

# The Duolingo Method for App-based Teaching and Learning



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Cassie Freeman\*, Audrey Kittredge\*, Hope Wilson\*, and Bozena Pajak\*

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## 1 About Duolingo

Duolingo was built with a singular goal: to bring high-quality education to everyone on the planet by harnessing the power of technology. Our free, bite-sized lessons feel more like a game than a textbook, and that’s by design: Learning is easier when you’re having fun.

Duolingo is both playful and built on serious learning science. Our teaching methods are grounded in learning science research and our curricula are informed by national and international standards. Below, we describe in more detail the Duolingo Method for app-based teaching and learning that we have developed, tested, and improved over the years.

## 2 Intro to the Duolingo Method for App-based Teaching and Learning

The Duolingo Method consists of five pillars, illustrated below. In the sections that follow, we describe each pillar together with the learning science that supports it. The

Duolingo Method was developed by our learning scientists, educational content developers, and curriculum designers, collaborating with designers, creative producers and product leaders. Together, we use our knowledge of cognition, learning, and pedagogy along with subject matter expertise (in language, literacy, or math education) to craft experiences and features that we then rigorously test. We have a recursive process of development and improvement. We stay up-to-date on the latest research and use that research along with our own internal learning science studies to inform feature and content development. Then, we use our internal experiments service to run hundreds of experiments, or A/B tests, each week, measuring even the smallest adjustments to our products to ensure they improve the learning experience. This allows us to be confident in our product decisions.

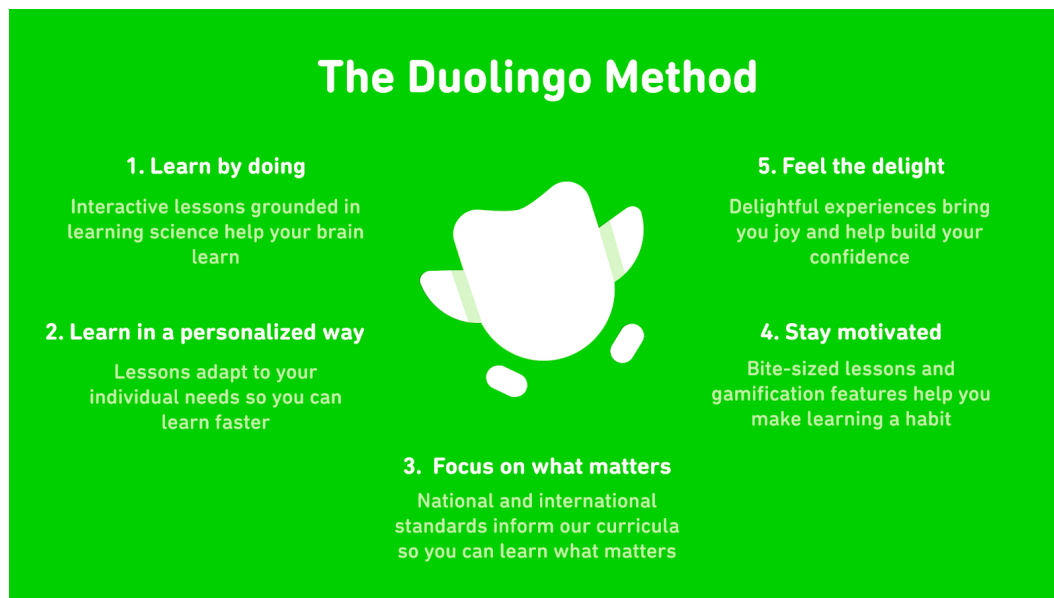
In addition to our A/B tests and internal learning science studies, we also conduct research studies on the overall efficacy of our products, and we fund external research on product efficacy with researchers across the globe. These studies use established independent tests and measures to assess the learning value of our apps, ensuring that we are helping learners achieve their goals.

The Duolingo Method is central to our development and testing across all our products. We illustrate the details of the method by highlighting examples from the Duolingo Language app, Literacy app, and Math app throughout this document.

The Duolingo Language app is the most popular language-learning platform and the most downloaded education app worldwide. The app makes learning new languages fun and motivating with bite-sized lessons that feel like playing a game.

\*Duolingo, Inc.

**Corresponding author:**  
Cassie Freeman  
Duolingo, Inc. 5900 Penn Ave  
Pittsburgh, PA 15206, USA  
Email: [cassie@duolingo.com](mailto:cassie@duolingo.com)



The course curricula are informed by international language teaching standards and are designed to prepare learners for real-world communication. The app includes a large variety of activities to comprehensively teach vocabulary, grammar, pronunciation and spelling conventions (including additional instruction for languages with a different writing system), as well as provide practice with the key integrated skills: reading, listening, writing, and speaking. Duolingo offers over 100 total courses across more than 40 distinct languages, from Spanish, French, German, and Japanese to Navajo and Yiddish.

The Duolingo Literacy app is designed to provide an engaging and educational early literacy curriculum to young readers. The app targets key components of reading identified by the National Reading Panel et al. (2000), including 1) alphabets, 2) phonological awareness, 3) phonics and decoding, 4) fluency, 5) vocabulary, and 6) comprehension.

The Duolingo Math app is designed to make math fun for all ages. With fast-paced, bite-sized lessons, this app teaches elementary math and brain training content, from multiplication and division to fractions and decimals as well as geometry and measurement. The Math app offers a gamified experience with delightful sound effects and animations. Interactive tools like clocks and rulers help learners of all ages enjoy math.

Now, let's turn to the five pillars of the Duolingo Method.

## 2.1 Learn by Doing

Across Duolingo products, learners interact with rich, captivating educational content from the very first time they open the app. Our interactive lessons are designed to draw attention to exactly what learners need to notice about a concept without the need to rely on explicit introductory overviews. Then, careful repetition of content with the right amount of variation enables learners to gradually pick up patterns — patterns in everything from letter sounds to verb use to shape categories — even if they don't realize it. This type of learning over time is essential for learners to internalize new material so they can use what they learn in new contexts in the app and in the real world. When our learners need more support to understand the exercises they're working through, we provide them with easy-to-understand, plain-language explanations.

### The science:

Our approach to helping learners learn by doing is grounded in the science of attention, reasoning, memory, and interactivity. For our approach to work, we craft educational experiences that leverage just how people's brains function. People possess a wide array of cognitive tools related to memory, reasoning, and attentional capacity that help them learn. These tools develop throughout childhood and help people process large amounts

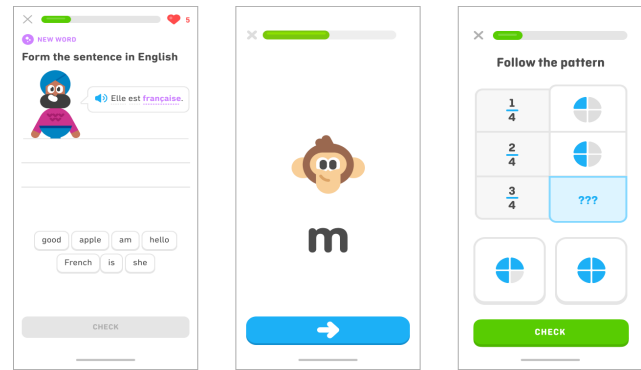
of information, notice similarities and differences, and integrate physical experiences with abstract concepts.

