Chapter 17
Putting the Education Back in Educational Apps: How Content and Context Interact to Promote Learning

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A digital revolution is changing the lives of today's children. On the one hand, this dramatic "culture change" of childhood is worrisome because science simply does not have the resources to evaluate these apps quickly enough in a rapidly changing market. With over 170,000 educational apps available world-wide in the Apple App Store (Apple, 2016) alone, researchers cannot test every app before it is offered to parents with an assurance that the app actually has proven educational value and parents often do not know where to start when it comes to selecting apps. Further, most (but not all) apps are created by developers who are not experts in cognitive development. The sheer volume of apps developed for the preschool market, however, offers an unbridled opportunity, if there were an easy and accessible way to evaluate the educational value of apps. Harnessing the potential of educational apps might be particularly useful for children in families of low socioeconomic status (SES). Reports indicate that at least 65 % of low SES families have tablets or smartphones (Common Sense Media, 2013). By capitalizing on the educational power of

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apps on devices that are **already in the homes of children from across different socioeconomic groups,** we are on the verge of an educational revolution.

In a recent article for *Psychological Science and the Public Interest*, Kathy Hirsh-Pasek and Jennifer Zosh with colleagues who study media from different perspectives (Roberta Golinkoff, Michael Robb, James Gray, and Jordy Kaufman [2015]) proposed that the relatively new, multidisciplinary field dubbed the *Science of Learning* has identified key "pillars" that support learning across any platform—whether it be in the classroom, in the living room, or the screen. Learning scientists have distilled decades of research to suggest that optimal learning occurs most when children (or adults!) are **active** (minds-on), **engaged** (not distracted), are learning **meaningful** information (applicable or relatable to their lives) in a **socially interactive** environment (using our most powerful resource—social partners). Further, this learning should occur within a context of a supported learning goal. In other words, when a learning environment (in real life or digital) has a particular educational goal and the context is structured with playful learning in mind, educational value is maximized. Here, we review how these evidence-based principles generated by the Science of Learning can be directly applied to the evaluation and creation of educational apps. Our approach is not to evaluate every app on the market or even at this time to offer guiding principles for any particular content area be it reading or mathematics; instead, we propose a framework that will allow parents and early learning professionals to make individual-level app decisions based on the Science of Learning. Using this approach unlocks a world of truly "educational" apps, helps parents evaluate educational value from among the 170,000 available apps and helps developers better understand how to infuse apps with real educational value.

17.1 The Context of the 170,000 App Problem and a Potential Solution

What created the marketplace for over 170,000 apps? Many believe that the digital revolution can fill the gap left by an ailing education system. Parents are bombarded with the fact that we are falling behind in international testing scores. The recent release of the 2012 international test Program for International Student Assessment (PISA), for example, examines the scores of 15-year-olds in many countries around the globe (Organisation for Economic Co-operation and Development [OECD], 2012). The USA performed below average in mathematics (27th, behind such countries as Slovenia, Liechtenstein, and Estonia) and only average in both science (ranked 20th), and reading (ranked 17th). Despite the fact that playtime is decreasing in an effort to compensate for these scores, we are not seeing dramatic gains in performance. Perhaps digital technology will offer the magic sauce that allows true educational practice to jump the school walls in ways that will make our children smarter and later increase these scores.

On December 10, 2006, *Time Magazine* suggested that if Rip Van Winkle woke up today the one familiar setting he would recognize would be the American school, with the only change being the color of the chalkboards—black to white (Walls & Steptoe, 2006). Rip would see children sitting passively, receiving information spoon-fed by teachers who are preparing them for the proscribed exam. These images were reinforced by the No Child Left Behind (NCLB) Act, which was originally enacted in 2001 continued until 2015. Although NCLB aimed to provide quality education to all children regardless of age, race, SES, and location, the implementation of NCLB has resulted in a system that emphasizes teaching to a high-stakes test and drilling students on "facts" that are rapidly changing (Darling-Hammond & Adamson, 2014; Ravitch, 2010). Indeed, the PISA scores discussed above were from the cohort of students whose entire educational career had been under NCLB. Though testing has surely increased under NCLB, this national education reform policy did little to close the achievement gap (Dillon, 2009). Critics worry that despite efforts to remedy the situation, the context of a test-focused education system will reward teaching-to-the test, resulting in less learning overall (Roediger, 2014).

