that lead to agency, well-being, and economic security. However, mathematics has historically been recognized as a "gatekeeper" discipline, exclusionary for students from historically and systematically excluded backgrounds and inaccessible to students with learning disabilities for whom traditional pencil and paper approaches may be a barrier (Douglas & Attewell, 2017; Martin et al., 2010). Exacerbating this issue, mathematics remains an area with significant need for digital tools that can facilitate broader access to enriching learning experiences and mathematics content (Bouck, 2012).

Likewise, the edtech design process has historically been exclusionary. Professional designers, not end users, have traditionally been at the center of the design process. Well-intentioned tactics such as user personas often fall short because they are grounded in the assumptions of engineers who are experts in their field, not in authentic input from end users (Norman, 2013). Participatory design strategies decentralize the designer and centralize user experience, honoring their content and context expertise (Pautz Stephenson et al., 2022). A participatory model such as a Research-Practice-Industry Partnership (RPIP), which directly involves educators and learning sciences researchers in a collaborative and iterative R&D process, can yield a product more likely to be used–and used appropriately–and therefore more likely to have the desired impact for learners.

Digital Promise partnered with Texthelp and University of California, Irvine (UCI) in a study on the future of math inclusion. This white paper provides an overview of that study and the results of our collaborative work with teachers, researchers, and industry partners. Our findings suggest that digital math authoring tools like Texthelp's Equatio show promise for making math more accessible and easy to communicate, allowing more students to participate and succeed in mathematics.

Conceptual Framework

Digital Promise defines Learner Variability as the recognition that each student has a unique set of strengths and challenges across a whole child framework that are interconnected and vary according to context. It embraces both students' struggles and strengths (Pape, 2018). Harvard scientist Todd Rose, in his groundbreaking book *The End of Average* (2016), posited that we limit our potential as a society by trying to conform everyone to an average, and described principles of individuality:

- Every individual has a unique set of talents.
- Talents are "jagged." Individuals will excel at some things and not at others.
- Talents are context dependent. An individual may excel at a talent in one context but struggle with the same talent in another setting.
- There are many ways to reach the same outcome, and what works well for some may not work well for others. The best path towards success is the one that works for that individual's unique talents and traits.

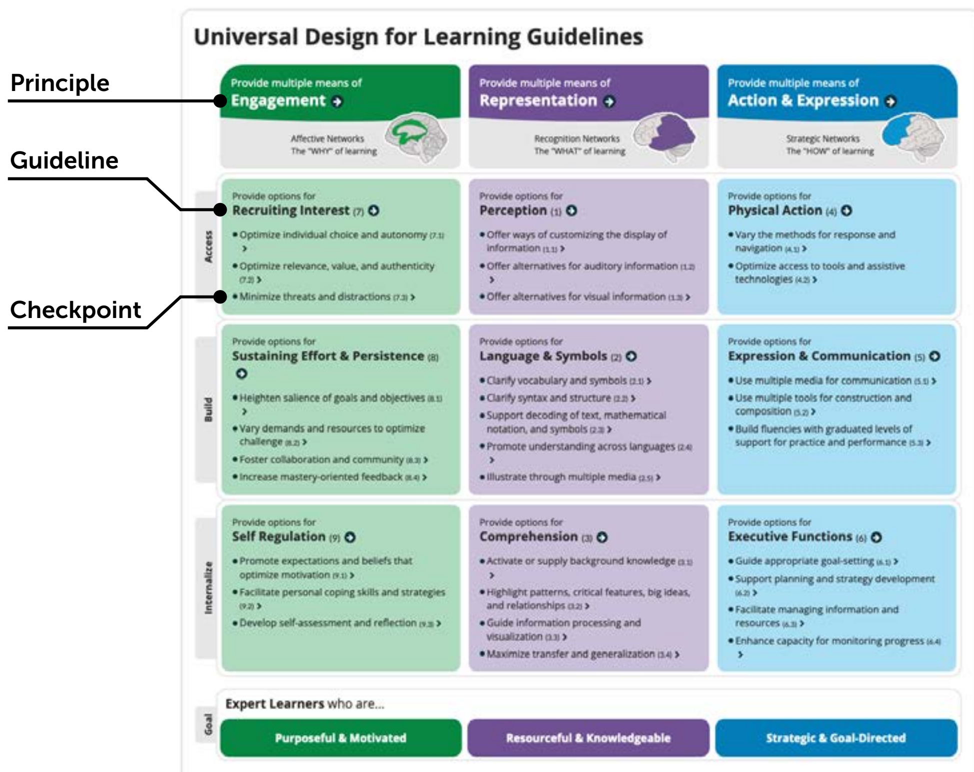
Rose argues that this is highly problematic in educational settings, where we have historically and relentlessly measured learners against an average. In concept and practice, learner variability opens up the doors to culturally responsive and strength-based, inclusive teaching and learning for each student (Pape, 2018). According to CAST, a nonprofit education research and development organization led by leading neuroscientists, cognitive scientists, and learning scientists, the most widely replicated finding in education research is that learners vary in their response to instruction: "In virtually every report of research on instruction or intervention, individual differences are not only evident in the results; they are prominent" (CAST, n.d.). Teaching to the average excludes and is particularly detrimental to students "at the margins"—those who have been historically and systematically excluded.

To operationalize these ideas, CAST developed the Universal Design for Learning (UDL) framework. UDL provides the conceptual framework for this study and grounds our methods and analyses in learning sciences research.

Universal Design for Learning

The UDL framework is designed around the three networks of the brain: the affective network, which controls engagement; the recognition network, which controls perception and comprehension; and the strategic network, which controls expression and navigation of the learning environment. Those networks are aligned with three principles: provide multiple means of Engagement, Representation, and Action & Expression. The framework is then organized into Guidelines with Checkpoints that offer suggestions for implementation (see Figure 1).

Figure 1



UDL Guidelines (From © CAST, Inc. 2018)

The UDL framework is research-based at multiple levels. In addition to the empirical research in neuroscience that guided the development of the three Principles, the Guidelines are grounded in the work of Piaget; Vygotsky; Bruner, Ross, and Wood; and Bloom; and concepts such as Zone of Proximal Development, scaffolding, mentors, and modeling are evident throughout the framework (CAST). Each Checkpoint is grounded in learning sciences research, and a bibliography of supporting empirical/quantitative research and scholarly reviews/expert opinions is provided for each. For example, Checkpoint 2.3, Support decoding of text, mathematical notation, and symbols, cites research on scaffolded hypertexts, synthetic speech feedback, and assistive reading software across a range of learner needs, including average and less skilled readers, and learners with dyslexia and attention disorders (CAST).

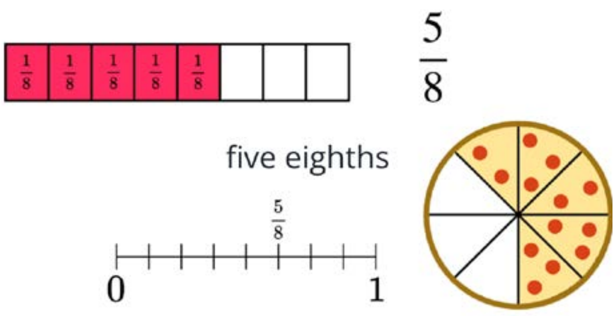
Because of the framework's solid research backing and body of related implementation research, its use in instruction and technology development is specified in public policy, beginning in 2008 with the Higher Education Opportunity Act. The Office of Educational Technology's Edtech Developer's Guide (U.S. Department of Education [USDE], 2015) encourages developers to apply UDL when creating learning tools and environments. Most recently, their National Education Technology Plan (USDE, 2024) discusses UDL's role in closing the digital use divide when educators employ the framework in designing instruction. The UDL framework has been used as a resource for Digital Promise's Learner Variability Navigator, and to inform ongoing work in technology tools, such as Texthelp's Equatio.

Mathematics and Universal Design for Learning

The core Principles of UDL—Engagement, Representation, and Action & Expression—are especially relevant in mathematics. Each of these Principles presents a synergy with the nature of mathematics as a discipline, and more specifically with mathematics learning, which relies on the ability to communicate mathematical concepts and ideas. In mathematics classrooms, teachers and students engage in conversation, draw visual models, and write solutions to problems, all of which are communicative activities that support student learning.