One specific cognitive tool that drives learning across the lifespan, starting during early fetal development, is implicit statistical learning (Conway, 2020; Frost et al., 2019; Krueger & Garvan, 2014; Rebuschat & Monaghan, 2019; Saffran et al., 1996). This is a basic function of human cognition by which the brain is able to observe the frequency of events in its environment, make hypotheses about the patterns behind these events, and then use these hypotheses to make predictions about future events, all without conscious awareness. Ultimately, statistical learning lets people learn the rules that govern things like language and math; a learner's brain makes an unconscious hypothesis about a word, a shape, or a rule, and then, when that hypothesis is upheld through further evidence, it is incorporated into the learner's knowledge of the world.

All Duolingo products have been created to take advantage of, and enhance, people's natural ability to pick up on regularities. Each lesson is designed to focus on a small number of distinct learning objectives, which are taught through carefully constructed content (e.g., multiple exercises highlighting the same grammatical structure, such as negation in English: "I speak English, but I don't speak Italian", "I don't study Spanish; I study French"). After the initial introductory exercises, learners are exposed to additional strategically chosen examples that further guide them toward the relevant pattern by leveraging their unconscious statistical learning processes. Even in instances where learners aren't provided with explicit information about the concepts they are learning, they are expected to draw connections for themselves as they move to more and more complex topics. This pedagogical approach was inspired by the key learning processes at play in early infancy, and has been shown to be effective for different age groups and across many contexts, including second language learning, probability, and literacy (Dienes & Berry, 1997; Frost et al., 2013).

To ensure a smooth introduction to any new concept, lessons draw on learners' prior knowledge to give them a foothold into comprehension. In the Language app, a new grammar pattern might be introduced by using sentences that — except for the new pattern — are similar to ones from the learner's first language. In the Literacy app, a new letter-sound pairing is presented with a familiar object whose name starts with the letter. In the Math app, a new mathematical principle is introduced using a pattern exercise to help familiarize learners with representations of numbers and shapes.

In addition to leveraging learners' implicit statistical learning abilities, we carefully craft exercises that support learners using their analogical reasoning abilities. In the Language app, for instance, we use analogy and contrast across exercises to expose learners to examples of given patterns. For example, when first introducing grammatical gender in Spanish, we construct



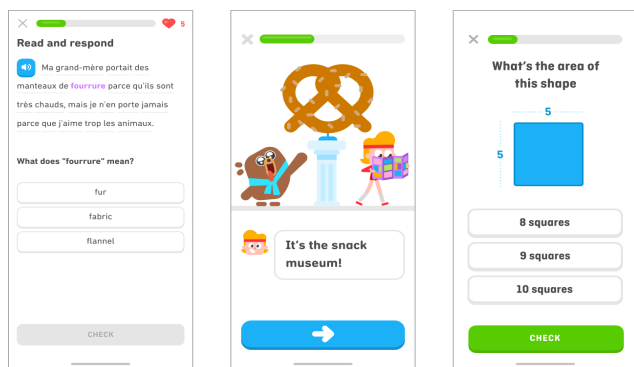
sets of sentences that illustrate the pattern of adjective endings (-o vs -a) as associated with either masculine or feminine gender (like Tom es americano; Anna es americana; Jorge es mexicano; María es mexicana). The systematic variation in adjective endings (-o with masculine names and -a with feminine names) and the analogy between different sets of adjectives (i.e., the same -o vs -a pattern) draw learners' attention and, over many examples, facilitate noticing the underlying patterns (Ellis, 2005). In this way, our learners use basic cognitive mechanisms — analogical skills and statistical learning processes — to learn how words change form and how they combine with other words to make meaningful sentences (Behrens, 2017). Learning through analogy is especially useful in supporting transfer to new contexts (e.g., Gentner & Smith, 2013; Sidney, 2020), so learners can take their knowledge out of the app and into the world.

We use similar techniques to teach spelling patterns in the Literacy app. In the Math app, we spatially align concepts to be compared so learners draw connections between similar elements and notice where they are different. For instance, in the "follow the pattern" exercise above, learners may feel like they are just following a pattern on the right, but they actually can't follow it without also integrating information from the left.

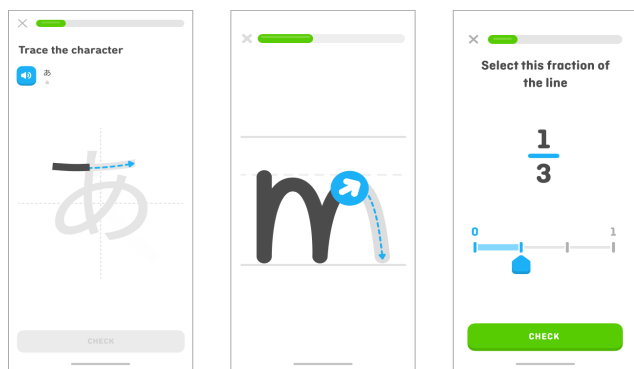
As learners progress through a course, Duolingo challenges them to engage with progressively more complex topics. Using analogy and contrast, we ask learners to make finer discriminations between answer choices (e.g. in the Language app, moving from what a verb means to making judgements about verb endings based on the context and position in a sentence). This approach allows learners to build out their understanding of concepts piece by piece.

To further support implicit statistical learning and learning through analogy, we direct learners' attention to the most relevant parts of the screen. We use affordance-based design so learners know where to look as well as how to interact with the screen (Andersen et al., 2021; Maier & Fadel, 2009). For instance, we use text color to draw attention to key aspects of a sentence, math problem, or written words as they are narrated in a story. Helping learners see what they need to pay attention

to through this type of signaling is an effective strategy across learning domains (Alpizar et al., 2020; Mayer & Fiorella, 2014; Noetel et al., 2022).



Finally, we use high levels of interactivity, taking advantage of embodied cognition. Embodied cognition occurs when our perceptions and physical interactions with the world are integrated with how we represent abstract ideas (e.g., Tran et al., 2017). For instance, we get a sense of how big something is based on how long it takes to travel across it. To help learners use embodied cognition, we have them touch the screen and physically manipulate components to create an answer. This type of active learning, when learners make decisions about incoming information rather than passively absorbing it, leads to better learning outcomes (Zosh et al., 2018). In the Language and Literacy apps, learners trace characters or letters to associate the written form and sound, and in the Math app learners must physically slide their finger across a fraction number line to get an answer, all while receiving haptic feedback at fractional intervals on the number line. In the Language app, we have learners speak along with text so they practice producing language in a conversational context, further bringing these ideas into the real world. Across learner ages and types of content, we use this interactive approach to learning, where individuals must engage with the concepts through their actions, to drive better outcomes (Hirsh-Pasek et al., 2015).



While Duolingo methodology focuses on supporting learners in implicit statistical learning, we also leverage explicit instruction when it can further enhance learning. This is especially helpful for concepts or rules that are complex or nuanced, and yet can be articulated relatively easily in an explicit way (e.g. when there are multiple levels of formality in a language or when learning a formula in math). In the Language app, for example, we might provide an explicit tip about how Spanish has two words for “you,” the informal “tú” used with friends and in other informal contexts, and the formal “usted” used in contexts that require a higher level of politeness. Particularly in the case of grammatical rules, explicit instruction can be helpful for adults learning a new language (Goo et al., 2015). Explicit instruction doesn’t replace the need for learners to engage with the material in a more implicit way over a long period of time, but it can help set learners on the right path and make learning more efficient.

