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Adding a Teacher Dashboard to a Functioning Web App

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Adding a Teacher Dashboard to a Functioning Web App

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In this paper, I describe the design process used to update a math-fact fluency application for classroom use, including the addition of a teacher dashboard and features to make the app more useful in a classroom environment. I described the type of features that teachers requested during interviews; the types of modification that needed to be made in order to adapt to classroom use; and the challenges in preserving best practices with users whose familiar methods are sometimes in conflict with research-based methods.

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INTRODUCTION

Everybody Math is a math-fact fluency app, primarily to be used in lower elementary school, but appropriate for older students who have not yet memorized their math facts. I designed the original app in 2019 as an implementation of research-based methods of teaching fact fluency. Since then, I have been testing and refining it with the help of individual students and parents. Prior to the work described in this paper, the design of the app was for use by a single student, with no reporting to or management by a teacher/parent. It had not been used at scale or in classrooms. Prior design iterations had established its validity for student use.

The purpose of this project was not to focus on individual students as learners. Rather, the purpose of this project was to expand the app's capabilities to connect students with mentors who can monitor and direct student learning in a data-informed manner. The lessons learned from this case may be helpful to other designers who seek to create teacher or mentor dashboards to student-centered learning apps.

RELEVANT RESEARCH

The research regarding math-fact fluency is generally not well known but is crucial to the design decisions in this project. While a full literature review is beyond the scope of this paper, I begin with a short summary of the relevant research to situate the subsequent design decisions. (See Figure 1.)

Important Principles for Teaching Math-Fact Fluency

Fluency

Math-fact fluency means that a student can recall a math fact directly from memory, without using any counting strategies or mnemonic devices. When a student is fluent, or automatic, with a math fact, they can answer that math fact in less than one second,

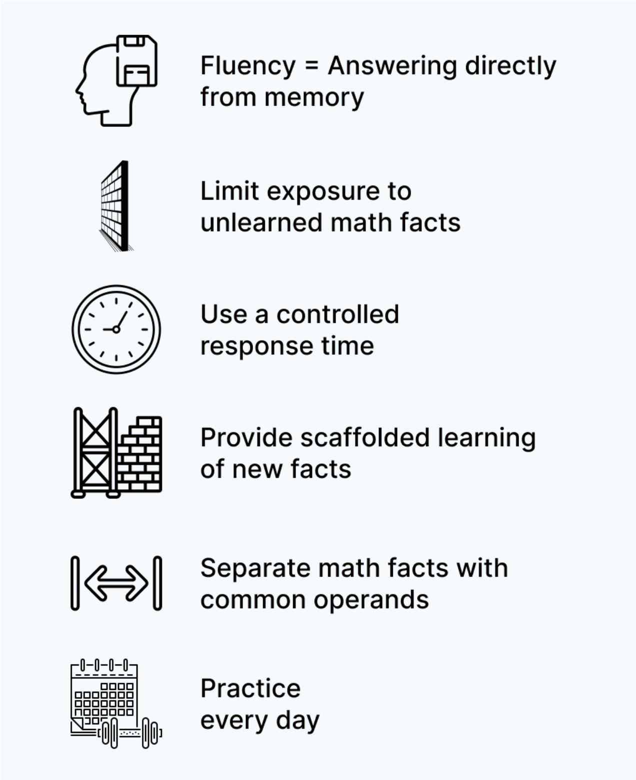


Figure 1. Essentials of teaching fact fluency

while computational strategies take longer (Crawford, 2003).

The National Mathematics Advisory Panel categorizes automatic recall of addition, subtraction, multiplication, and division facts as an element of whole-number fluency that is an essential part of a student's foundational understanding critical to success in algebra (National Mathematics Advisory Panel, 2008).

Limit Exposure to New Facts

While a student is developing math-fact fluency, new math facts should be introduced only one or two at a time, and these new math facts must be completely fluent before additional math facts are introduced (Hasselbring, et al., 1988, Crawford, 2003). Because math facts take multiple days of practice to become automatic, it is important to verify, at the beginning of practice, that the student can still answer "learned" facts fluently, before introducing new ones.

Controlled Response Time

A student must be required to answer within a "controlled response time" that stretches their ability. Students who don't answer within the time limit should be given the answer and required to repeat it. Without this requirement, students may make faster computations, but never make the final shift to automaticity. Computer-based drill-and-practice is ineffective without controlled response time (Hasselbring, et al., 1988).

Scaffolded Learning

When learning new math facts, students need to be given math facts with a controlled response time that is specific to the student and adapts over time (Hasselbring, et al., 1988). If students are allowed to give incorrect answers, those will "compete" with the correct answer in memory. Therefore, problems should be presented in an order and at a speed that allows students to answer correctly nearly all of the time (Goldman & Pellegrino, 1986).

Separate Common Operands

Math facts should be learned in an order that separates common operands. For example, $9 \times 5 = 45$ should not be introduced at the same time as $9 \times 7 = 63$, because they share a common operand, the number 9 (Campbell & Graham, 1985). This separation helps to avoid interference errors in the student's working memory.

Practice Consistently

In order to make significant progress, it is essential for students to practice consistently. As demonstrated long ago by Hermann Ebbinghaus (1885), newly established memories decay rapidly from one day to the next. Subsequent research has shown that spaced repetition is an effective means of improving long-term memory, and that initial repetition intervals should be short. (Landauer et al., 1978) Students who review recently learned math facts daily will experience more rapid growth than students who do not.

Overview of the Design of the Everybody Math Student Application

The student application is divided into rounds, each of which serves a specific purpose (see Figure 2).