Mathematics communication presents unique challenges because it requires a variety of sign systems and modes of communication, such as symbols, diagrams, graphs, and language, all of which work together to convey mathematical meaning (O'Halloran, 2015; McMahon, 2022; Schleppegrell, 2007; Sfard, 2008). For example, in Figure 2, we see several different representations of the fraction *five eighths*. By using these different representations, the relationships between parts, wholes, numerators, and denominators become more apparent than they would if students were only exposed to the symbolic form or the language *five eighths*. The symbols, language, and multiple diagrams work together to offer students different ways of seeing and understanding the same fraction.

Figure 2



Multiple representations of the fraction five eighths, created using Equatio Mathspace

When students have opportunities to create, use, and connect multiple representations, this enables them to develop deep understanding of mathematical concepts (NCTM, 2014). These communicative resources also offer students a variety of tools they can use to support their own thinking and reasoning (Sfard, 2008). For example, virtual manipulatives such as the red fraction bars shown in Figure 2 are dynamic representations that can be easily modified to show the same whole divided into different numbers of equal parts and different numbers of shaded parts. If students have an understanding of how to use and make sense of fraction bars, then they can use fraction bars as a resource to build new understandings when they are exposed to more challenging content, such as adding fractions with unlike denominators. In this way, the use of multiple representations is about more than communicating with others. It gives students the tools they need to explore, discover, and reason through new or difficult situations as they continue to build mathematical knowledge.

With the need for multiple ways to communicate mathematics comes a need for tools that can support students in sharing and understanding mathematics in its different forms (Hiebert et al., 1997). Digital environments in particular can make it difficult to represent mathematics; if the only means of sharing one's thinking is with a text box, for example, this significantly limits teachers' and students' capacity to use other modes and representations. Tools that are designed with UDL in mind offer multiple means of Engagement, Representation, and Action & Expression, all of which are necessary for communicating and developing mathematical meaning. In this way, tools that are designed with UDL in mind are especially well suited for supporting mathematics learning.

Despite the apparent compatibility between mathematics learning and UDL, there is a limited body of research that has brought the two together (Thomas et al., 2015; Root et al., 2020). Though some scholars have described the benefits of UDL technologies in STEM disciplines (Izzo & Bauer, 2015), even fewer studies have considered the role of technology in making mathematics more accessible through UDL. This study considers these three areas together, examining the role of digital technologies in supporting UDL practices in mathematics teaching and learning.

Digital Mathematics Tools for UDL

Educators can implement UDL without modern digital technology, but educational technologies are uniquely suited to support it. Digital technologies have been shown to increase student engagement in mathematics, both with peers and with learning activities (Fabian et al., 2016). Technology can also provide easy access to multiple mathematical representations (Pierce et al., 2011) and ensure those representations are accurate.

Equatio is Texthelp's advanced equation editor, and it includes features such as a Desmos graphing integration, handwriting recognition, language translation, and a screenshot reader with the ability to quickly and easily copy and paste math without losing formatting. Equatio also features Mathspace, a digital space where learners can work freely with equations, shapes, and freehand drawings. Our initial exploration of Equatio's suite of tools showed that it can support a wide range of UDL guidelines and checkpoints. For example:

- Equatio provides accessibility features to all users, such as speech-to-math, a screen reader that scans and plays math content aloud, and a predictive equation editor (Guideline: Physical Action, Checkpoint: optimize access to tools and assistive technologies).

- The predictive equation editor enables users to easily create exponents, shown as actual exponents vs. as the ^ symbol (Guideline: Recruiting Interest, Checkpoint: minimize threats and distractions). Students also do not have to take the extra cognitive step of decoding the ^ symbol (Guideline: Language & Symbols, Checkpoint: support decoding of text, mathematical notation, and symbols).
- Equatio offers students choice in how they show their work via the equation editor, creating a diagram in Mathspace, or inserting a photo of handwritten work (Guideline: Recruiting Interest, Checkpoint: optimize individual choice and autonomy).
- Teachers and students can use Mathspace to represent the same data in different ways, for example, as a set of numbers in a list, a histogram, a box plot, and a table with descriptive statistics (Guideline: Expression & Communication, Checkpoint: use multiple tools for construction and composition; and Guideline: Language & Symbols, Checkpoint: illustrate through multiple media).
- Mathspace can be used to create student assignments and provide feedback. Equatio also integrates with Google Docs, so teachers can provide real-time feedback as students show their work with Equatio (Guideline: Sustaining Effort & Persistence, Checkpoint: increase mastery-oriented feedback).
- Teachers can create guided notes templates in Mathspace with clearly marked spaces for students to add their notes, reflections, and self-assessments, and teachers can modify curriculum materials so students have adequate space to work (Guideline: Self Regulation, Checkpoint: develop self-assessment and reflection; Guideline: Comprehension, Checkpoint: guide information processing and visualization; and Guideline: Executive Functions, Checkpoint: facilitate managing information and resources).

Equatio has the potential to support more accessible math learning opportunities because it was designed with UDL in mind. However, the power of such tools lies in how they are used. We wanted to learn how real teachers in real classrooms were using Equatio in practice, in order to better understand how such tools can support more inclusive and accessible mathematics learning experiences.

Research Questions

While Equatio was designed using the UDL framework, the developers sought insight into actual classroom practice. Was Equatio being leveraged in ways that supported the UDL Principles? Therefore, this study is guided by four research questions:

1. For what purposes do teachers use Equatio?
2. How do teachers use Equatio to design instructional activities that support engagement? (Engagement)
3. How does Equatio help students develop understanding of mathematical language, symbolism, and diagrams? (Representation)
4. How do teachers use Equatio to develop and communicate mathematical concepts? (Action & Expression)

Methods

This study is grounded in participatory design strategies that decentralize the designer, center the user experience, and honor educators' content and context expertise (Pautz Stephenson, et al., 2022). Through a Research-Practice-Industry Partnership (RPIP) model and mixed methods of data collection and analysis, we examined authentic use cases and user feedback, which yielded insights relevant to both classroom practice and product development.

Research-Practice-Industry Partnership

The RPIP model integrates professional learning, research, and development by bringing together diverse, cross-sector expertise and shifting power dynamics so that all participants have a voice (Pautz Stephenson et al., 2022). Each party is deeply engaged because their unique value propositions are honored: Developers build inherent utility and user experiences and immediately use evidence of efficacy and impact to inform development, educators gain new instructional practices and resources, and researchers generate knowledge for the field of learning sciences.

In this project, educators, researchers, and product developers intentionally worked together towards a common goal, grounded in learning sciences research. A central facilitator from Digital Promise ensured each party was deeply engaged and that their unique value propositions were honored. Facilitation methods also ensured that all participants' voices were equitably included. In the following subsections, we describe each of the partners.

Our Research Partners

The data collection and analysis efforts in this study were a collaborative effort between Digital Promise and University of California, Irvine (UCI). A learning sciences researcher from Digital Promise, specializing in mathematics learning, conducted the qualitative aspects of the study. A senior research and development scientist from UCI led survey implementation as well as quantitative data and telemetry analysis.

Our Industry Partners

Texthelp is a family of accessibility products designed to help everyone understand and be understood. Their vision is to advance the literacy and understanding of 1 billion people around the world by 2030 (Texthelp). Throughout the project, we met regularly with Texthelp's senior leadership to discuss emerging findings, and two members of their product development team engaged directly with educators in focus groups (see Data Collected, below).