To summarize, with the Duolingo Method, learning by doing helps learners use the cognitive toolkit they already have, attend to the important aspects of concepts, and interact with these concepts in carefully scaffolded sequences so they continuously deepen their understanding in an active way.

## 2.2 Learn in a Personalized Way

Duolingo meets learners where they are and leverages their own responses and in-app behaviors to help them improve. From providing more practice where learners need it, to adjusting exercise order and difficulty, to providing feedback based on learner responses, we personalize the learning environment to boost learners’ growth and long-term knowledge. We know that giving learners just the right level of difficulty leads to greater engagement and more learning.

To accomplish this, we built our own machine learning models. There are many machine learning models in the world, but for the specific language, literacy, and math-related problems we were looking to solve, we had to build our own. Known internally as Birdbrain, this system uses data from the more than 1 billion exercises completed daily on Duolingo to learn both how proficient our learners are and how difficult the content is for each of them. This is the secret sauce behind our personalized daily lessons: Birdbrain helps pick and sort exercises for each learner and then generates dynamic lessons based on the learner’s particular progress and learning needs. At the time of writing, Birdbrain is the largest-scale student model used in all of language learning technology.

### The science:

We know that each learner is unique, which is why we’ve developed personalization techniques that leverage learning science principles and adjust to every individual’s needs. Using Birdbrain, the difficulty level of our lessons is tailored for each individual learner to help them improve where they need it most.

Targeting a learner's zone of proximal development, Duolingo provides them with content that is just difficult enough to be challenging, but not so challenging that they cannot achieve it with a little scaffolding (Plass et al., 2015). For example, adaptive exercise sequencing responds to how well a learner is doing: if a learner is performing well in a lesson, our algorithm selects slightly more challenging exercises. If they make a mistake, they receive a hint, and an exercise targeting the same concept is resurfaced at the very end of the lesson so they can answer it accurately, improving their likelihood to remember the correct idea.

Duolingo also makes use of the concept of “desirable difficulty,” where learners see difficult exercises that appear just outside their reach; this learning strategy enhances learners' ability to remember the content longer term and retrieve it when needed (Bjork & Bjork, 2011). Typically, these more difficult exercises occur at the end of a lesson and, if a learner consistently gets them incorrect, the difficulty level of the exercises is decreased. Importantly, Duolingo avoids “undesirable difficulty” like making fonts difficult to read or providing tricky instructions that make learning harder (Gaspelin et al., 2013).

We know that people remember and forget at different rates, which depend on individual differences and the varying content they are trying to learn. In addition to providing learners with the right level of difficulty to keep them moving forward, we also resurface content learners have already seen when we think it's most beneficial to review: during personalized practice sessions through Birdbrain's dynamic lesson generation, utilizing the powerful learning concept of spaced repetition. At Duolingo, spaced repetition means learners revisit new content frequently after they've first learned it, but later on they revisit that content less frequently, as long as they're consistently showing they know it. Spaced repetition has shown benefits across the lifespan and over many different content areas including learning words, grammar, and mathematics (Carpenter et al., 2022), and it is beneficial for long-term retention of what's been learned (Kelley & Watson, 2013; Latimier et al., 2021). By using Birdbrain to model learner knowledge, Duolingo is able to optimize what learners need to review and when they should do it, personalizing their learning and review experience, which has shown even greater effects on retaining learning than a non-personalized review schedule (Lindsey et al., 2014).

To summarize, across apps, Duolingo varies the types of exercises and content learners encounter at the time that's best for them, supporting long term remembering and transfer to new contexts. By using Birdbrain, we have learners work on the content that they need most, personalizing their practice to make learning long-lasting.

## 2.3 Focus on What Matters

It is not enough just to teach well: we also need to teach what our learners need to know. Our curriculum is informed by national and international standards to provide comprehensive coverage of what's considered important for each field of knowledge. We draw on documented standards to design our courses: for language, we use the Common European Framework of Reference (CEFR); for reading and math, we rely on the Common Core State Standards.

We use these standards to ensure that we're covering all that learners need to know and so that we take learners from beginner to more advanced levels in a sequence consistent with other educational experiences. And, since we know that standards may not address everything our learners need to know, we leverage the knowledge of our learning experts to create a well-rounded curriculum.

### The science:

Building our courses to standards serves our learners in three primary ways.

First, standards such as the CEFR and the Common Core State Standards have been based upon rigorous evaluations of learning and have been developed by leaders in their respective fields. These standards lay out what should be taught — ensuring that learners encounter everything they need to know to hit particular skill levels — and when this content should be taught — ensuring that complex topics aren't presented before the learners have a strong enough basis of knowledge to understand them. As such, a course that follows the recommendations of an established set of standards will be teaching content that is demonstrably useful to learners.

Second, standards allow learners to generalize and transfer their knowledge. Because both our math app and a classroom curriculum are informed by the Common Core State Standards, the knowledge gained in one medium can be more easily used in the other. By teaching to a standard, we make it easier for learners to utilize what they've learned on Duolingo in other learning environments, and we make it easier for them to use their existing knowledge on Duolingo.

Finally, standards give learners a way to conceptualize and talk about their knowledge. By having content benchmarked to particular standards, we help learners understand how much they've learned. And the standards can serve as a reference point for them to tell others about the progress they've made, as well as assisting administrators auditing the quality of instructional materials in supporting learner progress.

At the same time, although standards are useful in many ways, they are not always exhaustive. The CEFR, for example, specifies the competencies that language users should have at various levels of proficiency. However, it does not provide



comprehensive lists of words and grammar that need to be known at each proficiency level for each language. Moreover, there are some skills — such as those around digital literacy and vocabulary — which evolve quickly and need frequent reassessment. As such, Duolingo’s learning experts take existing standards and, as needed, update or elaborate on them to ensure that we’re teaching in a way that aligns both to standards and to what our learners need.

## 2.4 Stay Motivated

The hardest part about learning — especially when learning something complex — is staying with it. The brain is built to learn, but it is also built to seek out things that are exciting and novel and interesting. Often, the brain will not perceive the hard work of learning new words or shapes or letters as sufficiently rewarding, and so a learner’s attention will wander. And then learning stops happening.

Duolingo keeps the brain engaged. Through techniques of gamification, we ensure that learners keep coming back to the app and spend enough time with our learning material that they are able to successfully absorb new knowledge from it. Where the brain’s instinct is often to give up when learning gets difficult, we design our apps to use delight and enticing features so that learners can overcome their frustration and inertia, and keep learning.

### The science:

Engagement is one of the key factors that lead to skill development. The more learners interact with content, the more opportunities they have to learn. Yet one of the difficulties of self-regulated learning, such as learning online, is that some learners will often drop out of learning experiences. Expectancy value theory suggests that learners decide whether or not to do something based on how likely it is they think they will be successful in achieving their goal and how much they value the goal (Wigfield & Eccles, 2000). To help learners stay on track, our apps integrate insights from prior work done in the tech and gaming industries, as well as from scientific research into behavioral psychology and our own experimentation.