Proving

In the proving round, the app reviews math facts that have been learned recently to see if the student can still answer them fluently. If not, then any math fact that still needs practice will be used for "Scaffolded Learning" during the upcoming practice session.

Pretest

During the pretest round, the student is given the opportunity to demonstrate any math facts that they already know, in order to skip the Scaffolded Learning step for those math facts. Students are allowed to skip math facts during the pretest, since we don't want to require them to answer unfamiliar math facts. Math

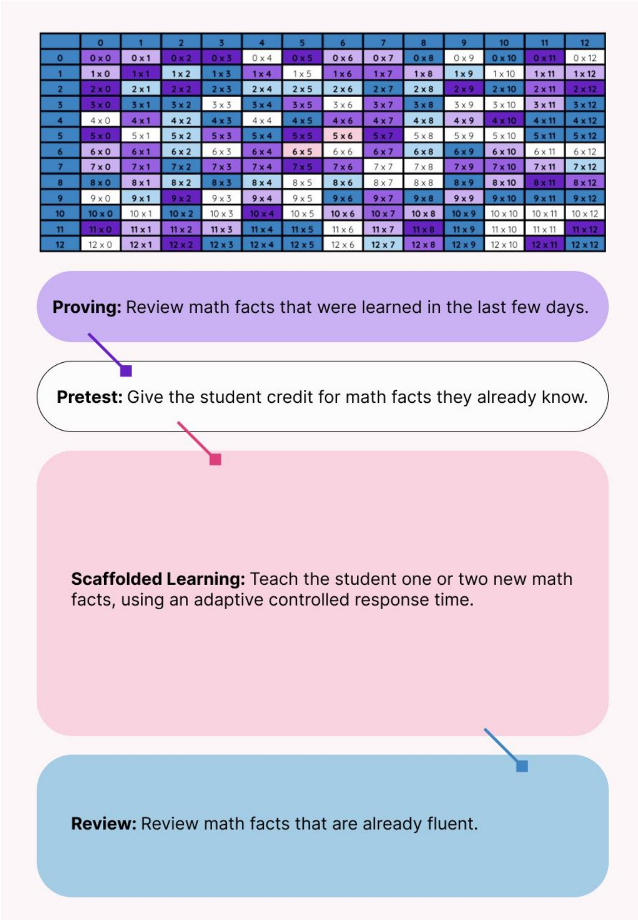


Figure 2. Progress through an Everybody Math practice session.

The student reviews recently learned facts and takes a short pretest to find math facts that aren't already known. One or two unknown facts (especially recently learned facts that the student doesn't remember well) are presented for scaffolded learning. Finally, already-fluent facts are reviewed in order to keep them fresh in the student's memory.

facts that can be answered fluently during the pretest are considered "recently learned" for review purposes.

Scaffolded Learning

Scaffolded Learning is the primary portion of the daily practice session. It includes several rounds, each with its own purpose. During the first round of Scaffolded Learning, a new math fact is introduced, along with its answer and several different formats the students might see, such as answer on the left vs. right or vertical vs. horizontal. In the following round, the new math fact is presented with random numbers to type as spacers in between repetitions of the new math fact. As Scaffolded Learning progresses, the random numbers are replaced with fluent math facts as spacers. The response time is decreased and the number of spacers between each repetition of the new math fact is gradually increased.

By the time the student completes the Scaffolded Learning portion of their practice session, they have answered the new math fact correctly, within a time limit indicating fluency, three times in a row with several spacers in between.

Depending on the user settings, the student may be introduced to one or two new math facts on a given day. As described above, one or both of the "new" math facts may be a repeat from prior days if the student still needs practice with a recently learned math fact.

Review of Fluent Facts

Finally, the student is presented with a review of already-fluent math facts, in order to keep them fresh in memory.

This structure of the student application has been refined in multiple design cycles across four years, with students practicing individually, supervised by their parents. During that period, the student user experience has been improved by adding multiple forms of real-time feedback about the student's progress in learning math facts and their progress through a single day's practice. In addition, more time is spent on the presentation of the math fact and the formats in which it might be seen. Subtraction and division math facts within the same "fact family," such as 12 - 4 = 8 and 12 - 8 = 4, were divided into separate practice items, while multiplication and addition math facts in the same fact family are considered one math fact for practice purposes. Multiple forms of input, including speech, multiple choice buttons (including every possible choice), and a number pad, were added to the keyboard input. Speech was also implemented as a potential output. Badges and simple games were created to increase student engagement.

The purpose of this design cycle was to create a teacher/parent dashboard to allow mentors to both see and influence their students' practice.

DESIGN PROCESS

Interviews and Surveys

To assess the needs of classroom teachers, I set up a booth in the exhibit hall of an edtech conference for teachers. For two days, I conducted informal interviews with teachers, school administrators, and math coordinators who passed by the booth. I talked to approximately 50 teachers/admins in discussions lasting 5-30 minutes. This process was much more valuable than I expected.