Our Teacher Partners

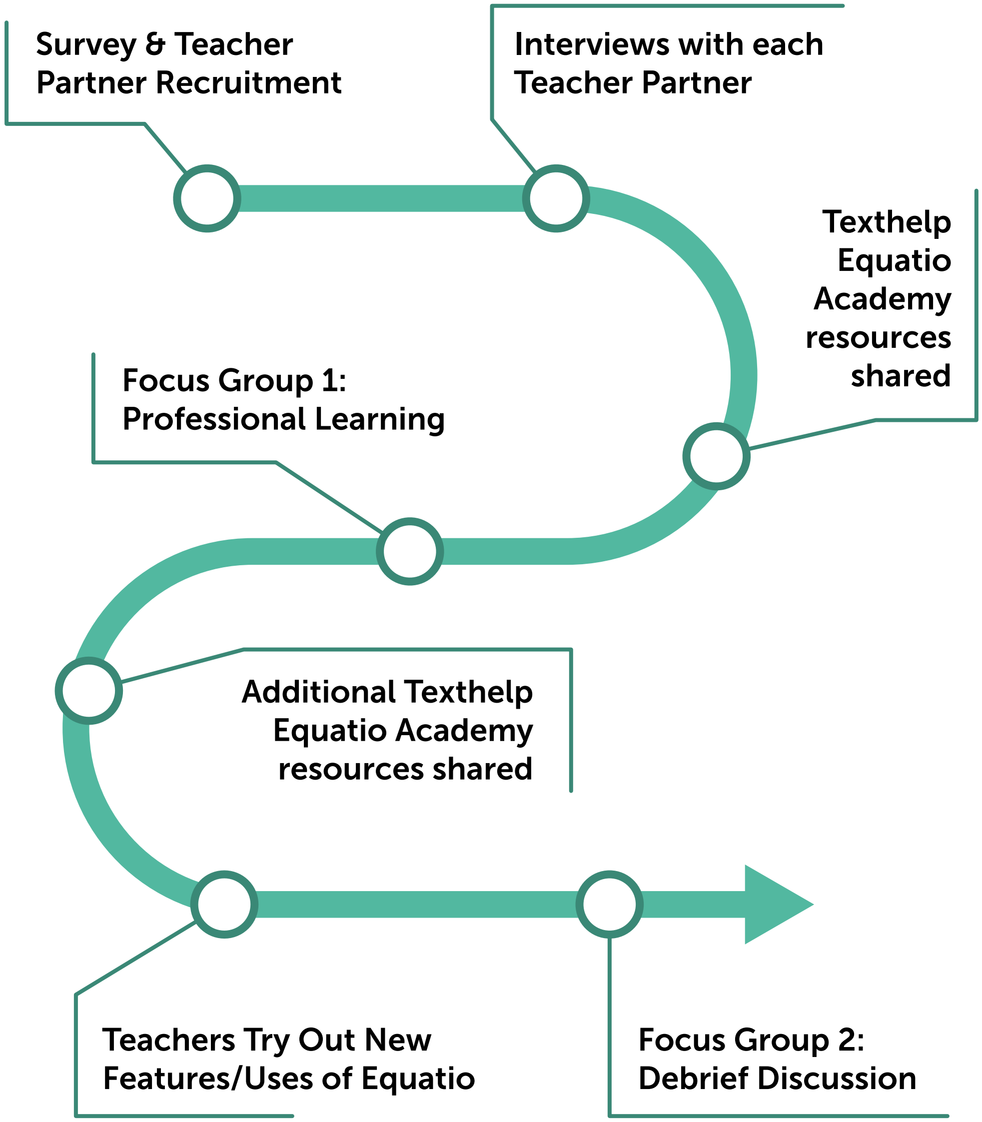
Digital Promise recruited nine teachers to participate as partners in this research. To meet the criteria for participation, candidates must have been current teachers of mathematics in grades K-12 in the United States who use Equatio in their practice. We gathered a pool of candidates from a larger group of teachers who completed a survey about their Equatio use (see Data Collected). The survey included questions about their interest in further research in addition to descriptive information about their teaching context (i.e., role, grade level, content area, and region), which we used to select candidates who were a good fit for our study.

The nine teachers in the study were selected for variation in location, grade levels, and content areas taught in the present school year. This resulted in a group of teacher partners from nine different states[2] who currently teach grades 4-12 mathematics. Our partners teach grade level mathematics content for grades 4-8, prealgebra, algebra 1, algebra 2, geometry, precalculus/trigonometry, calculus, and mathematics for engineers, an advanced applied mathematics course that includes differential equations and linear algebra.

Data Collected

In this mixed methods study, we used a large-scale survey of Equatio users together with qualitative data from our nine teacher partners. For the smaller set of nine teachers, we conducted virtual interviews, a series of two focus groups intended for teacher professional learning, and collected artifacts shared by teachers.

Figure 3



Timeline of data collection and professional learning for teacher partners

2 California, Florida, Georgia, Massachusetts, New Jersey, North Carolina, Pennsylvania, Tennessee, Virginia

Survey

We collected quantitative survey data from 332 Equatio users. The survey was shared via email channels, including a list of teacher users from Texthelp as well as Digital Promise networks. Inclusion criteria for the survey required respondents to reside in the United States and to have recently used Equatio. The survey included questions in the categories shown in Table 1.

Table 1

Category	Description
1) Teacher characteristics and background	Role, location, years of experience, grade level, and content areas taught
2) General product familiarity and use	Frequency of use, familiarity with Equatio, purposes for using Equatio
3) Use of Equatio for inclusive instruction and UDL	Awareness of specific affordances for supporting inclusive practices
4) Technology adoption	Perceived usefulness, ease of use, intention to use
5) Technostress	Perceived complexity of Equatio (Tarafdar et al., 2007), impacts of Equatio use on time and amount of work (Califf & Brooks, 2020)
6) System usability scale (Brooke, 1996)	Users' attitude toward Equatio's ability to fulfill their needs

Note: Categories 1 and 2 included multiple choice items, Category 3 asked respondents whether they were using Equatio to support UDL practices, and if so, they were asked to answer a set of Likert scale items for those practices. Categories 4-6 utilized Likert scale items asking respondents to rate their agreement with a given statement.

At the end of the survey, respondents had the option to indicate interest in further research and respond to two open response questions about their interests and needs. We used these questions, along with their responses to Category 1, to select our nine teacher partners.

The sample of survey respondents reported from all five regions of the United States (i.e., northeast, southeast, midwest, southwest, and west), had an average of 15.39 (SD = 9.28) years in education and were evenly distributed across urban, suburban, and rural settings at the time of the survey. A majority of the participants, 222 (72%), were either single-subject mathematics teachers or multiple-subject teachers. Most reported working with high school students, 197 (64.71%), with the remainder working with students in either middle school or elementary grades, and a small number, 5 (1.63%), working in higher education.

Interviews

Each of our nine teacher partners participated in a 1-hour virtual interview about their experience teaching mathematics, familiarity with Equatio and its features, current use of Equatio including student use, and their perspectives on Equatio as it relates to the UDL Principles of Engagement, Representation, and Action & Expression. We invited teachers to share their screen to demonstrate their workflows, allowing us to see firsthand what they do when they use Equatio. These interviews provided a baseline for teacher use, as well as insight into what teachers were interested in learning about as part of the focus group professional learning opportunities, which we used to inform the focus group protocols.

Focus Groups and Professional Learning

After interviews were complete, we shared relevant Texthelp Equatio Academy resources with our teacher partners, including videos, training guides, and full-length on-demand webinars. Next, we conducted a series of two virtual focus group meetings, which were led by a central facilitator and attended by teachers, researchers, and Equatio product experts to provide opportunities for all parties in the RPIP to learn from one another. The nine teachers were grouped according to grade level, with one group consisting of grades 4-8 teachers and the other consisting of grades 9-12 teachers, ensuring discussions were relevant to their grade levels and content areas.

The first round of focus groups followed a modified consultancy design. Teachers prepared an instructional challenge or question that they believed Equatio could help them solve. For example, the question shared by Ms. F, who teaches fourth grade, was "How can I use [Equatio] to differentiate for all the different levels in my classroom?" Each teacher had a dedicated time to share their challenge or question, and the group discussed possible solutions.