It is in this context that the educational app revolution has occurred with haste. Parents want academic success for their children and may be turning to "educational" apps because of what they are seeing—and not seeing—in schools. We are in the midst of a time where we are seeing below average test scores, yet apps not only allow for more educational practice, but they also offer the promise of individualized instruction in ways that were not possible before. Much of this knowledge comes from a growing body of data in the newly amalgamated field of the Science of Learning.

Since the creation of the *Journal of Learning Science* in the early 1990s, the term "Science of Learning" has appeared at the forefront of cognitive and developmental psychology. In the 1999 publication of *How People Learn*, a report from the National Research Council (Bransford, Brown, & Cocking, 1999), the authors wrote, "… the new Science of Learning is beginning to provide knowledge to improve significantly people's abilities to become active learners who seek to understand complex subject matter and are better prepared to transfer what they have learned to new problems and settings" (p. 13). One key aspect of the Science of Learning is that its multidisciplinary approach brings together findings from psychology, linguistics, computer science, animal behavior, machine learning, brain imaging, neurobiology, among others. A second key aspect of this field is the nature of the questions it asks. Instead of solely asking what we should teach children—that is, what **content** children need to know—it also asks *how* children learn best. That is, if learning is to occur and "stick," what **contexts** enable children to learn flexibly and generatively so that they can apply what they have learned (e.g., Benassi, Overson, & Hakala, 2014; Golinkoff & Hirsh-Pasek, 2016; Pellegrino, 2012; Pellegrino & Hilton, 2013; Sawyer, 2006).

In this piece, we review what the Science of Learning has taught us about how children learn. A few tenets have emerged as pillars for learning across any context (e.g., in real life or in digital apps). When children are **active** (minds-on), **engaged** (not distracted), thinking about **meaningful** information, and in **socially interactive** situations, learning is maximized. Here, we apply these pillars of learning to educational apps. As we apply each of the pillars, we consider the *content*, or what children need to know and *context*, or how they can best learn what they need to know (Guernsey, 2014). By uniting what we know about learning—both in terms of content and context—with the technology that is already in the homes of today's children, we are in the position to equip families and developers with the knowledge to solve the 170,000 app problem.

17.2 Pillars of Learning

17.2.1 Active—Learning Is Maximized When Children Are "Minds-on"

At first glance, apps appear to have an inherent benefit over other forms of screen media such as television or video because children usually have to tap and swipe rather than just sit passively. While any type of physical action may benefit learning (Chi, 2009), the Science of Learning suggests that simply tapping and swiping is not enough. The Science of Learning repeatedly finds that when humans are "minds-on" and **mentally** active, learning is maximized. This minds-on perspective can be supported via both content and context.

17.2.1.1 Content

Imagine watching a child swiping from left to right. In one scenario, he may be mindlessly cutting a piece of fruit that flies up in the air. In another case, he may be playing with angles to create a slingshot for a piece of fruit to enter a goal. These are two very different situations: one requires relatively little minds-on thinking and one engages a child in playing with concepts from physics.

In some ways, it is easiest to embrace the content aspect of minds-on learning. The Science of Learning has repeatedly found that children learn best when the task requires just a little more of children than they could otherwise do on their own. Identifying this sweet spot—akin to Vygotsky's zone of proximal development—helps children to attend and stay on task (Wright & Huston, 1983). Pushing children out of their comfort zones little by little contrasts with strategies that advocate "hot housing" children to go beyond developmental norms, that have been found to stifle creativity and increase anxiety (Sigel, 1987). It is important that the app content is not too easy or too hard, but just right. The Goldilocks approach suggests a number of age- and developmentally appropriate guidelines for learning. Common Core standards, while sometimes viewed as controversial, really represent a massive effort to quantify what children should aspire to at a particular grade level. These guidelines can then be utilized by parents and app developers to determine the content supported by apps. If material is too easy, children can easily adopt a more minds-off approach (as any adult who plays a game designed for preschoolers has experienced). Similarly, if material is too difficult, children may simply stop trying. Knowing what content is developmentally appropriate is especially important as parents are not always an accurate judge of the benefit—or lack thereof—of their own child's progress when using products specifically aimed at teaching young babies advanced skills such as reading (DeLoache et al., 2010; Neuman, Kaefer, Pinkham, & Strouse, 2014). The more challenging, and likely more important, aspect of learning that apps may struggle with is the context that they set for learning.