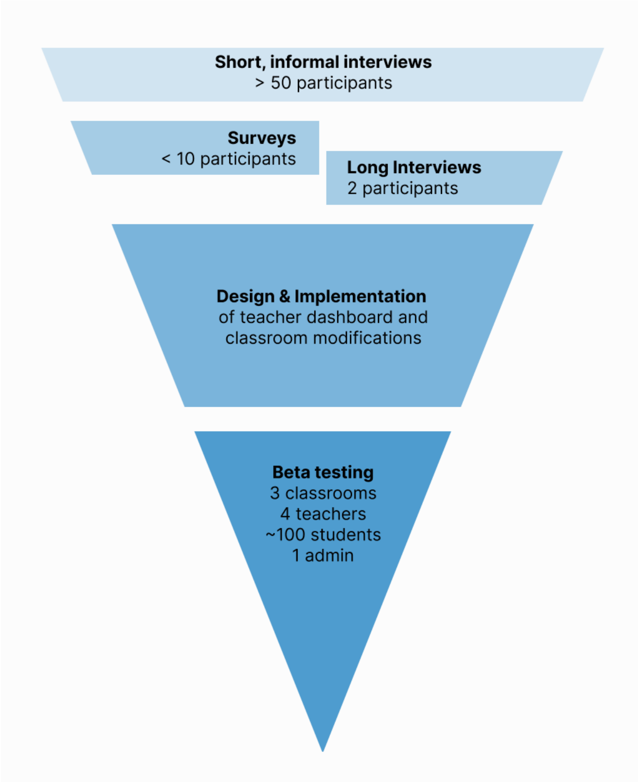


Figure 3. The design process for the teacher dashboard and additional modifications for classroom use.

During those informal interviews, I revised my understanding of how teachers at various grade levels understand, value, and approach fact fluency in their classrooms and what tools they would like to have for teaching fact fluency, such as the ability to assign math facts to be learned. By the second day of the conference, my findings had reached saturation, and the conversations had become almost predictable.

After the conference, I surveyed K-6 teachers and conducted two full-length interviews (see Figure 3). The results extended but did not contradict my understanding of the teachers' needs. Some of the most common requests included:

- Interruption tolerance - students can save work and log out, then resume after recess or other interruptions
- Time limits - teachers can set an upper limit on the amount of time students will spend practicing
- Availability via the web and available for any hardware and software platform
- Efficiency - students won't spend time learning math facts they already know
- Gamification or other elements that will help student engagement
- Teacher Assignments
  - Ability to assign math facts to be learned,
  - Ability to assign practice by time (as homework)
- Reporting
  - Reporting on students' current status and recent progress
  - Reporting on when students log in and what they accomplish during that time
- LMS integration

User Testing in Classrooms

In order to begin user testing in classrooms, I implemented a few features essential to classroom use, including interruption tolerance and a minimal interface allowing a teacher to create an account, add a class, and see student progress, as well as the data collection necessary to support it. The software was already web-based, so that didn't require a change.

I began my user testing with a classroom of first graders at a charter school starting in mid-October. The class practices simultaneously at 10:00 a.m., after returning from their first recess. My initial feedback from the first-grade classroom was via email with the teacher. I observed the class near the middle of December and interviewed the teacher a few days later.

Near the end of October, I added a classroom of fourth-, fifth-, and sixth-grade students at a private academy. Because it is a learner-led school, the students are responsible to do their practice at a time of their choosing, sometime between 9:00 a.m. and 11:00 a.m. each day. I was invited to meet with the students for fifteen-minute discussions, once before they had started using the app and again after they had used it for two weeks. The classroom teacher, the director of the academy, and the teachers of other classrooms all provided their own feedback, as well.

In January, the private academy added an additional classroom with second-, third-, and fourth-grade students. (The classrooms overlap somewhat in grade levels.) A few students in the first grade also began using the app. The teachers corresponded with me via text message when they had a request or suggestion.

While testing in the classrooms, I made updates to both the teacher dashboard and the student app in response to feedback from teachers and students. The testing and updates are ongoing at the time of this writing.

DESIGN DECISIONS

Redesign, Not Addition

In this design cycle, my intent was to create a dashboard for parents and teachers, an additional piece to build as a companion to the student app. However, it became apparent, even in the interview stage, that the student app itself needed to be redesigned for use as a mentored learning tool, especially in a classroom setting. The redesigned elements of the student app fall into these main categories:

- General classroom-specific design
- Classroom-specific design for in-class use
- Classroom-specific design for homework
- Response to mentor assignments
- Data Collection

In the following sections, I will discuss specific examples in each of these categories.

General Classroom-Specific Design

When teachers discussed what they wanted in an app, they often spoke in the context of using the app specifically as a homework assignment or for in-class use. The features they requested reflect the intended use. Some attributes, however, were common among all teachers. One in particular is worth mentioning:

Web-based - While parents automatically turn to the app store on their preferred device, teachers overwhelmingly requested a web-based application. This allows students to use the app in any hardware context (Chromebook, iPad, parent's cellphone) and any software context (any operating system, any browser). It also makes the app available to students in a wider range of physical locations outside of school, since the student need not have access to a specific hardware device on which the app is installed.

Teachers expressed a strong belief that web-based software requires less setup and less tech support by the teacher or for the teacher and is easier to integrate into a learning management system.

Classroom-Specific Design for In-Class Use

Distractions - Isabella (a pseudonym) has a classroom of 22 first graders. They begin fact practice at the same time, and each child is allowed to move on to another activity when they have finished. Because the app goes through specific rounds of scaffolded learning and review, it is important for the students to finish a complete practice session.

Isabella's class had been using the app for several weeks by the time I observed them, but it was immediately apparent that many students had not been completing their practice sessions in the weeks leading up to my observation. In addition, it was evident that some of the students had no self-efficacy for finishing or making progress. Dialogue between teacher and students evidenced that they had even identified a particular round as a major barrier.

It was easy for me to see what the problem was. Every ten or twenty seconds, a student would say something out loud, such as telling a particularly rowdy student to sit back in her seat. Each time, half of the students would look up for a few seconds, then return to their screen. While they were distracted, the math fact they had on screen had exhausted its controlled response time and been marked "not fluent."

Some of the scaffolded learning rounds, which focus on narrowing down a student's response time, continue until the student is able to answer the new math fact correctly and quickly, multiple times in a row. Each time a student timed out on the scaffolded math fact, their progress in the round was reset.