During these discussions, teachers were able to learn from the ideas shared by other practitioners, as well as from Equatio product experts who provided just-in-time professional learning about features or uses of Equatio that were relevant to the questions teachers raised. At the end of the consultancy, teachers used the ideas they gained from the discussion, both of their own challenges and of others' in the group, to make a plan for trying a new feature or way of using Equatio for 4 weeks. They wrote a commitment to trying this new approach in their classroom, as well as a hypothesis about how this would support themselves and/or their students. For example, Ms. K's commitment statement was "I commit to trying the Mathspace features on the Texthelp site over the next 4 weeks. My hypothesis is that this will support me and/or my students by providing the opportunity to show what they know and ability to claim ownership of their learning."

In the second round of focus groups, teachers prepared an artifact based on the new feature or use of Equatio they tried in their classroom. Each teacher partner had a dedicated time to share the artifact as a way of demonstrating what they tried, discuss whether their hypothesis was confirmed in practice, and reflect on whether and how their new use of Equatio may have supported Engagement, Representation, and Action & Expression.

Data Analysis

Survey

We analyzed survey responses descriptively, utilizing frequencies and percentages of teacher responses for each item. In this report, we share descriptive statistics for survey items that were relevant to the qualitative findings.

Interviews, Focus Groups, and Artifacts

To analyze the qualitative data, we first conducted within-case analyses for each teacher followed by a cross-case analysis (Miles et al., 2014). We recorded, transcribed, and coded all interviews and focus groups with corresponding artifacts. The four research questions informed the coding process by providing a focus on these four research categories: 1) purposes for using Equatio, 2) Engagement, 3) Representation, and 4) Action & Expression.

The analysis began with within-case analyses of each teacher's interview as well as their participation in both focus groups. This included attention to the specific challenge or question they raised to the group, as well as their suggestions and contributions to other discussions. We also analyzed artifacts shared during interviews and focus groups, including teachers' written commitments to try something new with Equatio in their classrooms. We coded transcripts with a focus on the four research categories, using video and artifacts to provide additional sources of data. After coding for each case, we created a written portrait of each teacher that included their baseline Equatio use, professional learning experience throughout the study, implementation of the new use of Equatio they tried in their classroom, and how the UDL Principles of Engagement, Representation, and Action & Expression related to their work with Equatio throughout the study.

We then conducted cross-case analyses to identify themes across the nine teachers in the study, with attention to the four research categories. We searched for common themes across teacher participants as well as cases that diverged from these common themes (Corbin & Strauss, 2015).

Findings

From the beginning of the study, we observed wide variation in how teachers used Equatio in their practice. Although we saw many similarities in teacher use, no two teachers used Equatio in exactly the same way. All nine teachers were using the equation editor and predictive library of symbols, equations, and formulas, often to create instructional materials and assessments. A few teachers also used the Desmos graphing integration and Insert Mathspace feature. Some used Equatio with their students, while others were the only users in their classrooms. Several teachers used the screenshot reader, which allowed them to copy and paste mathematical tasks and solutions without losing formatting.

We saw much more limited use of Equatio and its features early in the study. For many teachers, they were unfamiliar with the full suite of available tools, and they were unaware that Equatio could be used to support practices grounded in UDL. This is consistent with survey responses from the larger set of teachers, which indicated that the majority of teachers were not using Equatio to implement UDL practices. Across the 11 survey items about awareness of specific affordances for inclusive instruction and UDL, on average approximately 22% of respondents reported using Equatio to support a given UDL-based practice.

The focus groups provided our teacher partners with additional exposure to features and ways they could use Equatio, both from our Equatio partners and from other practitioners. For example, most teachers were unfamiliar with Mathspace; when they learned about its capabilities from an Equatio product expert, all teachers expressed value in using this feature, regardless of grade levels and content areas taught. As described above, many teachers entered these professional learning experiences unaware of many of the ways they could use Equatio, for example, to create assessments in Google Forms, to have students use Equatio on the digital whiteboard, or to have students submit assignments and receive feedback in Mathspace. At these focus groups, teachers also learned about different settings, such as the ability to change the language for students to read and write mathematics in their native language.

After the first focus group, teachers spent 4 weeks trying something new with Equatio in their practice. All nine of their commitments included a desire to use the Mathspace feature. According to their hypotheses, our teacher partners expected Mathspace to support teaching and learning by increasing student engagement and collaboration, providing students with opportunities to work with multiple mathematical representations, allowing students space and resources to show what they know, and embedding assessments and feedback into course materials.

When we reconvened after 4 weeks, we saw a broader variety of methods by which teachers were utilizing Equatio. They were using more features, and they were integrating these features together in ways they had not done prior to the first focus group. This allowed us to see a broader range of possibilities for how Equatio can support teachers in their practice and, in particular, their use of UDL.

In the sections that follow, we elaborate findings related to our four areas of focus: 1) Purposes for using Equatio, 2) Engagement, 3) Representation, and 4) Action & Expression. We share themes that emerged across our nine teacher partners, as well as relevant findings from the larger-scale survey. We also elaborate UDL practices that teachers described throughout the study, including prior to and after professional learning, to illustrate the range of possibilities for this tool to support UDL in practice.

Purposes for Using Equatio in Practice

As we learned more about how our teacher partners were using and experimenting with Equatio in their work, we were struck by the versatility of Equatio. The most common ways teachers and their students used Equatio can be found in Figure 4.

Figure 4

Teacher Use of Equatio	Student Use of Equatio
• Design lesson materials • Adapt curriculum • Create and implement assessments • Differentiate instruction • Provide feedback • Offer accommodations • Show multiple representations • Copy and paste mathematics without losing formatting	• Complete assignments and assessments • Show what they know in different ways • Build diagrams in Mathspace • Work with virtual manipulatives • Share work with their classmates • Read, hear, and write math in their native language • Submit assignments and receive feedback using Mathspace

We also heard repeatedly from teachers how much they value student access to Equatio for all of their students. They taught in different settings, where their students had differing access to Equatio and its features; for example, in one teacher's case, only her students who required assistive technology had access to Equatio. In cases where all of a teacher's students had Equatio on their devices, they were able to leverage Equatio in more robust ways and incorporate it into more of their workflows, such as by implementing an assessment, receiving digital submissions from students, and providing timely feedback.

This diversity of purposes for using Equatio highlights the versatility of this tool. Equatio can support both teachers and students in carrying out these core tasks of teaching and learning mathematics. Thus, the capabilities of this tool in practice go beyond its capacity to support UDL—Equatio is especially beneficial for students who require assistive technologies, but its benefits extend to *all* teachers and students in mathematics.

Designing Activities for Engagement

Our teachers described several ways in which Equatio supports designing learning experiences that provide multiple means of Engagement. Four themes in particular were dominant across all cases: 1) Equatio simplifies and accelerates teacher workflows, which supports them in creating engaging, relevant content for students, 2) Equatio's clean, professional appearance removes distractions and barriers, 3) Mathspace recruits interest and provides students with choice in the tools they use, and 4) Equatio provides opportunities for teachers to increase timely, relevant feedback for students.

Simplified Teacher Workflows to Support Engagement

All nine of our teacher partners emphasized the importance of Equatio in their workflows when creating instructional materials. Equatio was unilaterally described by our research partners as a "time-saver," making it easier and faster to create lesson slides, activities, assessments, and other materials for students. This reflects a similar finding from the survey, with only 5% of survey respondents disagreeing with the statement "Equatio saves me time," and 42% strongly agreeing.

Because of the workflow support Equatio provides, teachers described their ability to more easily create differentiated materials. For example, one teacher described how she uses the Edit Math feature to keep the same problem structure but swap out numbers to make the problem more challenging (e.g., changing from whole numbers to decimals). This allows teachers to quickly create assignments and assessments with different difficulty levels, ensuring students are provided tasks that are appropriately challenging.

> *You can generate problem sets so easily for kids who need more repetition and more connections.*
> *—Ms. W, High School Geometry*

Teachers often create materials in advance, but because of the speed with which they can create materials with Equatio, they also are able to quickly create new tasks or problems in the moment. In other words, they formatively assess student understanding and make adjustments to their instructional materials in real time to either cover previous content or advance to more challenging content based on students' current needs.