17.2.1.2 Context

A key factor for promoting a minds-on context is what the app asks children to do. Apps can set up a "mental workspace" within the context of an app. The data is clear that minds-on thinking is optimal for learning—even beginning in early infancy. In a study of 3-month-old infants, Sommerville, Woodward, and Needham (2005) find that when outfitted with Velcro-equipped mittens that allow them to reach out and "stick" to objects, infants learn about goal-directed reaching. With the sticky mittens, infants are also more apt to interpret others' reaching as goal-directed and are more likely to perform these goal-directed reaches themselves (Libertus & Needham, 2010).

Similar benefits of active, minds-on learning appear throughout childhood. When preschoolers with low expressive vocabularies experience "dialogic reading," in which adults involve children in the story by active techniques such as prompting, asking questions, and talking about the content of the story, they showed greater vocabulary gains than children who listened silently to stories (Hargrave & Sénéchal, 2000). Another study showed that children are more likely to comprehend novel words in a story if they ask questions and label objects while reading compared to children who engage in more passive listening (Sénéchal, Thomas, & Monker, 1995). In a direct comparison of active versus more passive vocabulary learning, Zosh, Brinster, and Halberda (2013) find that when 3-year-old children use the process of active elimination of a wrong answer to determine the referent of a novel object, they show better retention of that label compared to children who are told the novel object's label. This effect holds despite the fact that children who learned the label in the more active condition actually spent less time looking at the target object. Their "minds on" approach to learning was more powerful than passive viewing.

Benefits of active learning are evident even in later childhood. When middle school students were asked to draw chemical reactions, they showed better comprehension of the chemical mechanisms underlying those reactions compared to those who were asked to explore them with dynamic visualization (Zhang & Linn, 2011). Similar effects were seen with ninth grade students—students who only read about chemical processes showed inferior learning compared to those who actively generated their own drawings (Schwamborn, Mayer, Thillmann, Leopold, & Leutner, 2010). In more informal contexts such as in science museums, superior learning happens for children actively involved in the experience. For example, when children question, comment, and discuss what they see, they learn more than children who do not engage in these behaviors (Borun, Chambers, & Cleghorn, 1996; see Haden, 2002 for a review). This benefit might not be limited to learning outcomes. High school chemistry students involved in active learning lessons had fewer misconceptions and a more positive attitude about chemistry than those in more traditional classes (Sesen & Tarhan, 2010).

The evidence is strong: learning in an active, minds-on context is better than sitting back and receiving information. This effect is apparent across the lifespan. Thus, while content may be similar in "educational" apps, the context in which the information is presented may differ. Consider two apps with the same goal of teaching preschoolers the shape and sounds of letters of the alphabet. On one extreme lies an app that simply shows a letter and makes a sound. The app goes from one letter to the next and children can simply watch the "show." The design of the app is bright and the sounds are child-directed. Imagine a child watching this app from A-to-Z, probably many times over the course of a week—or even a day. Compare this example to an alternative app that not only shows children what each letter looks like, but also asks the child to trace the outline of each letter and once it is completed, the child is rewarded with the sound the letter makes and 1–2 examples of words that start with that letter. As the child gets faster at tracing the letter, the app might ask children to point to the picture of an animal whose name starts with that letter. Both of these apps show children what the letter looks like and plays audio to show them what it sounds like. But in the latter example, children exhibit more minds-on thinking by tracing the letters and, eventually, being asked to use their knowledge to decide between two or more choices. In this way, this app promotes increased minds-on thinking. Indeed, preliminary evidence suggests that learning is increased when parents use an app alongside their children that promotes this type of minds-on thinking (Schmitt, 2015).

17.2.2 Engaged: Learning Is Maximized When Distractions Are Limited

Learning occurs best when adults (or children) are engaged—meaning that they stay on-task and are not distracted. In the arena of classroom engagement, Fredricks, Blumenfeld, and Paris (2004) distinguish between *behavioral* engagement (e.g., following the rules and participating), *emotional* engagement (e.g., emotional reactions to content) and *cognitive* engagement (e.g., motivation to learn and effort to gain deeper understanding). Each type of engagement has a common theme—staying on-task. A key pillar highlighted by the Science of Learning is how focused engagement—or staying on-task and being present in the learning context—is central for learning.