The last three students to finish were all stuck in the final round of scaffolding, the same round that teacher and students all agreed was the "hard" one. For each of the three students, I interrupted her practice to point out that there was a particular math fact that needed to be answered quickly, and that doing so would end the round (and the student's misery). Each of the three immediately focused on that math fact and finished the round within moments.

For classroom students two years older, or those working at home, distraction does not seem to be a big enough problem to derail a student's progress, but in this instance, it had become a major barrier for roughly half the class. In my discussions with the teacher, we brainstormed modifications that could help her distractible students.

She was very enthusiastic about the suggestion of a "Go" button, which will appear before the presentation of a math fact if the response time for that math fact influences the progress of the round. Students will have to click on the Go button, committing themselves to staying focused long enough to answer that one math fact, before it appears.

The Go button feature is in the implementation phase right now. Because it is quite intrusive, it will not be the default behavior for all students. Therefore, it will be helpful to also have a tool to detect distracted students and call the teacher's attention to them, so that the teacher can give them guidance and, potentially, turn on the Go button feature when it is the best solution.

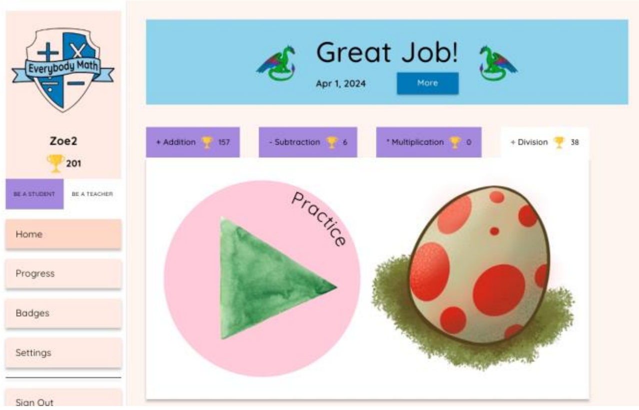


Figure 4. Victory banner at the end of practice. Students can continue to practice, but returning to the home page will display the victory banner.

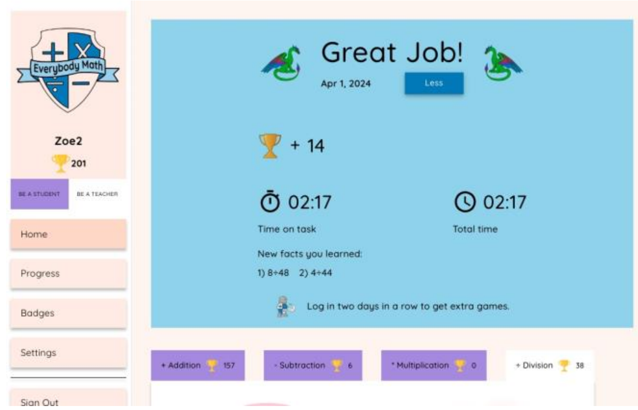


Figure 5. Expanded victory banner shows details of the student's practice. These details are also available on the teacher's "My Class" page.

In the future, I'd also like to explore ways of detecting when a student is fluent and should move on, even if some of their answer times are inconsistent.

Obvious Visual state - Students need to finish their scaffolded learning in order to get to the review of fluent math facts, but Isabella wasn't sure who was finishing and who wasn't.

Although the app puts up a message when the students finish, the message disappears after they acknowledge it, and Isabella couldn't keep track of which students had finished. Their status was also displayed by a progress bar on their practice screen, but Isabella had to be close to the student to see it.

After discussing it with her, I added each student's practice status for the current day at a prominent position on the home screen of the teacher dashboard. Because she is actively roaming the room as her students work, results visible on the teacher dashboard are not a complete solution, so I also added a persistent congratulatory banner to the top of the student's home screen, in a visually distinct color that could be seen from a distance. This allowed her to confirm a student's status from across the room (see Figures 4 and 5).

Interruptions - In a classroom setting, students are sometimes required to leave what they are working on and finish it later in the day. This especially applies to work, such as fact practice, that is done individually, rather than as a group. Teachers want students to be able to sign out of the work environment but have all of their work restored when they log in again, even if they didn't finish a practice. The implementation of this change isn't interesting, but I mention the feature because it is valuable for future designs.

Time Limits - Some teachers want to be able to fit fact practice into a specific time slot during the day, so they want to be able to guarantee that students will be done within a certain amount of time. For a mastery-based app, this is a real challenge, as the time to mastery varies by student; interrupting a mastery-oriented session may prevent the student from moving on.

At present, I have implemented a partial solution, which is to allow the teacher to limit a student to learning one math fact per day, rather than two. However, there are some difficulties with this solution:

1. It requires an intentional action by the teacher.
2. It applies to the student's work every day, rather than adapting to their success on a daily basis.
3. It reduces overall time needed but doesn't actually limit the student to a specific time window.
4. The need for it is evidence that the design of the app is not working well for some students. Students who are not constantly set back by momentary distractions are able to finish in well under fifteen minutes.
5. The problem of time limits is compounded by the fact that some teachers want to assign students to use the app for very short, inconsistent intervals to fill available time.

In a future iteration of design, I intend to test three approaches to the time limit problem. The direct approach is to respond in real time when students are taking a long time during their practice, by limiting them to just one math fact.

An indirect approach is to continue experimenting with solutions for the distraction problem, which I believe is the major factor in students taking a long time to finish.

Because it is also necessary to handle the situation where students are given short and unpredictable time intervals for fact practice, I also want to explore strategies for allocating time most effectively when student practice time is erratic, which I will discuss below.