> *If [my students] finish something quickly, I can in a pinch just go ahead and create something else for them to do, without them sitting there and waiting and getting frustrated, or getting bored or becoming hyper… they can sit and watch me create them and suggest a math problem.*
> *—Ms. K, Middle School*

Removing Distractions and Barriers

We repeatedly heard from teachers about the benefits of the clean, professional appearance of materials they create with Equatio. The digitized symbols, text, and diagrams are more legible than handwriting, and they are more accurate. Number lines are straight, graphs are drawn to scale, fractions are shown with a horizontal bar rather than a diagonal slash, and exponents are smaller in size and in the correct location (e.g., 3^2 vs. 3^2). This removes distractions and enables students to focus on the most important features of the mathematics they are learning, rather than on trying to create these various representations by hand. As one teacher described:

> *In terms of creating something that is easily accessible to students that is laid out how I want it to look and that looks professionally laid out. It… looks like something that would be in their official math book. I think that that is really a good entry point for them: that they don't have to figure out a typeface in order to figure out what they're actually doing in math.*
>
> *—Ms. C, Fifth Grade*

Teachers also reported using Equatio to adapt curriculum materials to remove extraneous information and barriers for students. Ms. M, a high school algebra and precalculus teacher, describes the need to cut much of the existing curriculum, which was designed for longer class periods than her school's schedule allows. Using the screenshot reader with the ability to copy LaTeX and MathML code, she can copy and paste the most important information from her digital curriculum into the materials she shares with students.

For her fifth grade students, Ms. C also adapts curriculum materials, which often provide too little space for her students to write and show their thinking. By using Equatio, she is able to create new materials that remove this barrier for students. Similarly, Ms. W describes how she uses Mathspace to make accommodations for students by adjusting the sizing of problems and diagrams:

> *Some kids can solve problems if you simply make them bigger. So that would be a great way to differentiate. Just make the problem bigger… sometimes just doing an accommodation like that can help the kids see it.*
>
> *—Ms. W, High School Geometry*

Equatio provides support for teachers to make their curriculum materials accessible, which in turn removes barriers for students.

Mathspace for Recruiting Interest

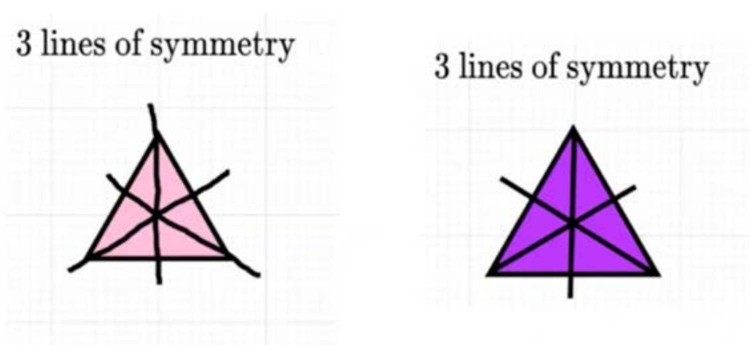
Equatio Mathspace was an especially important feature for supporting Engagement. All of our teacher partners chose to explore Mathspace further as part of this RPIP. Mathspace provided students with the ability to build, create, and explore, often through interactive tasks. It also offered a more flexible two-dimensional space for showing work, organizing ideas, and working in an environment that is not limited to a line-by-line format.

For teachers whose students used Equatio, their students had choice in the tools they used to achieve their learning goal. One example comes from a fifth grade teacher whose students completed a Mathspace assignment about lines of symmetry. The teacher asked students to create shapes with different numbers of lines of symmetry (e.g., 1 line of symmetry only, 5 lines of symmetry, or no lines of symmetry). Students first created their shapes then drew the lines of symmetry for the shapes they had built. In this lines of symmetry exercise, the teacher described several of the choices students made about how to create their lines of symmetry:

> *Students used the traditional shape features. Others found unique [shapes]. Some figured out how to change the colors. Some chose to draw by hand. Some chose to use the line tool, so it was nice and straight...We had a student that color coded each one to show that they were separate [lines].*
> *—Ms. C, Fifth Grade*

Figure 5 shows how students opted to use different tools when creating their shapes and lines of symmetry. The image on the left illustrates a students' choice to draw lines by hand, while the figure on the right illustrates a students' choice to use the line tool available in Mathspace. The ability for students to type, draw or write freehand, or use their library of existing formulas, symbols, and shapes simultaneously supports providing multiple means of Action & Expression by offering students multiple tools for construction and composition.

Figure 5



Student work samples showing how students opted to draw by hand or use the line tool when sharing their thinking in Mathspace

Mastery-Oriented Feedback

We also heard from teachers that Equatio simplifies their workflows for providing timely and relevant feedback to students. In addition to providing a flexible space for creating diagrams and other representations, Equatio Mathspace provides workflows for receiving student submissions and providing feedback. Ms. C, whose students completed the Mathspace assignment about lines of symmetry, used this feature with her students to collect responses to this multi-slide Mathspace assignment. She then provided specific feedback directly to each student based on what they did on each slide.

Another teacher, Mr. L, uses Equatio within his school's learning management system, which allows him to create Google Doc assignments for each student.

> *[Equatio] allows them to show their entire process, all of their work. And then I can send them feedback in the moment.*
> *—Mr. L, High School Algebra & Precalculus*

Students use Equatio to fill in responses in their respective Google Docs, and Mr. L monitors their responses as they work. When he notices a student in need of support, he can provide in-the-moment feedback in their individual document, or he can approach a student or small group to have a conversation.

Developing Mathematical Representations

As described in the conceptual framework, communicating mathematics requires using and connecting multiple representations. Equatio provides a way to represent mathematics in all of these different forms by bringing together an equation editor to produce symbols and tables, Mathspace to create diagrams and work with virtual manipulatives, a Desmos utility to show graphical representations, and text mode to incorporate language.

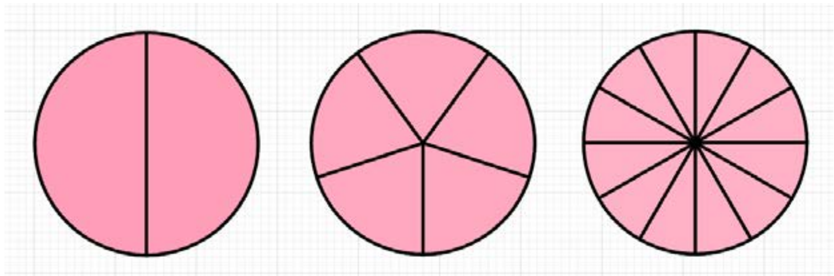
Two themes in particular showed how teachers use Equatio to support the UDL Principle to provide multiple means of Representation: 1) The ability to connect symbols, diagrams, graphs, and language, especially within Mathspace, and 2) Support for decoding mathematical notation.

Connecting Symbols, Diagrams, Graphs, and Language

Our teacher partners indicated that Equatio Mathspace is especially powerful for representing mathematics in its different forms and to make connections between those representations. Many of the mathematical objects in the Mathspace library are dynamic representations that students can manipulate and experiment with. For example, fourth grade teacher Ms. F described how she used Mathspace to show that the same whole can be divided into different numbers of equal parts without changing the whole. The fraction diagram she used was a smart shape, which immediately updated to reflect different denominator inputs. Students could see in this dynamic representation that the number of equal parts and the size of those parts was changing, while the size of the whole remained the same. Figure 6 offers a static example of the fraction circle smart shape with different numbers of equal parts in the same whole. In the more dynamic

Mathspace representation, students would be able to see the number of parts changing as they entered different denominator values.

Figure 6



Fraction circles in Mathspace

Teachers of higher grade levels and content areas also expressed the value of Mathspace for creating and connecting multiple representations. Ms. W, a high school geometry teacher, uses color to help students more clearly see relationships and structures involved in trigonometric ratios. For example, when teaching the meaning of sine and cosine as ratios of side lengths in a right triangle, she will color code in Mathspace to help students see how angles and side lengths of a right triangle are shown in the trigonometric ratio.