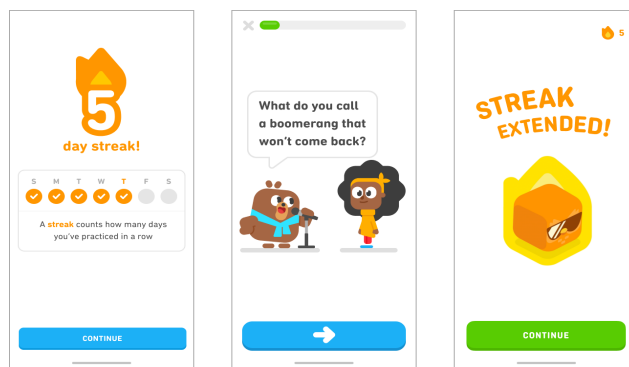
We use a number of different tools to ensure that learners stay engaged. One such tool is “bite-sized” lessons. We split all the material into manageable chunks in order to decrease perceived effort, and make it easier for learners to stay motivated and do one more lesson. On average, a lesson takes no more than a few minutes, which means that completing multiple lessons in a row is easily achievable and gives learners a higher sense of accomplishment.

In addition to decreasing the perceived effort to do a lesson, Duolingo helps learners see how successful they are by providing immediate feedback, celebrating correct answers, and showing progress on a learning path. Positive reinforcement

comes at key intervals as learners engage with the material. Each lesson consists of multiple exercises, with a reward — a pleasant sound and a brief celebratory animation from our world characters — coming after each completed exercise. Then, after a session is finished, the learner receives a larger dose of positive reinforcement in the form of rewards such as unlocked material, XP, or in-game currency. By providing frequent rewards, we keep the brain engaged with the material — and the more time spent on task, the more learning happens.

Another tool we use to ensure that learners stay engaged is a reward for daily app use. In the Language and Math apps, we give learners a “streak” to support learners in coming back each day to learn, providing a daily reward which people find inherently valuable (Silverman & Barasch, 2022). A learner’s streak indicates how long they have been actively and continuously learning with Duolingo. Every day that a learner does a session with Duolingo, their streak is extended, and when a learner hits particular streak milestones they earn special rewards. Research has shown that streaks are highly motivating and when people are made aware of how long their streak is, they have even more desire to keep it going (Silverman & Barasch, 2022).

The Language and Math app streaks are highly motivating, and a badge of pride for many learners, who have the ability to share their progress with others over social media. To help learners maintain their streaks, Duolingo also employs notifications, which have been shown to motivate action through salience and urgency, making practice feel noteworthy and important (Bartoli & Benedetto, 2022). For our youngest learners, in lieu of a formal streak the Literacy app provides a daily joke they can react to with an emoji to get them excited about building a habit of reading.



For learners more motivated by competition and goal-setting, our Language app features leaderboards, in which learners are able to see how much their friends — or strangers — have been learning and use that to motivate themselves. In studies of gamified learning, leaderboards have been shown to be more effective motivators than learners’ goals of simply doing their best (Landers et al., 2017). Duolingo uses leaderboards to

provide the extra motivation learners need to push themselves to learn more. Collaborative social mechanics also help learners stay accountable to their goals. Friends can celebrate each other's milestones, achieve joint goals together, and send words of encouragement or gifts, which support both learning and motivation (L. Zheng et al., 2019).

Finally, we also keep learners motivated through the sheer joy of exploration. As learners' skills grow, so too do the features available to them. The learners' journey is externalized in what they see on the screen before them. And so everyone — children and adults — can take satisfaction from seeing their measurable progress as they move through Duolingo's learning products.

## 2.5 Feel the Delight

We seek to make learning a fun activity that can feel truly rewarding, and to make our environment and experience feel every bit as entertaining as the very best TV shows or games. We're very aware of the fact that people have a lot of distractions online and on their devices — they can read the news, play games, browse social media, and watch videos. So we aim to make our app as fun and rewarding as any of those other activities, through actual quality storytelling, humor, emotional moments, and enjoyable activity — all while also giving learners a sense of accomplishment as they complete increasingly challenging tasks. We create a delightful “world” using diverse characters, humor, and fun animations; a world that's a perfect environment for learning, a pleasant space where learners can feel comfortable and vulnerable, where they don't feel embarrassed, and where they can build up their confidence.

### The science:

Duolingo leverages the emotional design principle which states that people learn better when the design of a learning experience induces an emotional state conducive to learning (e.g., curiosity, confidence, low anxiety, etc.) without increasing the need to process irrelevant information (Plass & Hovey, 2021). Joyful experiences, which often involve positive emotions, are linked to increased learning (Zosh et al., 2018), and a metaanalysis of emotions in technology-based learning demonstrated a small, positive correlation between enjoyment and learning outcomes (Loderer et al., 2020).

Duolingo uses cheerful characters from a variety of backgrounds to provide brief supportive messages while learners are doing exercises and at key moments to keep them engaged. More than just happy faces, each character has their own personality and backstory (aspects of which are revealed in short messages and longer-form stories), making them more interesting and meaningful to learners.

It's tough to learn when you're worried about how well you'll do. For some language learners, the idea of speaking in a language they are learning can be intimidating. For some math

learners, seeing numbers can set off alarm bells, making it hard to concentrate and leading to math avoidance. Anxiety can prevent learners from focusing on what they need to learn and holding it in their minds long enough to use it (Moran, 2016). Anxiety in second language learning and mathematics have been long-standing concerns (Ashcraft & Krause, 2007; Teimouri et al., 2019). Duolingo supports learners who may have anxiety by starting everyone out with receptive exercises with tappable hints so they can choose their level of scaffolding. Moreover, having learners do many exercises that teach the same bite-sized concepts may also help decrease anxiety through desensitization (Ramirez et al., 2018). In order to help learners feel comfortable trying new and possibly difficult things, Duolingo uses effort-based praise and encouragement, which has been shown to increase perseverance (Dweck, 2007), along with humorous images to keep the messages memorable.

Duolingo uses approaches to decrease learners' anxiety, and also uses science to increase learners' confidence. Across Duolingo apps, learners receive feedback on their answers along with supportive messaging. Feedback is helpful in remediating errors generally, and researchers have found that when learners received feedback on their answers for which they had low confidence, they were more likely to retain correct ideas (Butler et al., 2008). Along with feedback, the Language app gives learners ample opportunity to practice speaking and listening in low-stakes ways so they develop greater confidence in these communicative skills.

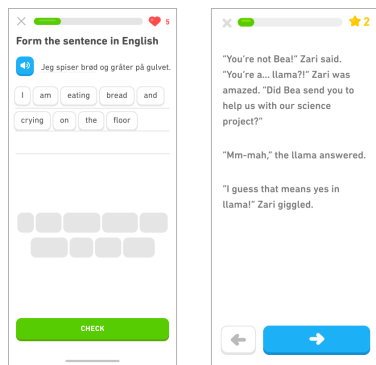
In addition to supporting learners through decreasing anxiety and building confidence, Duolingo uses other modifications to the learning environment to help learners be pleasantly engaged, without distracting from the learning experience. Duolingo uses a clean, beautiful design with visually pleasing fonts and colors, integrated with easy to understand affordances, so learners know how they can manipulate items on their screen.

Beyond what the learner can touch, Duolingo makes use of haptics, vibrations on mobile devices which draw learners attention by providing them tactile feedback. Haptics, when in small bursts and low amplitudes, have been shown to be pleasant to learners (Salminen et al., 2009).