Classroom-Specific Design for Homework

For teachers who want to assign fact-practice as homework, three particular features were paramount: 1) teachers must be able to assign a certain amount of practice in a given time window, such as one practice session each weekday; 2) teachers need a concise report of how well the students fulfilled the assignment; and 3) teachers also need detailed reports of when students logged in, how much time they spent, and what they practiced. This information helps teachers identify students who need additional help or encouragement.

Response to Mentor Assignments

As mentioned above, teachers wanted the ability to assign students to practice within a specific time period, and this means that the student app must have the capability to display assignment requirements and completion status to students.

In addition, teachers wanted to be able to limit which math facts their students will learn. That is, they wanted to choose the order in which their students learn the math facts. Nearly every teacher who was surveyed or interviewed considered this a very important feature. To accommodate this request, the student app was modified to accept a prioritized list of learning objectives, each of which may have multiple math facts.

Data Collection

The student application had to be modified to store data that had not been recorded before implementation of the teacher dashboard. Much of the data was already in use in the student app, and was used and sometimes displayed in real time, but reporting features for the teacher dashboard require that the data be gathered and stored in a format that can be easily retrieved for display at a later time and in a manner that makes data available to another user (the teacher) while maintaining student privacy.

This includes data such as the status of each math fact and the number of math facts at various levels over time, information that is displayed for the student as they practice. But it also includes meta-data regarding when the student practiced, what they learned, and how long they spent, which was not recorded and, in some cases, not calculated before the implementation of the teacher dashboard.

In all, the modifications to the student application to make it classroom-ready were similar in magnitude to the creation of the teacher dashboard.

Research vs. Practice

During my initial interviews with teachers, I uncovered a challenge that I expect will require many iterations of design; the way teachers want to teach fact fluency is contrary to the research-based practices that will help them and their students to succeed.

Consistent Practice

One example is the time-limit problem mentioned above, in which fact practice is slotted into a time window that may not give students enough time to achieve mastery.

Closely related is the situation in which teachers expect students to practice in random short bursts at unpredictable times. Although this is not an ideal strategy for math facts, it is one that teachers say in interviews is their only option, based on the amount of material they have to cover and the amount of time they have, especially if they are trying to help kids catch up in learning math facts at a grade level in which no time is allotted for it.

While I have implemented multiple methods to automate research-based principles on the teacher’s behalf, consistent practice is one that cannot be directly implemented by the designer. It is so crucial, however, that it must be addressed if the app is to be useful.

One partial solution came from gamification. To encourage consistent usage, the app now provides badges for students who log in every weekday and for students who supplement their practice by logging in on the weekend. These badges can be earned repeatedly, with a count displayed for the number of times each badge has been earned. Several students have mentioned to me that they are trying to earn these badges, so I believe that they have some influence.

However, if the majority of students are going to succeed, it will be necessary to convince teachers to allocate adequate time for practice. Teachers with whom I have direct contact as beta testers have allowed themselves to be convinced through discussions directly with me. However, in their initial usage, their allocation of practice time was haphazard, even though they believe in the value of math-fact fluency. Teacher instruction is itself a design question which I address in the “Lessons Learned” section.

Finally, because some teachers will continue to assign fact practice erratically, a complete design solution would acknowledge this possibility. In discussion with teachers and other instructional designers, I have developed a design to ameliorate the effects of having fact practices cut short after an arbitrary amount of time.

Practice is already divided between scaffolded learning of new facts and reviewing fluent facts. These two phases can be considered "alternating" practice strategies for short sessions. In the case that a student completes Scaffolded Learning, but not Review, the next practice, whenever it occurs, could begin with the Review of fluent facts, followed by Scaffolded Learning if there is enough time. Because review of recently learned facts is particularly time-critical, implementation of a two-phase strategy could implement the Proving Round as the first round in any practice, regardless of which phase (Scaffolded Learning or Review) the practice session will implement. A two-phase strategy would lose the enormous benefits of daily practice but would still provide better utility for students than the current arrangement.

Another strategy that I discussed with one fourth-grade teacher during an interview was to provide a way for the teacher to specify how long the practice would be, so that the software could adapt more effectively. The teacher said that this strategy would be useless to him because the amount of time available varied by student and by day; he could not predict when he told them to practice how much time they would have for it; and even if he could predict it, he didn't have time to enter the information. However, this is an option that might be useful for some teachers and deserves additional exploration.

Assigning Math Facts

Because it is important to separate the presentation of new math facts with common operands, the practice of assigning students to learn a row of math facts, such as "all of the times fours" is particularly counterproductive. One of the better strategies is to allow students to learn the math facts in random order.

However, teachers put a high priority on the ability to assign math facts. In some cases, they want to limit their students to a smaller grid, such as 10x10, instead of the default 12x12 grid. Other times, they want to comply with a school-wide mandate to learn a certain set of math facts.

For practical reasons, it makes sense to give teachers this capability, but it is likely that many of them will use it to assign rows of math facts, since they are accustomed to working with the math facts in rows while helping students to develop conceptual understanding of mathematical operations. (e.g., doing exercises with the class in which they investigate the effect of multiplying by two and compare it to adding a number to itself. This is an essential exercise for conceptual understanding, but the pattern of learning about the whole row of "times twos" doesn't carry over into the development of automaticity).