One of our partners, Ms. T, shared work from two of her calculus students, both of whom were able to use Mathspace to solve an integral task that incorporated symbolic and algebraic notation side-by-side with a graph that provided a visual justification of their work:

> *I think it's very beneficial for certain parts of math, to have [a tool that is] so multidimensional. The possibility of showing different representations is very important for understanding.*
> *—Ms. T, High School Calculus*

Ms. T also shared a comment from one of her students, which they wrote on their assignment, describing how using Equatio helped them make sense of the formulas and check their answers:

> *I liked using Equatio. I learned a lot about writing equations. I used Desmos before, but only to graph functions…It was helpful to see the graph, while solving problems (make sense of the formulas, to check the answers).*
> *—Student A in Ms. T's Class*

The Desmos graphing integration allowed them to pull the graph into their Mathspace where they could see the visual representation as they worked out their solution, which highlights the way Equatio's features can be used to support students in reasoning and thinking about the mathematics. Their solution is shown in Figure 7.

Figure 7

(c) Express the remainder R4 as a RRAM and compare to the integral. $\int_4^\infty \frac{5x}{e^x}dx$

Use Desmos to create a sketch for the situation.

$$R_4 = \sum_{n=1}^{\infty} \frac{5n}{e^n} - S_4 = \sum_{n=5}^{\infty} \frac{5n}{e^n}$$

The function is decreasing, therefore the RRAM is an underestimate, $R_4 \leq \int_4^\infty \frac{5x}{e^x}dx$

$$\int_4^\infty \frac{5x}{e^x}dx = \lim_{b \to \inf} \left(\int_4^b \frac{5x}{e^x}dx\right)$$

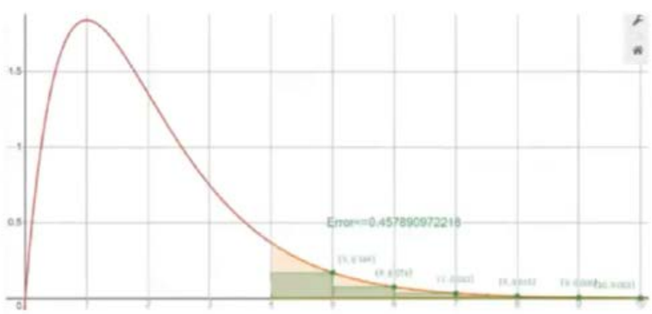
Using IBP: Let $u = 5x$ and $dv = e^{-x}dx$

$$\int \frac{5x}{e^x}dx = 5xe^{-x} - \int 5e^{-x}dx = -5e^{-x}(x+1) + C$$

$$\int_4^\infty \frac{5x}{e^x}dx = \lim_{b \to \inf} \left[-\frac{5}{e^x}(x+1)\right]_4^b$$

$$\int_4^\infty \frac{5x}{e^x}dx = \lim_{b \to \inf} \left[-\frac{5}{e^b}(b+1) + \frac{5}{4^4}(4+1)\right]_4^b = \frac{25}{e^4}$$

$$R_4 \leq \int_4^\infty \frac{5x}{e^x}dx = 0.457890972218$$



Ms. T's student solution to a calculus task involving the Right Rectangular Approximation Method for estimating integrals, creating a sketch of the RRAM situation in a graph, and calculating an integral to compare with the approximation. The student used both the equation editor and the Desmos graphing integration, organizing their work within a Mathspace created by Ms. T.

Regarding the larger sample of survey respondents, 40% indicated that they used Equatio to present multiple representations of math content, and 42% indicated that they used Equatio to help students visualize information through geometric figures, mathematical notation, graphs, tables, Venn diagrams, etc. Although this is still a small percentage of respondents overall, a greater percentage of teachers are using Equatio for this purpose than what we observed with other UDL practices.

Decoding Mathematical Notation, Syntax, and Structure

Despite only 18% of survey respondents indicating that they used Equatio to help students decode mathematical notation and symbols, we heard from our teacher partners that Equatio provided opportunities for students to decode mathematical notation in its many different forms.

One example was shared by Ms. R, who teaches middle school students. She describes how, in handwritten form, the difference between x as a variable and x as a multiplication symbol is difficult to decipher. Equatio clearly displays the symbol "x" in different ways to indicate whether it is a variable or the symbol for multiplication, which helps students decode the meaning of this symbol in the context of the problem (see Figure 8).

Figure 8

$$7x - 2$$

$$7 \times -2$$

Two meanings of the symbol "x," and the differences in the way these symbols are shown with Equatio. The first expression reads "seven x minus two" while the second expression reads "seven times negative two."

Ms. K, a middle school teacher, also describes how Equatio has helped her students understand the notation they see:

> *It has helped [my students] translate what they're hearing into what they're seeing and what they have to do.*
> *—Ms. K, Middle School*

Another teacher, Ms. B, describes how Equatio has helped her students make sense of some of the specialized symbols that are used in her precalculus class, especially Greek letters, which are often not introduced until higher level courses:

> *[My students] are like, what's that circle thing with the line through it? It's theta … as soon as you type theta, [Equatio] pops up with a symbol.*
> *—Ms. B, High School Algebra & Precalculus*

Ms. B elaborates about how the ability to quickly display an accurate symbol helps her students learn the name of the symbol theta, what it looks like (i.e., θ), and how it is used to represent angle measures in precalculus. Other teachers mentioned similar experiences with helping students understand mathematical notation.

> *Equatio gives [students] the opportunity to make the right symbols, put them in the right order, and learn the structure.*
> *—Mr. L, High School Algebra 2 and Precalculus*

These examples illustrate how Equatio can support the decoding of mathematical notation and help students understand the meaning of those symbols as they relate to other mathematical representations.

Expressing Mathematical Concepts and Ideas

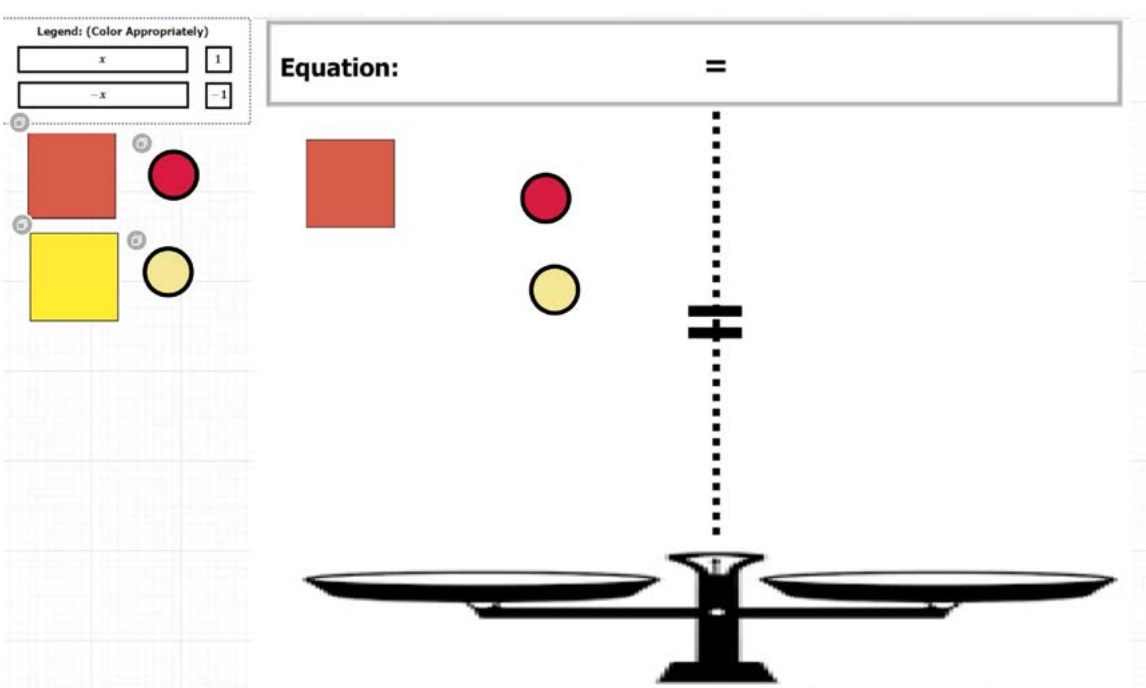
Regarding the UDL guideline to provide multiple means of Action & Expression, two themes emerged: 1) Equatio provides options for construction and composition beyond pencil and paper, and 2) Equatio supports students by providing a flexible, two-dimensional space to develop and express ideas.