Finally, Duolingo uses humor to delight and engage learners. From memorable sentences with absurdist humor and exaggeration to stories with funny plot twists, Duolingo's language content is entertaining and shareable. Duolingo's silly sentences use the idea of grammatical anchors to provide learners with examples of grammatical concepts (such as verb conjugation or word order) using sentences that are memorable (Endress et al., 2009).

In the Literacy app, stories employ humor through narrative twists and learners can get a daily joke. Humor engages the brain's reward system and increases the likelihood content will

be remembered and retrieved later, keeping learners engaged and coming back to learn (Mobbs et al., 2003; Schmidt, 1994).



The Duolingo Method for app-based instruction is built on learning science research and years of testing. But we haven't won yet! With A/B testing, in-house research, and independent efficacy studies, along with our own pedagogical expertise, we are constantly iterating to make the best experience for all learners.

### 3 Closer Look at Language, Literacy, and Math Apps

The five pillars of the Duolingo Method inform the way we develop all our apps, from our flagship Language app to our brand new Math app! The following sections take a deeper dive into how our method is used in these apps and how domain-specific research informs what we do to help learners succeed in language, literacy, and math learning.

#### 3.1 The Language App

Bilingualism or multilingualism offer many advantages. Knowledge of multiple languages, especially knowledge of English, has been linked to increased social and economic opportunity, including greater employability and greater mobility (Coleman, 2011; Gándara, 2018). What's more, there are also personal benefits to knowing languages, including increased intercultural competence (Liddicoat & Scarino, 2013), enhanced creativity (Dijk et al., 2019), and potential protection against the cognitive effects of aging (Bialystok, 2021).

Yet language learning is not equally available to everyone. Many mechanisms by which language might be acquired, such as language classes or travel abroad, are expensive, often prohibitively so. And for people who work full-time or have other obligations, it can be hard to find time to take formal language classes.

The Duolingo Language app is designed to provide free, universally available, and high-quality language education to

any and all who want it, whenever they want it. This section describes the science behind the Duolingo Language app and how we ensure it delivers results for all our learners.

Language learning involves building an incredibly complex set of skills, and not all of these skills develop at the same rate. For example, a person might be able to read a language without necessarily being able to speak it with great proficiency, or they might know a great deal of vocabulary but struggle to apply grammar rules consistently. Because of this, the Duolingo Language app does not rely on a single type of content, nor does it present that content in a single way; instead, the Language app strategically surfaces different learning experiences at different times so that learners can build a diverse repertoire of language skills.

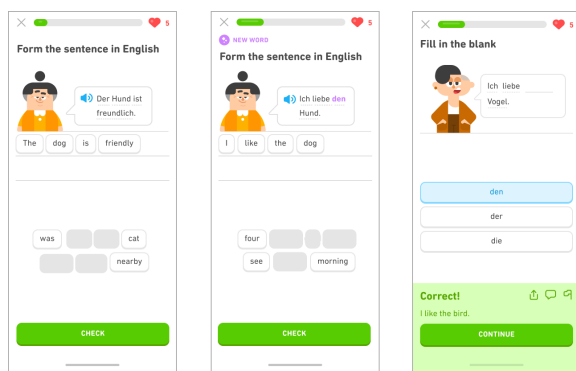
Below, we outline how the five pillars of the Duolingo Method — Learn by doing, Learn in a personalized way, Stay motivated, Focus on what matters, and Feel the delight — help lead learners through the difficult task of learning a language.

#### Learn by Doing

Our goal at Duolingo is to prepare our learners for real-world communication. We want them to be able to accomplish their goals using their target language. Consequently, we employ a learning-by-doing teaching methodology, focusing on maximizing how much people learn implicitly via interactive exercises. Because skills that have been learned implicitly are more automatic than skills learned explicitly (French & Cleeremans, 2015; Williams, 2009), an implicit approach is extremely important for building language knowledge. And, indeed, when a learner begins a session in Duolingo, they are not presented with a lecture or an explicit explanation; instead, they immediately jump into completing language exercises, such as identifying a new word from a picture or transcribing language from an audio file. These exercises are carefully designed and curated to leverage learners' capacity for implicit statistical learning (Erickson & Thiessen, 2015; Frost et al., 2019) so that they're able to discover the languages' underlying patterns.

For example, a curriculum creator might utilize the principles of analogy and contrast to highlight a new grammatical form, ensuring that the learner notices — maybe consciously, maybe unconsciously — the rules dictating that specific form. From here, the learner can form (conscious or unconscious) predictions about the language they're learning; instantaneous feedback then either confirms or denies these predictions, solidifying their knowledge (Dale & Christiansen, 2004). While the focus is on an implicit approach, explicit instruction is also used in cases when it can further enhance learning (e.g., to explain complex topics that are possible to articulate in a concise and straightforward way, such as formality distinctions in a language).

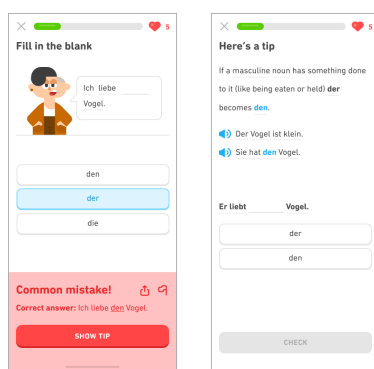




### Learn in a Personalized Way

Learners come to a new language with a variety of prior experiences. Some learners might have previously studied the language they're learning, while others may speak a similar language already or have extensive language-learning experience; this gives these learners a pre-existing bank of knowledge to draw upon that affects how quickly they learn (Hirosh & Degani, 2018). And individual differences, such as language-learning aptitude and self-regulation, can strongly influence learners' performance (Dörnyei, 2010).

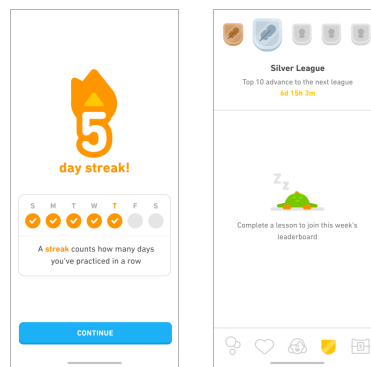
The Duolingo Language app supports each learner by tailoring the difficulty of the curriculum they're engaging with to the individual learner. AI-powered personalization adjusts the difficulty level so that learners can keep receiving language input that remains comprehensible and manageable. Additional personalized feedback is provided in the form of explicit tips in plain language when learners make grammatical errors.



### Stay Motivated

Because language is such a complex skill, it is vital that language learners stay engaged and motivated. Motivation has been consistently demonstrated to be one of the most important predictors of language-learning success (Dörnyei, 1998). Yet it often takes multiple years to learn a language to a high level of proficiency, and maintaining motivation for that length of time can be difficult even for highly engaged learners. Both intrinsic motivation — a type of motivation that originates with

the learner, in which they push themselves to learn — and extrinsic motivation — which comes from a source other than the learner, such as rewards and praise — have been shown to be linked to improved performance for learners (Ng & Ng, 2015).

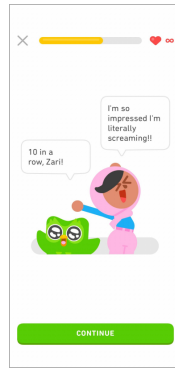


Duolingo helps build both types of motivation for our learners. Extrinsic motivation comes through gamification features: The Language app uses streaks and notifications to keep learners coming back each day, as well as features like leaderboards to increase the amount of time that learners spend learning. Meanwhile, we also make spaces for learners to build their intrinsic motivation by inviting them to set their own goals and by constructing delightful content that piques their interest and helps them find their desire to learn.