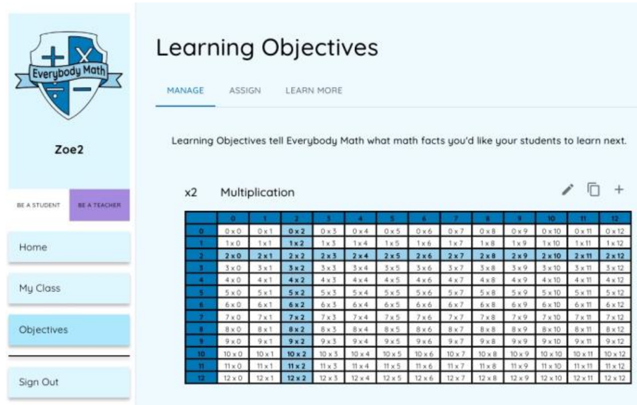


Figure 6. Learning Objectives

Allowing teachers to create learning "objectives," rather than assignments, allows the app to choose the next math fact for the student to learn using research-based practices while also prioritizing the teacher's goals.

Just-in-time instruction for the teacher appears as text at the top of the page, with more detailed information in a video on the "Learn More" tab.

In a discussion with other instructional designers, we developed the following strategy: in place of math fact "assignments," allow the teacher to define "learning objectives." The learning objectives will be considered whenever the app needs to choose a new math fact to be presented during scaffolded learning (math facts that are already fluent or recently learned will not be affected by the learning objectives). Each learning objective may contain any subset of math facts, and the teacher can assign multiple learning objectives to a student.

To adhere to research-based practices, Everybody Math will guarantee that the two new math facts learned on the same day will not share any common operands. After that requirement is met, priority is given to the learning objectives defined by the teacher. This may result in the math facts contained in the learning objectives being interspersed with other math facts not prioritized by the teacher, especially if the teacher has defined a learning objective that includes a single row of math facts. However, it will still accomplish the learning objectives as quickly as possible (the teacher's goal) without violating principles of best practice.

LESSONS LEARNED

Lesson #1: Teachers Need Instruction and Have No Time

When I discovered difficulties in Isabella's class, I had the chance to discuss solutions with her in our interview a few days later. Some of the problems were due to Isabella's lack of understanding about how fact fluency should be taught and how to use the software effectively. When I began to suggest a "tip of the day" on her home screen, Isabella responded before I finished the question.

"I wouldn't read it. I just don't have time."

Her statement encapsulates a major problem for technology that implements new practices. In most software, the user interface must be designed to help users identify *how* to do a task. When the user isn't familiar with the research upon which a tool is built or the practice it is designed to implement, they may not know *what* tasks they need to do, *why* they need them, or *when* they are appropriate. In this case, educating the user on underlying principles is an additional layer of design that must be considered. Unfortunately, people who are using new software often don't have time to learn about its philosophy and functionality in detail.

Effective use of Everybody Math depends on the teacher knowing the basics of fact fluency methodology, including the importance of consistent practice and that the students need to complete a full practice session (including Scaffolded Learning and Review) each day.

The use of individual features also requires knowledge. Some features, such as a student overview, are similar to what teachers are familiar with in other contexts. A feature such as Learning Objectives is a more difficult design challenge. In order to use it effectively, a teacher must first understand the difference between teaching conceptual understanding, which often involves grouping similar math facts, and teaching direct recall, which is most effective when common operands are separated. In addition, the teacher needs to understand how and when the learning objectives will be applied.

In future iterations, I will experiment with different methods of teaching the teacher. Based on my initial interviews and observations, I expect to use at least the following methods:

General Training

- Short instructional videos including general principals and the "why," "when," and "how" for individual features
- Quick Tips on the teacher home page
- Increased emphasis on consistency in training materials

Just-In-Time Training (See Figure 6)

- Short text-based tips directly on the relevant page
- More detailed text-based instruction available via a "learn more" button directly on the relevant page
- Links to individual videos directly on the relevant dashboard page

Lesson #2: Ease-of-Use

Ease-of-use for classroom teachers includes convenient access to information in both the student view of the application and the teacher view. The victory banner on the student's home page allows the teacher to respond quickly to students when she is about in the classroom, without quick access to her own dashboard. It has to be clearly visible across the room.

In the teacher dashboard, the teacher needs general feedback about her students' progress, summaries that will help her to identify students who need additional support, and at-a-glance information about the practice status of each member of the class.