Anyone who has ever tried to talk to a child playing with an app likely has experienced the "zone out"—the child does not respond, or, if he or she does respond, it is likely with a mumbled "what?" In this sense, apps (or television) appear to maximize children's attention and prevent them from being distracted (even from the questions or commands of their parents). However, research teaches us that this "zone out" is not sufficient for learning. Instead, the high-quality, active learning that children exhibit when playing with apps can be maximized when the child stays "on-task" and is not distracted by competing or nonessential content. Adding social interactions to media use is another way to combat the effects of "zone out." Strouse, O'Doherty, and Troseth (2013) found that when parents were trained to use dialogic reading questioning techniques (e.g., pausing, asking questions, and encouraging story-telling) when watching educational television with their 3-year-old children, story comprehension and story-related vocabulary was increased relative to a condition where parents directed children's attention to the show but did not use questions.

By managing the context of the child's experience (with screens of any type), adults can help promote minds-on, engaged learning.

When thinking about how apps might promote this engagement, one must consider how the content of the material and also the learning context an app inspires—either helps children to stay on task or encourages distraction.

17.2.2.1 Content

When it comes to learning content, it is tempting to espouse the "more is better" model. To take the earlier example of an alphabet app, parents might be attracted to an app that simply does not have tracing but also includes multiple examples of that letter using different fonts, words displaying on the screen that start with that letter, and an animal game where the child matches the sounds of animals whose name starts with that letter to the animal name. It is easy to buy into the idea that more learning will occur if the app goes beyond letters. However, it is crucial to determine what information is necessary and supportive to a learning goal (avoiding overload). In the above example, an app that moves children through those features as the child demonstrates increased understanding will be better for learning compared to one in which the child is overloaded with too many features at one time. Another consideration is to determine what information may be extraneous and distracting to the goal or learning objectives. An example comes from an investigation of parent-child interaction with electronic toys. Zosh et al. (2015) found that when parents and children interacted with a traditional, non-electronic shape sorter, children heard higher quality and more on-topic language than children who played with an electronic version of the same toy. Instead of hearing about shapes, children in the electronic condition heard unrelated songs and much of the conversation was about the toy rather than conceptual information about shape. Indeed, Mayer (2014) notes that when the amount of extraneous material is limited, deeper learning occurs. Mayer calls this concept the "coherence" principle.

Apps need to give just enough extra detail to help keep children engaged and on-task, but not provide so many "extras" that the actual meaningful information is hidden or lost.

17.2.2.2 Context

While many adults do not hesitate to check email, talk on the phone, and text while driving, recent data suggests that children are beginning to multitask with media sources, too. Among children under the age of 8, 16 % of children report using more than one type of screen media "most" or "some" of the time (Rideout, Foehr, & Roberts, 2010). Just as research demonstrates that only about 2 % of adults are "super taskers" who are capable of true multitasking (Watson & Strayer, 2010), studies with children have shown that they are particularly susceptible to the effects of distraction. Something as simple and seemingly noninvasive as a television playing in the background is related to lower attention in children and less engagement with the toys they are playing with—even if they are only distracted for a few seconds (Schmidt, Pempek, Kirkorian, Lund, & Anderson, 2008).

When it comes to apps, it is important to think about the ways the app itself may provide distractions that take away from the learning objectives. Research about a previous technological advancement—electronic books—has shown that the additional features they contain distracts children instead of increasing their engagement. This is an important finding considering that books, toys, and apps, commonly add, rather than subtract, proverbial "bells and whistles" in the form of extra buttons and sound effects. Even "pop-up" books, whose pages open up to create three-dimensional displays, can impede rather than support children's vocabulary learning and story comprehension, as compared to traditional books (Tare, Chiong, Ganea, & DeLoache, 2010). Similar effects have been seen with electronically enhanced books relative to traditional books. Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, and Collins (2013) found that 3-year-olds (but not 5-year-olds) showed better comprehension and memory for a story that was a traditional book rather than an electronically enhanced version of the same story. Similarly, Krcmar and Cingel (2014) found preschoolers' comprehension of story details was increased when parents read the traditional version of a book relative to the electronic version and follow-up analyses suggested that this was due to an increase in distraction talk. However, Lauricella, Barr, and Calvert (2014) do not find a cost of electronic books per se but do find that interaction is key: "For both types of storybooks, child attention, child language, and parent engagement were significant predictors of story comprehension. Our results suggest that a storybook is a storybook, whether the story is presented on paper or electronically, although the ways in which parents and children engage with the storybooks may differ as a function of the platform." (p. 17). Together, these results suggest that the *context* promoted by electronic books or apps is likely what causes either costs or benefits to learning.