### Focus on What Matters

Most learners who are studying a language want to learn how to communicate, and so Duolingo language courses are designed to teach real-world communication. Each unit of a course has a particular, real-world communicative goal. As a learner progresses through these units, they encounter language typical of a wide variety of scenarios; in any given unit, they might learn how to chat with friends about movies, how to request help with a computer, how to discuss literature and history, or any number of other concrete topics.

By building curricula grounded in real-world language and scenarios, we ensure that learners are prepared to do things with the language they learn. And to ensure that we're taking our learners through the right communicative scenarios, we align our curricula to the Common European Framework of Reference for Languages [CEFR; (Europe, 2020), a set of standards that describe what a language user should be able to do at various levels of ability. Although there are several standards that might be used to describe language ability, we utilize the CEFR in particular because of its international recognition and its grounding in communication.



### Feel the Delight

Numerous studies have shown that not only is anxiety extremely common amongst language learners, experiencing anxiety while learning language can create an “affective filter” that leads to lower achievement (Krashen, 1982; Y. Zheng, 2008). Duolingo mitigates the negative effects of anxiety by introducing a warm, inviting world of low social pressure and low judgment. Animations featured throughout the app are cute and quirky. Stories feature a cast of characters who are able to laugh at themselves. And we ensure that our content is funny and lighthearted through things like “silly sentences” so that our learners see language learning as something fun, instead of something anxiety-inducing. Our lighthearted and nonjudgmental approach creates a welcoming learning space even for those who have struggled with their fear of learning a new language in the past.

## 3.2 The Literacy App

Reading ability is strongly linked to academic success: In the US, children who are not proficient readers at the end of third grade are unlikely to graduate from high school (Fiestier, 2010). Yet 60% of children globally are not learning to read at a basic level (UNESCO, 2017), and recent disrupted learning environments worldwide caused a decline in reading achievement (UNESCO et al., 2021). The goal of the Literacy app is to reduce global illiteracy by introducing new readers to the magic of reading: unlocking and discovering the meaning of written language.

To help children learn to read and love doing it, the Literacy app engages them in bite-sized lessons and story-based activities, all grounded in scientific research. This section explains the science behind the Literacy app’s teaching approach. First, we explain how the Literacy app implements the five pillars of the Duolingo Method, and then we go into more detail on how we use this method to teach foundational skills for reading.

### Learn by Doing

In the Literacy app, we harness the power of implicit statistical learning to teach literacy concepts, and we do this in a way

that draws on children’s prior knowledge. For instance, we first present the letter-sound pairing together with a familiar object whose name starts with the letter, and then we expose children to the letter-sound pairings many times to strengthen this knowledge. We also use analogy and contrast across exercises to teach learners spelling patterns. For instance, we show learners three words (not, lot, note) and ask them to identify two that rhyme, which highlights the difference between the “O” and “O\_E” spelling patterns. To further support implicit statistical learning and learning through analogy, we use on-screen graphics to direct learners’ attention to relevant information, such as highlighting written words as they are narrated in a story. Importantly, we also leverage explicit instruction at key moments, which is critical for literacy learning. For instance, we present very brief introductions to new concepts, such as stating the sound a letter makes (e.g. “M says mmm”). Throughout the entire Literacy app, we adopt a “minds-on” approach to learning (Hirsh-Pasek et al., 2015): Each exercise involves a single small task with instructions spoken aloud to mentally engage children and ask them to take action instead of passively observing. Since physical manipulation of objects can also help children learn (Callaghan & Reich, 2018), we include visual and kinesthetic activities as we introduce each letter, such as letter-tracing, that reinforce letter shape recognition and help children learn handwriting skills (Santangelo & Graham, 2016).

### Learn in a Personalized Way

The Literacy app personalizes children’s learning experience in several ways. At the beginning of the curriculum, children write their own name, and the relevance of this meaningful activity to their everyday lives supports children’s learning of letters (Zosh et al., 2018). Children also receive personalized feedback on their responses to all activities in the app: sound effects, color cues, and movement all signal right or wrong answers (Callaghan & Reich, 2018). When relevant, we also provide hints to help children improve, such as highlighting the initial letters in a text where a child is looking for words that start with a target letter. Adults can further personalize children’s learning by selecting one of many levels in the app for children to start with. Following recommendations for gamified learning (Callaghan & Reich, 2018; Yee, 2013), the levels gradually scaffold learners to more difficult content as they progress through the curriculum.

### Focus on What Matters

The Literacy app’s curriculum is based on the foundational skills for reading outlined in the Common Core state standards for kindergarten, first grade, and second grade English Language Arts (Association, 2010). With more than 40 states adopting these standards, our curriculum is relevant to the majority of young children learning to read in the US. Specifically, our curriculum teaches phonemic awareness, phonics, fluency, vocabulary, and comprehension, because current research

supports inclusion of these foundational skills in a reading program (National Reading Panel et al., 2000). Later in this section, we describe how Duolingo teaches these skills in greater detail.

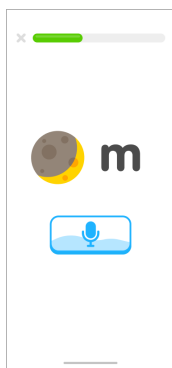
### Stay Motivated

We keep our young learners motivated by following principles of gamification (Miklasz, 2021; Yee, 2013) and recommendations for child-centered design (Schlichting, 2020). To provide learners with a sense of progress (Yee, 2013), we place lessons on a linear path. Each time the learner completes a lesson, the next one on the path unlocks, creating an “intrinsic loop” that motivates learners to keep learning (Miklasz, 2021). We include animations between activities to celebrate children’s progress and help them take a mental break. This builds children’s sense of accomplishment, and also helps to reset their attention and perform better on the next activity (Schlichting, 2020; Yee, 2013). One of the main ways we motivate learners is with our stories and their recurring cast of characters, which respond to children’s interest in engaging narratives (Yee, 2013). We also help children connect emotionally to the app activities by giving them a mission to help our app characters collect books and return them to a library (Schlichting, 2020). This framing also appeals to children’s love of collecting things (Schlichting, 2020).

### Feel the Delight

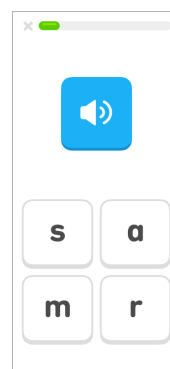
Our learning content is served up in a large variety of exercises that often feel like mini-games, such as playful scenarios in which children are asked to identify letters, initial sounds, and sight words. This makes the content approachable, engaging, and more enjoyable for learners. The Literacy app’s charming child versions of the Language app characters, brought to life through stories, are designed to bring learners joy and to motivate learning through encouraging mid-lesson celebrations (Schlichting, 2020). Through their delightful and humorous narratives, our stories also encourage a desire to read and an inspiration to learn (Duke et al., 2011; Schlichting, 2020).

We use the Duolingo method to teach the five foundational skills for reading: phonemic awareness, phonics, fluency, vocabulary, and comprehension.