Flexible Expression with Assistive Technologies

Teachers specifically mentioned benefits of Mathspace for expression, because it provides a more flexible environment for students to use when developing ideas and sharing their thinking.

In one example, middle school teacher Ms. R used Mathspace to create a balance scale with algebra tiles that students could use as a virtual manipulative for solving equations (see Figure 9). Her students manipulated the different squares and circles as they modeled and solved one- and two-step equations.

Figure 9



The balance scale and algebra tiles used by Ms. R's students. Squares represent one x, and circles represent a 1. The color of the shape indicates whether the value is positive (yellow) or negative (red).

These virtual manipulatives offered Ms. R's students the opportunity to move tiles around, add or remove them from the scale, organize them into "zero pairs" (i.e., a red circle plus a yellow circle equals zero), and solve equations in a more interactive environment.

Mathspace also has built-in dynamic smart shape representations that offer similar opportunities for students to interact with mathematical objects. Ms. F, a fourth grade teacher, describes how the smart shape fraction circles helped her students:

> *I try in real time, show [my students] the movements...to try to make them understand this as a whole. And if I shade the whole thing in, it doesn't matter how many parts I break it into...Then I just click a button and boom. It goes to 4 parts, and 3 parts... so they visually could see...That was great, and they totally got it.*
> *—Ms. F, Fourth Grade*

Our industry partners also highlighted additional features that are available for students to use for expression, including speech-to-math and handwriting recognition. Consistent with survey responses, which showed that only 18% of teachers use Equatio to provide multiple means of composing mathematics content, our teacher partners were not typically using these features. However, they did express potential for these features to support their students. Teachers specifically mentioned benefits of these Action & Expression features for their students who struggle with writing, because it would offer them an alternative to express themselves that does not rely on pencil and paper.

Space to Express and Develop Ideas

Another theme related to expression was around the idea of providing space for students to show their work and develop their ideas. Mr. L is a high school algebra 2 and precalculus teacher whose students use Equatio for nearly all of their assignments. At the beginning of the study, he shared that he appreciated the way the equation editor allowed his students to show all of their steps when working through a problem. During the first focus group, he committed to trying Mathspace with his students. After trying this new way of using Equatio, he shared the added benefit of students being able to use Mathspace together with the equation editor:

> *Using Mathspace gave them a little bit more flexibility... because you're going to do some side work...It's not going to lend itself to a perfectly linear logical structure.*
> *—Mr. L, High School*

Again, Mathspace showed up as a valuable tool for students to express their thinking, because it provides students with more flexibility in the multidimensional environment. Additionally, many technology tools in mathematics only accept a final answer as input. This means teachers have little information about how students arrived at an answer, and students may not have the tools available to support them in working through a problem or reasoning with representations that make sense to them. Equatio offers students opportunities to develop and express their thinking in these different ways, beyond final answers.

Implications for Practice, Product Development, and Future Research

With these findings in mind, we turn to implications for practice, product development, and research.

Implications for Teacher and Student Practices for UDL

Equatio already has built-in features that support the UDL guidelines, but this study highlights the power of classroom practice for using such tools to their full potential. Through the learning experiences teachers design, they can provide opportunities for their students to experience the benefits of UDL in mathematics. Our teacher partners shared real examples of how they used Equatio in their mathematics instruction, and these examples illustrate the possibilities of this digital math tool for supporting accessible and inclusive mathematics learning experiences. For practitioners who are working to design accessible, inclusive, and powerful mathematics learning experiences for their students, this study offers models of this type of instruction.

UDL emphasizes the need for multiple means of Engagement, Action & Expression and Representation. Research in mathematics education describes the same need for students to use and connect multiple representations (NCTM, 2014; Pape & Tchoshanov, 2001; Tripathi, 2008), learn to communicate their mathematical thinking in different ways (Sfard, 2008), and have space to express and develop their ideas (McMahon, 2022). Virtual manipulatives such as those provided within the Mathspace environment not only are shown to support mathematics learning (Moyer-Packenham & Westenskow, 2013), but they are also a form of assistive technology (Bouck et al., 2020). Because of this alignment between UDL and mathematics learning, we posit that mathematics instruction grounded in the principles of UDL, such as the examples teachers in this study reported with Equatio, is likely to support improved student outcomes.

Implications for Product Development

We share three recommendations for developers, specifically related to how they can help teachers learn about the full potential of their products and how to leverage that potential to support meaningful mathematics learning. In this study, teachers' primary barrier to meaningful use was not ease of use, it was a general lack of awareness of the range of possibilities for Equatio, a barrier we have seen in other research on education technologies that support learner variability (Tare & Shell, 2019). Professional learning on digital tools often varies by context and impacts implementation fidelity. For product developers, this implies a need for educating users about features and ways of using the product *within* the product. It also indicates a need for both teacher- and student-facing resources that are easily accessible and tailored to various content areas. Product developers should also recognize the social nature of teacher resource sharing and consider creating communities and spaces where practitioners can share and discover ideas, resources, and templates to use in their classrooms.

Feature and Use Case Discovery

A key takeaway for product developers is to ensure users are aware of a product's potential and how it can be used. Early in the study, our teacher partners often shared specific requests or needs related to Equatio. Most of these needs could be addressed by features of Equatio that already existed. For example, several teachers requested the ability to create number lines, visual diagrams, and other representations beyond symbols and graphs, which is possible to do using Equatio Mathspace. Teachers learned about these features and uses through the resources we shared, as well as through the professional learning and collaboration they engaged in as part of this RPIP. One teacher described how much she appreciated learning about the AI forms creator feature:

> *There are things that I just learned about [in the focus group] that I didn't know I needed, like the AI [forms creator] for Google forms… after seeing that today, and how easy it was to insert the math. I didn't realize I needed it until you gave it to us. So I really appreciate that.*
> *—Ms. K, Middle School*

In addition to finding ways for teachers to discover features, another implication is to find ways for teachers to learn how those features can be used in service of their instructional needs. Given the general lack of awareness of both our group of teacher partners and the survey respondents about how Equatio could support UDL practices, an important implication of this work is finding ways to inform users about how they can make the most of Equatio to support student learning.

One idea that was shared in a focus group was to have a chatbot that can help teachers learn about features and uses. The chatbot could respond to queries such as "How do I create a number line?" with tutorials and other information about related features and uses. Because teachers may not realize what they need, it would also be important for the chatbot to routinely expose users to new resources and features. Telemetry data from the specific user account could be leveraged to personalize recommendations.

Resources for Both Teachers and Students

When asked about resources, teachers indicated that resources for both students and teachers were valuable. Teachers tend to be responsible for onboarding students and helping them get started using technology tools. Although their students were generally able to get started with Equatio with little support, teachers did indicate a clear desire for student-facing resources, such as one-pagers with basic introductions to the Equatio toolbar, general instructions for how to use various features, or relevant keyboard shortcuts and key terms to use when searching within the library of available formulas, symbols, and shapes.

Resources can also be tailored to specific content areas and grade levels to help teachers and students focus on the most relevant features and uses for their work. For example, the Desmos graphing integration is more relevant to algebra, precalculus, and calculus instructors; the virtual base ten blocks, fraction bars, coins, and clocks in Mathspace are more relevant to elementary teachers; geometry teachers would benefit from knowing where and how to find circles, different types of triangles, three-dimensional solids, and angles in Mathspace.

Leaders at Texthelp also suggested that they can use the findings of this study to formalize what they share with their district customers, which would then be disseminated to teachers. Improved onboarding materials might include a series of one-pagers such as "Equatio's Top 10 Uses" and "How Students Can Use Equatio."

Community of Practitioners

Another implication of this work is the value of community resources and support for teachers to learn about the product and how others are using it. Teachers in our study shared resources, asked questions, and provided support to one another about how Equatio could be used to meet their needs and the needs of their students. When asked what resources they would appreciate most, overwhelmingly our teacher partners expressed a desire for a community space to share and discover ideas, templates, pre-made activities, and other resources. They also suggested that these resources could involve online, asynchronous communication and sharing. Product developers might use community platforms to help facilitate this collaboration and sharing of resources among users.