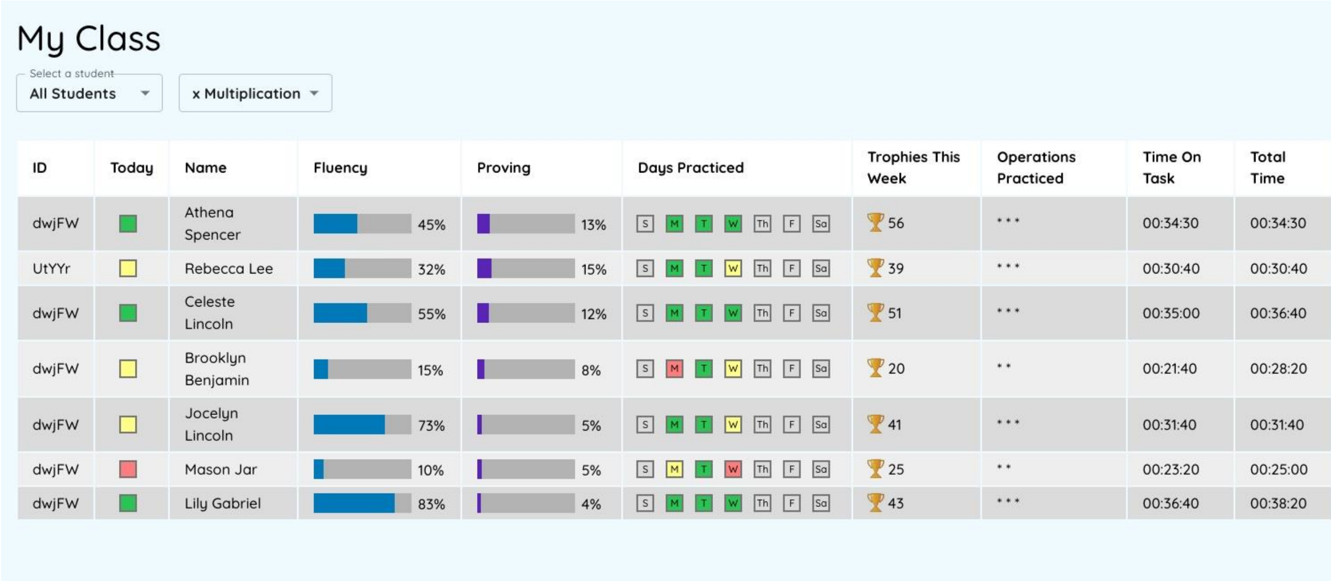
Lesson #3: Teachers Care About Trophies

When I observed Fiona's class of fourth- and fifth-graders during their second week using the software, one of the students approached Fiona to show her the badge they had just earned. After praising the student, she turned to me and said, "I promised them a pizza party when they have earned eight badges." She requested that I add some indication of badges earned to the teacher dashboard.

Later, she described a plan to add a requirement for grade advancement. Students at Fiona's school are advanced between grades based on competencies, rather than by age. The teachers and school administrator were discussing the addition of a fact-fluency requirement for each grade level, which they expressed as a number of trophies.

Although fact fluency is the real goal for the teachers and administrators, they also find meaning in the extrinsic motivational elements that were designed to engage students. Based on my conversations with them, I believe their interest stems from an emotional connection with their students, an element of personal validation for the teacher, and using the trophies as an easy way of gauging student progress.

In my discussion with the admin, I convinced him to use the percentage of facts that are fluent, rather than trophies, which don't map directly to fluency. His initial



My Class

Select a student: All Students | x Multiplication

ID	Today	Name	Fluency	Proving	Days Practiced	Trophies This Week	Operations Practiced	Time On Task	Total Time
dwjFW		Athena Spencer	45%	13%	S M T W Th F Sa	56	• • •	00:34:30	00:34:30
UtYYr		Rebecca Lee	32%	15%	S M T W Th F Sa	39	• • •	00:30:40	00:30:40
dwjFW		Celeste Lincoln	55%	12%	S M T W Th F Sa	51	• • •	00:35:00	00:36:40
dwjFW		Brooklyn Benjamin	15%	8%	S M T W Th F Sa	20	• •	00:21:40	00:28:20
dwjFW		Jocelyn Lincoln	73%	5%	S M T W Th F Sa	41	• • •	00:31:40	00:31:40
dwjFW		Mason Jar	10%	5%	S M T W Th F Sa	25	• •	00:23:20	00:25:00
dwjFW		Lily Gabriel	83%	4%	S M T W Th F Sa	43	• • •	00:36:40	00:38:20

Figure 7. Classroom summary

Fluency (percentage) was emphasized while still displaying the trophies earned this week. Time on task and total time help a teacher recognize when a student is getting distracted. Today's practice status is also available at a glance, preceding each student's name.

resistance was based on the fact that the trophy count was easy to see. Only when I reminded him that I wrote the app and could provide whatever feedback was useful did he change his mind. Shortly thereafter, I made the measurement of fluency for each student much more prominent in the teacher dashboard and de-emphasized trophies (see Figure 7). However, teachers still want to connect with the motivational metrics their students are seeing, and I expect this will not change.

Lesson #4: Finding the Middle Ground

When teachers requested the ability to assign math facts, the feature they imagined was in conflict with research on fact fluency. In order to satisfy their request while preserving good practice, Learning Objectives was implemented with two important aspects: 1) The feature is designed to provide the teachers with their underlying need (students learn a particular set of math facts), rather than the exact feature they described. 2) Just-in-time instruction and broader-view training help the teacher to understand why it works the way it does and how to use it most effectively.

Similarly, in the case of measuring student progress, the solution was to 1) educate users about the purpose of trophies vs. "fluency percentage" and 2) make it convenient for them to access the appropriate metric.

In each of these cases, it was possible to accommodate user's feature requests that threaten the theoretical grounding of the tool. The general solution was to approach the problem from two directions: identifying what they need to do and communicating what they need to understand.

Potential solutions for the problem of inconsistent practice fall into these categories, as well. They seek to accommodate the teachers' need to fit fact practice in at odd moments and will best succeed if teachers understand the research-based methods employed by the tool.

Lesson #5: Students in Classrooms Interact More with Peers and Less with Adults

As I described earlier, the distraction caused by fellow-students in Isabella's first-grade classroom had a negative effect that was significant enough to require modification to the software. However, not all interactions were negative. In the same class, I noticed that nearly every student announced when they had finished, and students around them sometimes responded by saying, "I'm almost done, too" or by making a show of working intensely. Among the fourth- and fifth- graders, students would show a badge they earned to each other. In classrooms, the students' interactions with each other influence how they approach a task.

In contrast, the classroom students' interaction with the teacher while using the app usually occurred when they told her they were finished, or when she noticed a particular student who didn't seem to be engaged. For the older classes, students do their fact practice at different times during the morning, and the teacher is not roaming the room looking for difficulties. To help teachers, who can't devote full attention to every child, it is important to have persistent information about each student's practice status and feedback that can help teachers identify students whose practice is unsuccessful or ineffective.