### Phonemic Awareness

Phonemic awareness (the ability to recognize the individual sounds in spoken words) is important because recognizing individual sounds is a first step in attaching letters to those sounds (phonics) (R. S. Johnston et al., 2012; Juel et al., 1986). The Literacy app activities encourage children to notice initial sounds in spoken words, to select images that begin with the same sound, and to segment words into individual sounds. Most phonemic awareness activities in the Literacy app include letters, which is an especially effective approach (National Reading Panel et al., 2000).



### Phonics

Our early curriculum has a heavy emphasis on phonics (systematic knowledge of the relationships between written symbols and spoken sounds). Research suggests that a systematic, explicit phonics program improves reading outcomes (Adams, 1998; National Reading Panel et al., 2000). We specifically use a synthetic phonics approach, in which sound-symbol relationships are taught in a sequence that begins with the most consistent and frequently-occurring patterns, building systematically from there so that learners can form words as quickly as possible. There is evidence that synthetic phonics is more effective and has a greater long-term, positive impact on disadvantaged learners than other approaches (R. S. Johnston et al., 2012; R. Johnston & Watson, 2005; Machin et al., 2018). We introduce letter names simultaneously with letter sounds, resembling real-world literacy instruction in which letter names provide a mental “hook” that help children remember the letter sound (L. Ehri & Roberts, 2006; Share, 2004; Worden & Boettcher, 1990). We then demonstrate how to blend those familiar letter sounds together to form recognizable words through a variety of decoding (sounding-out) and encoding (spelling) activities. At the early levels of our curriculum, children are guided through narrated texts that encourage them to notice the letter-sound they are learning. As soon as possible, they begin to read decodable sentences and texts primarily on their own. At more advanced levels, the focus turns to teaching word spellings as patterns (e.g. “spoon”, “moon”, “soon”), starting with the simplest patterns and then moving to more complex patterns (Bear et al., 2016).

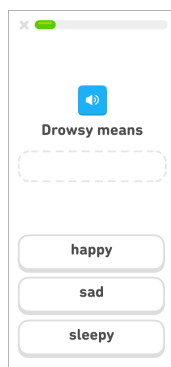
### Fluency

Developing fluency (the ability to read a text accurately and quickly) is important to improve reading speed and reduce effort (National Reading Panel et al., 2000). We build towards fluency with our story activities, where learners see the same common words multiple times when reading and rereading the stories (Rasinski, 1990). We also support fluency by helping learners become quicker at reading a set of high-frequency “sight words” (such as “the”), which are not fully decodable because they do not follow regular spelling patterns. Research suggests that introducing some sight words, especially in an integrated way with decoding instruction, is beneficial for young learners (Fuchs et al., 2001; Gunn et al., 2010). We often present sight words along with letter-sound lessons (e.g. teaching the sight word “see” just after teaching the letter “s”), to help children make the connection to letter-sound cues and remember the words (L. C. Ehri, 2014; Miles et al., 2018). Our inclusion of sight words also allows learners to read a greater, more interesting variety of texts before they are able to rely completely on their beginning phonics skills.



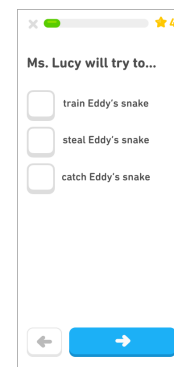
### Vocabulary

Vocabulary (knowledge of words and their meanings) is critical for building comprehension (Burns et al., 1999). We embed target vocabulary items in our interactive stories, and ask questions that invite children to discover or deepen knowledge of these target words.



### Comprehension

Comprehension (the ability to engage with text to unlock the meaning of words, sentences, and longer passages) is the ultimate goal of reading instruction, and develops at the same time as basic literacy skills such as phonics (Broek et al., 2005). We build comprehension by surrounding our phonics lessons with interactive story activities from the very beginning, so that learners see examples of the targeted letters and sounds in meaningful, connected text. As children read, they answer comprehension questions. These questions build vocabulary and encourage making text-based predictions, both of which are good practices for building comprehension (Duke et al., 2011).



## 3.3 The Math App

Math skills are essential to both academic and life success. From financial literacy to problem solving skills, greater mathematics training is associated with better quality of life (Gilmore et al., 2013). However, many people do not have access to high quality mathematics education, with millions of school-aged children out of school globally and more than half of children not meeting minimum achievement standards in reading and math (United Nations Department of Economic and Social Affairs, 2021). Moreover, simply thinking about mathematics can cause anxiety, leading people to pursue fewer math courses and suffer decreased performance (Lau et al., 2022). The Duolingo Math app is designed to make math fun for all ages. With student and brain training content, this app teaches elementary and everyday math content in playful, bite-sized lessons. The app offers a gamified experience with delightful sound effects and animations. Interactive tools like clocks and rulers help learners of all ages enjoy math.

The Duolingo Math app uses the five pillars of the Duolingo Method as well as two additional learning science informed themes that apply most to support math learning. First, we take a closer look at how Duolingo Math uses the Duolingo Method. Then, we introduce two additional principles specific to the Duolingo Math app: use multiple mathematical representations and manipulate virtual tools.

### Learn by Doing

Learning by doing is at the heart of all Duolingo's apps, and the Duolingo Math app is no different. Each skill has a discrete learning objective with sequenced and varied exercises that position learners to use their cognitive tools: implicit statistical learning and analogical reasoning. We help learners pay attention to what's important about a representation by using visual highlighting. For example, when clocks are showing elapsed time in hours, we draw attention to how much time has passed by shading the clock from 12:00 to the relevant hour mark. Highlighting works alongside our design principle of simplicity; for example, during our math exercises, every element on a screen is directly tied to the task or a learning outcome. The Duolingo Math app exemplifies learning by doing in its approach to interactive exercises to support embodied cognition. In addition to moving hands on a clock, learners physically slide their fingers along time scale number lines to match the time displayed on an analog clock, deepening their understanding of time relations. When practicing division, learners can create groups and drag items from the set to ensure they are equal. Division through grouping with manipulatives is an efficacious way to support learners early in their understanding (Sidney & Alibali, 2017).

### Learn in a Personalized Way

The Duolingo Math app encourages learners to follow their interests and start with the content they want to learn. Because each unit begins with an accessible introductory skill, it's not necessary that learners complete all prior skills and units before moving to the next unit. Within a unit, learners get a personalized experience at the end of lessons and at the review skill. When learners make a mistake, they have an opportunity to do the exercise again immediately and then at the end of their lesson, engaging in personalized practice. At the end of each unit, a review skill presents previous mistakes along with other exercises from the unit so learners are practicing what they need to in a mixed, interleaved review setting, which is beneficial for later recall (Foster et al., 2019).

### Stay Motivated

Whether brain training or learning math content for the first time, staying motivated can be a challenge. Just like the other Duolingo apps, the Duolingo Math app uses bite-sized lessons with sequencing that eases the learner into the skill. Then, we leverage rewards to keep learners going within a lesson. Speed rounds also offer a fun challenge for retrieval practice, and by allowing learners to choose to do speed rounds timed or untimed, we support those who may be negatively impacted by the presence of a timer (Mooij et al., 2020). Correct responses are followed by a pleasant sound and a flash of green, and empowering messages occur at unpredictable intervals throughout a lesson to maximize their impact (Alexiou & Schippers, 2018). We also encourage learners to keep coming

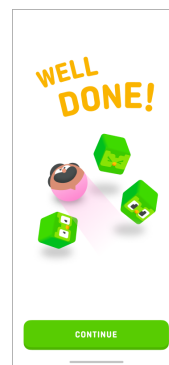
back through a streak mechanic with cheerful, math-specific notifications and animations.