This raised an important question for the team at Texthelp: How can we identify and communicate with math educators? They recognized the need to be intentional around how they engage with their educators. As we observed in this RPIP, teachers not only learned from one another, but they also learned from Equatio product experts who provided real-time, relevant professional learning about the product and its potential. Given the explicit requests from our teacher partners for community engagement and their reported benefits of communicating directly with Equatio experts, we see promise for community platforms to help connect practitioners not only with each other but also with product developers.

Implications for Learning Sciences Research

This study offers implications for future research that explores the connections between UDL and mathematics teaching and learning. Additionally, future research could address some of the limitations of this study to learn more about classroom practice, student use, and the needs of teachers and students in different contexts.

UDL and Mathematics

For many of our teacher partners, they were already implementing UDL practices as part of their mathematics instruction. We see an opportunity to continue exploring the connection between UDL and mathematics. Given the apparent synergies between the UDL Principles and what we know about mathematics teaching and learning, future research could explore this relationship further. For example, what is the impact of intentional professional learning around UDL Guidelines on mathematics instruction?

Addressing Limitations

This study represents a first step towards understanding the potential of UDL-focused tools to support mathematics teaching and learning. It has some limitations, which could be addressed with future research. One limitation of this work is the reliance on teacher reports. All instructional practices were reported by teachers, rather than observed in classrooms. Future research should include observations of real classroom practice to see firsthand how this tool is used to support UDL instruction.

Additionally, future research could explore the specific needs of teachers and students within different contexts. Although we have some insight into how grade level and content area shaped teachers' needs with respect to product features and uses, additional research could bring to light some of the ways in which context shapes the specific needs of teachers and students with respect to features and ways of using digital mathematics tools.

Conclusion

The goal of this study was to better understand how teachers and students use Equatio and how it can be used in ways that research suggests lead to instructional improvement and student learning in mathematics. Because of the study's nature as an RPIP, teacher perspectives and existing learning sciences research directly informed product development for Texthelp and Equatio.

We've seen through this study that the future of math inclusion is about much more than providing accessibility tools to those students who require them. With tools like Equatio, what is necessary for some is beneficial for all. By examining authentic teacher use cases, we can see how the future of math education includes tools that support students in becoming what UDL refers to as "expert learners": purposeful and motivated, resourceful and knowledgeable, and strategic and goal directed.

This study also gives us insight into the future of edtech research and development. Through this RPIP, our industry partners witnessed firsthand the power of working in partnership with educators and researchers. They gained real-time product feedback and classroom insights, and authentic examples of desired implementation. An increasing number of edtech products are seeking out this type of research, and this report illustrates the types of findings that can emerge.

Digital Promise and Texthelp plan to continue this study in the coming months, building upon these initial findings by observing classrooms where Equatio is in use. Just as we set out to find authentic teacher use cases, we want to see firsthand how students are using Equatio. By including students in this continued collaboration between researchers, practitioners, and edtech developers, the future of math inclusion will give more students access to positive and inclusive mathematics learning experiences.

References

Bouck, E. C. (2012). Assistive technology and mathematics education: Reports from the field. Journal of Computers in Mathematics and Science Teaching, 31(2), 115-138.

Bouck, E. C., Park, J., & Stenzel, K. (2020). Virtual manipulatives as assistive technology to support students with disabilities with mathematics. Preventing School Failure: Alternative Education for Children and Youth, 64(4), 281-289.

Brooke, J. (1996). SUS - A quick and dirty usability scale. Usability Eval. Ind.

Califf & Brooks (2020). An empirical study of techno-stressors, literacy facilitation, burnout, and turnover intention as experienced by K-12 teachers. Computers & Education, 157, 103971.

CAST. (n.d.). UDL: Research evidence. https://udlguidelines.cast.org/more/research-evidence

CAST (2018). Universal design for learning guidelines version 2.2 [graphic organizer]. Wakefield, MA. udlguidelines.cast.org

Corbin, J. & Strauss, A. (2015). Basics of qualitative research: Techniques and procedures for developing grounded theory. 4th ed. Sage.

Douglas, D., & Attewell, P. (2017). School mathematics as gatekeeper. The Sociological Quarterly, 58(4), 648-669.

Fabian, K., Topping, K. J., & Barron, I. G. (2016). Mobile technology and mathematics: Effects on students' attitudes, engagement, and achievement. Journal of Computers in Education, 3, 77-104.

Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K. C., Wearner, D., Murray, H., & Human, P. (1997). Making sense: Teaching and learning mathematics with understanding. Heinemann.

Izzo, M. V., & Bauer, W. M. (2015). Universal design for learning: enhancing achievement and employment of STEM students with disabilities. Universal Access in the Information Society, 14, 17-27.

Martin, D. B., Gholson, M. L., & Leonard, J. (2010). Mathematics as gatekeeper: Power and privilege in the production of knowledge. Journal of Urban Mathematics Education, 3(2), 12-24.

McMahon, L. H. (2022). Talking past one another and getting on the same page: Communication in mathematics teaching and learning. (Doctoral dissertation)

Miles, M. B., Huberman, A. M., & Saldańa, J. (2014). Qualitative data analysis: A methods sourcebook. 3rd ed. Sage.

Moyer-Packenham, P. S., & Westenskow, A. (2013). Effects of virtual manipulatives on student achievement and mathematics learning. International Journal of Virtual & Personal Learning Environments, 4(3).

National Council of Teachers of Mathematics (2014). Principles to actions: Ensuring mathematical success for all.

Norman, D. (2013). The design of everyday things. Basic Books.

O'Halloran, K. L. (2015). The language of learning mathematics: A multimodal perspective. The Journal of Mathematical Behavior, 40, 63-74.

Pape, B. (2018). Learner variability is the rule, not the exception. Digital Promise. http://hdl.handle.net/20.500.12265/16

Pape, S. J., & Tchoshanov, M. A. (2001). The role of representation(s) in developing mathematical understanding. Theory into Practice, 40(2), 118-127.

Pautz Stephenson, S., Banks, R., & Coenraad, M. (2022, June). Outcomes of increased practitioner engagement in edtech development: How strong, sustainable research-practice-industry partnerships will build a better edtech future. Digital Promise. https://doi org/10 51388/20 500 12265/158

Pierce, R., Stacey, K., Wander, R., & Ball, L. (2011). The design of lessons using mathematics analysis software to support multiple representations in secondary school mathematics. Technology, Pedagogy and Education, 20(1), 95-112.

Root, J. R., Cox, S. K., Saunders, A., & Gilley, D. (2020). Applying the universal design for learning framework to mathematics instruction for learners with extensive support needs. Remedial and Special Education, 41(4), 194-206.

Rose, T. (2016). The end of average: How to succeed in a world that values sameness. Penguin UK.

Sfard, A. (2008). Thinking as communicating: Human development, the growth of discourses, and mathematizing. Cambridge University Press.

Schleppegrell, M. J. (2007). The linguistic challenges of mathematics teaching and learning: A research review. Reading & Writing Quarterly, 23(2), 139-159.

Tare, M. & Shell, A. R. (2019). Designing for learner variability: Examining the impact of research-based edtech in the classroom. Digital Promise Global. http://hdl.handle.net/20.500.12265/81

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., & Ragu-Nathan, T. S. (2007). The impact of technostress on role stress and productivity. Journal of Management Information Systems, 24(1), 301-328.

Thomas, C. N., Van Garderen, D., Scheuermann, A., & Lee, E. J. (2015). Applying a universal design for learning framework to mediate the language demands of mathematics. Reading & Writing Quarterly, 31(3), 207-234.

Tripathi, P. N. (2008). Developing mathematical understanding through multiple representations.

Mathematics Teaching in the Middle School, 13(8), 438-445.

U.S. Department of Education, Office of Educational Technology, National Educational Technology Plan, Washington, DC, 2024.

U.S. Department of Education, Office of Educational Technology, Ed Tech Developer's Guide, Washington, D.C., 2015.