Lesson #6: Use the Right Amount of Text

The first implementation of Everybody Math was entirely text-based. It wasn't a design decision, just a practical reality. The focus was on implementing research-based methods for teaching math-fact fluency with a limited amount of time for development, and other considerations, including the appeal of the user interface, were mostly ignored. A graphical user interface was implemented gradually, with a goal of replacing all text with icons or other visual means of communicating information.

Visual depictions of fact fluency or progress through a practice session have been well received and greatly increased usability and user engagement. However, I found there were some things that users still wanted me to explain. A graphic generated for each round, illustrating the purpose and "win" conditions for the round, was a constant source of questions. Users didn't have enough understanding of how the app works to make sense of the information, so the graphic just gave them a sense that they didn't know what was going on. I replaced it with a help button that gives a text explanation of the current round for those who are interested.

In other cases, as already described, it was important to include text-based instructions to help teachers understand how a feature is intended to work and why (see Figure 6). Including this much text on a page would be frowned upon by most professional U/X designers, and it was a decision I struggled with for a long time. However, my efforts in this situation have led me to conclude that the degree to which controls can be intuitive is limited by the user's understanding of the tool. When the tool is educating the user, one impact on the design is the need for in-depth explanations, which require more text than is used in a traditional user interface.

Lesson #7: Watch people use your product in its intended environment

When I began beta-testing the software in Fiona's classroom, I was able to wander around the classroom, watching as the students opened the app for the first time. Within a minute, I had to stop them all to make an announcement, reminding them that their teacher wanted them to work on multiplication, not addition, the default option. Most of the students had seen the drop-down menu and made the correct choice, but four or five had started practicing addition. It was obvious that this needed to be part of the teacher's classroom setup options.

Later, I visited Isabella's first graders after she had been using the app for more than a month. Her reports were all very enthusiastic, and her requests minimal. I was looking forward to seeing the progress of her students and learning what adjustments could still be made by observing their practice and her interactions with them.

Some of the students had made significant progress, but I was dismayed to find that the distraction in the classroom was seriously hindering the progress of many of them, and that Isabella did not know how the app worked well enough to recognize the problem. Her class on the whole was doing better on math facts than any of her classes in prior years, so she was pleased and enthusiastic in her reports to me. Unfortunately, in that mode of communication, neither of us had enough information to realize that the major benefits of the software were not being realized for a significant portion of her students.

These incidents demonstrate an important lesson: always observe your product being used in its intended environment. I had spent over a hundred hours observing students using the app individually and responded to student and parent feedback for several years, but the classroom environment provided new challenges that I only discovered by observing them in person. The first-grade classroom, in particular, provided challenges different from the fourth grade.

DESIGNER REFLECTIONS

As I began this project, I had confidence in the existing student app, and my intent was to create a teacher dashboard as an add-on. As I commenced, I discovered that for the tool to be useful to classroom teachers, an add-on was insufficient. The data and features that teachers want required major modifications to the original app.

In addition, the classroom setting itself required accommodations to allow teachers to manage students as they practice and accommodations for students who have difficulty focusing in a distracting environment.

More importantly, the nature of the app is to implement research-based methods that are unfamiliar to the users of the new dashboard (teachers); this creates a context in which the primary goals of the user experience design include educating the teachers and maintaining best practices when the tool is used in non-ideal ways.

For instructional designers who plan to develop a software tool for use in classrooms, it will be helpful to analyze the needs of teachers separately from the needs of students. Here are some questions to consider before beginning the design of the teacher's user experience:

- What are the possible use-cases for the teacher? (examples: monitored in-class use, unmonitored in-class use, assigned homework)
- What does the teacher believe about underlying principles that govern the use of the tool? (examples: when students should use the tool, how long they should spend; efficacy of the tool; importance of the tool's impact)
- What does the teacher need to learn in order to use the tool correctly in each use case?
- What are effective ways of educating the teacher about proper use of the tool in each case where underlying beliefs conflict with best practice? (example: just-in-time information in the user interface, pop-ups to explain possible mistakes, general information videos)
- How will the teacher connect with the students' experience? (example: details of badges earned by each student)
- What data will be shown to the teacher, and what are the formats in which it will be useful for each use-case? (examples: time on task, success rate, total mastery of content)
- How can the tool be designed to balance or preserve best practices when used in non-ideal ways?

When designing the student's user experience for a tool to be used in a classroom context (in class or assigned by the teacher to use at home) consider these questions:

- What are the use-cases for the student?
- What information does the student need in each use-case?
- How/when will the information be communicated to the student?
- What barriers will the student face in each use-case?
- What user-interface design elements can help students overcome barriers?
- What user-interface elements will make the student feel comfortable using the app?
- How will students interact with peers or mentors in each use case?
- How can the tool facilitate positive interactions and reduce negative interactions?

User interface design has trended toward using less text over time, and a clean, simple look with visual signifiers is generally to be preferred. However, I found over multiple iterations of both the student tool and the teacher dashboard that elimination of text is not universally desirable. Visual signifiers are most useful when the affordances are already well-understood. Especially in cases where a tool is implementing functionality that is unexpected or misunderstood, I recommend asking:

- Does the user understand how and when the feature should be used?
- Does the best use conflict with the user's prior understanding or expectation?
- Does the actual function align completely with the user's expectation?
- Is there a visual signifier that is familiar to the user for this function or something similar? If not, is there a simple signifier that could be used?
- How much explanation is necessary to accompany the visual signifier?

Finally, it is worth repeating that observing the tool in use by real users in its intended context is the best way to discover the mistakes that you will undoubtedly make during design, regardless of how thoroughly you researched the context beforehand.

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