### Focus on What Matters

The Duolingo Math app was informed by a review of national and international standards and recommendations. We combined the United States Common Core State Standards and National Center for Teachers of Mathematics recommendations with OECD and TIMSS recommendations as well as academic research to arrive at content and sequencing that supports a variety of math learners and fits with what is known about mathematical learning progressions and the math adults need to be able to do in their everyday lives. Combined with our own research on learner needs, we developed and will continue to refine math content that is fun, useful, and fits with how people learn.

### Feel the Delight

The Duolingo Math app transformed the Duolingo Language app characters into exciting, 3-dimensional figures. These delightful characters create a welcoming supportive environment for learners to try out new math or improve their skills. The Duolingo Math app also supports tentative learners through simplified skill exposure with streamlined exercises with minimal words, effective at decreasing math anxiety (Ramirez et al., 2018). A beautiful theme with clear indicators of how to interact with the screen combined with haptics across exercises provides a multi sensory experience which engages and delights learners.



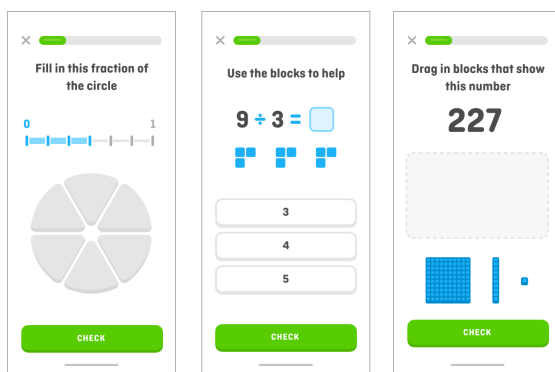
Just like the Duolingo Language app and the Duolingo Literacy app, the Duolingo Math app was developed with the Duolingo Method in mind. Two additional principles inform the development of the Duolingo Math app: use multiple representations and manipulate virtual tools. These principles are more applicable to the math domain than language learning or literacy, and we explain them below.

### Use Multiple Mathematical Representations

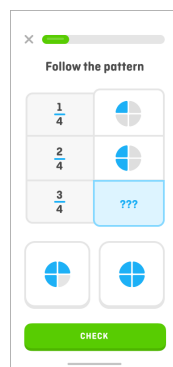
Ideas in math can be shown in different ways. Equations, pictures, and narratives can all be used to describe mathematical



concepts. Moreover, using multiple representations supports learners' analogical thinking abilities so they can determine what's important about a concept (e.g., why the number of sides is important for the idea of a triangle while the color is not). Across ages and content, when learners see and interact with multiple pedagogically appropriate representations of the same concept, they deepen their understanding, which can support transfer to new problems and situations (Ainsworth, 2014). In the Duolingo Math app, we use multiple representations to help learners understand part-whole relationships, moving between partitioned figures, number lines, number grids, and fraction notation. Because these representations also are at varying levels of abstraction, we construct lessons so learners experience representations which are closer to real objects before they interact with more abstract representations, informed by the concrete-representational-abstract (CRA) framework (Martin, 2009).



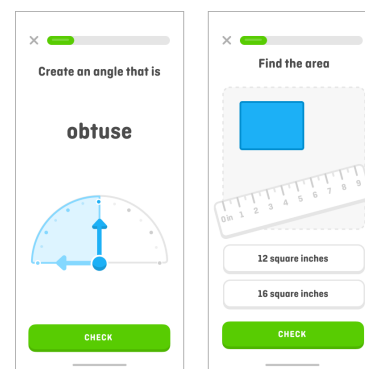
Learners experience the world first through real objects that they later understand can be referred to with words and symbols. Taking this into account, the CRA framework is frequently used to scaffold and sequence the student learning experience, and has been especially supportive for students with learning difficulties. At a finer grain, the progression in CRA is referred to as concreteness fading, where learners first see very realistic objects that become more and more abstract. Concreteness fading has benefits for a wide variety of learners and is an effective classroom practice as well (Booth et al., 2017).



In the Duolingo Math app, learners start with a follow the pattern exercise where they experience concrete representations alongside less concrete representations or, depending on their progression through the course, abstract representations. Later in the lesson or course, learners see less concrete representations co-presented with abstract representations in the form of numerals. Then, throughout the lesson, learners move between these representations to solidify their understanding, supporting efficient learning (Bouck et al., 2017).

### Manipulate Virtual Tools

In addition to the cognitive tools that learners bring with them to the Duolingo Math app, we provide them with virtual tools. These come in the form of virtual manipulatives that allow learners to focus on the most important mathematical aspects of the objects so they can deepen their understanding of the underlying concepts. Moreover, virtual manipulatives have unique affordances which can be changed to suit the learner's need or context (Sarama & Clements, 2016).



In the Duolingo Math app, learners interact with protractors, rulers, clocks, number lines, and create fractions through partitioning a variety of shapes. Studies of virtual manipulatives have found many advantages for students with learning disabilities, particularly in the case of the virtual number line (Bouck et al., 2021). More generally, virtual number lines allow learners to integrate space and number in ways that are tedious with real objects. With virtual number lines, the beginning and end points and intervals, as well as the amount of feedback from sliding across or tapping on the number line, can be changed according to learner needs. Highly interactive number lines have been shown to increase fraction understanding as well as magnitude extent (e.g., knowing the relationship between 2, 20, and 400; see Siegler (2022) for review). While virtual manipulatives have been in use for several decades, the arrival of touchscreens has increased their importance for teaching and learning (Moyer-Packenham et al., 2016). Because the Duolingo Math app is mobile first, we were able to create a learning environment informed by the cognitive science of these tools to support all learners in an engaging mathematical experience.

## Author Biographies

Cassie Freeman is a Senior Learning Science Manager at Duolingo. She leads Duolingo's Learning Science Lab and is the learning scientist for the Math app. Cassie holds a Ph.D. in Comparative Human Development (University of Chicago, 2015) and, prior to joining Duolingo, was Director of Learning Engineering at College Board.

Audrey Kittredge is a Learning Science Manager at Duolingo, advancing research-informed app development and efficacy evaluations for the Language and Literacy apps. She holds a Ph.D. in cognitive psychology (University of Illinois Urbana-Champaign, 2012). Before joining Duolingo, she conducted research on playful learning in early childhood education and parenting at Carnegie Mellon University, the University of Cambridge, and with UNICEF.

Hope Wilson is a Learning & Curriculum Manager at Duolingo. She has led development of a number of Duolingo courses, including those teaching English, German, and Arabic. She holds a Ph.D. in Slavic Studies with a focus on Linguistics (The Ohio State University, 2019), where her research focused on the intersection between language-learning and the acquisition of cultural knowledge.

Bozena Pajak is the Vice President of Learning and Curriculum at Duolingo, leading company's efforts at the intersection of learning science, pedagogy, and product development. She holds a Ph.D. in Linguistics (University of California, San Diego, 2012), and her research focused primarily on language learning in adulthood. Before joining Duolingo in 2015, she was a Postdoctoral Fellow in Brain and Cognitive Sciences at University of Rochester, and then a Research Associate in Linguistics at Northwestern University.

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