The distraction caused by the additional attributes is not limited to seemingly extraneous features. Children stay engaged and tend to learn more when additional features are not present, even when they were created to support a specific learning goal as in the case of pop-up books (Chiong & DeLoache, 2012). Finally, background music can also result in distraction. Barr, Shuck, Salerno, Atkinson, and Linebarger (2010) found that even simple instrumental music added to a video demonstration can serve as a distraction and prevent or limit infants' abilities to learn a new action. Further, the addition of mismatched sound effects to a demonstration of an action by either a live model disrupts imitation performance during the first 2 years of life relative to the same demonstration without sound effects (Barr, Wyss, & Somanader, 2009).

While apparent throughout the lifespan, the susceptibility to distraction appears to be strongest for the youngest learners. Kannass and Colombo (2007) examined how different types of distractions—ranging from no distractors, to intermittent, to continuous distractions—impacted 3.5- and 4-year-olds' task performance. Although the youngest children showed impaired task performance with any type of distraction, older children began to recover from distraction and only showed evidence of impaired performance when the distraction was continuous. This has important implications for setting the context for learning in childhood, a time when children are less able to regulate their attention and more likely to become distracted. Kindergarteners whose classrooms are highly decorated tend to show more time off-task and less learning compared to those in a less decorated and less distracting context (Fisher, Godwin, & Seltman, 2014). Not surprisingly, individual children differ in their susceptibility to distraction (Choudhury & Gorman, 2000; Dixon, Salley, & Clements, 2006), but in general, sustained attention abilities at 5 years (i.e., lack of impulsivity, focused attention) are related to later attention abilities at age 9 (Martin, Razza, & Brooks-Gunn, 2012). Distraction remains an issue for students throughout their education. Students who text during class are outperformed by those who do not (Dietz & Henrich, 2014) and college students who multitask during a lecture not only risk lowering their own performance but also that of the students sitting around them (Sana, Weston, & Cepeda, 2013).

A significant finding, then, is that staying on-task is a key pillar of learning. App "enhancements" should be rather limited, especially those designed for the youngest children. However, distraction is malleable for both children and adults (Kannass, Colombo, & Wyss, 2010; Neville et al., 2013) and varies not only with age (Kannass & Colombo, 2007) but across individuals (Martin et al., 2012). Together, these findings stress that the context of learning is crucial and that it is important to limit the distracting information in apps while keeping in mind that some children will be more susceptible than others.

17.2.3 Meaningful: Learning Is Maximized When the Material Links to Children's Lives

It is a relatively common occurrence for a parent to exclaim that their 2-year-old child can count to 20. However, when that same child is asked to give a caregiver four items, the child acts as if he or she has no actual concept of numbers. Clearly, children must move beyond rote memorization to achieve meaningful learning. In fact, Brown, Roediger, and McDaniel (2014) state, "People who learn to extract the key ideas from new material and organize them into a mental model and connect that model to prior knowledge show an advantage in learning complex mastery" (p. 6). Research affirms these ideas. Bransford et al. (1999) stress that competence is not simply the acquisition of facts but the ability to conceptualize those facts into a larger framework. Meaningful learning in apps can be achieved by being mindful of the content of the information we are sharing and the way we ask children to incorporate this information into their understanding.

17.2.3.1 Content

Findings in the Science of Learning suggest that, across the lifespan, humans show better learning for material that is meaningful to them and that can be linked to what they already know. Ausubel (1968) theorized that for learning to occur, we must make connections between the material we are trying to learn and our existing knowledge. The critical distinction here is between “meaningful” and “rote” learning. Rote learning is the equivalent of learning the names of all the numbers but having no real conceptual understanding of numerosity. Meaningful learning, on the other hand, is when new knowledge can “hook” onto existing information and more complex and complete conceptual understanding occurs. When a child can not only recite the count list to 20 but can also respond that 15 is more than 11 and that if you add 4 to 15, the result is 19, we would say that the child has a meaningful understanding of number. These same sentiments are echoed by Shuell (1990) and Chi (2009). Meaningful learning must connect to what is already known and the new information must be incorporated within a mental model to lead to true conceptual understanding (Novak, 2002).

Just like experience outside of the digital world, apps can contain meaningful or rote content. One can imagine an app that makes a game of tracing the numbers from 1–10 with your finger. While children may be able to trace the outline of each number, if they cannot later tell you how many cookies they have in front of them or do not understand that 5 is more than 2 and it is equally distant from 8, their learning is shallow at best. Thus, it is crucial for the material presented in apps to have meaning and move beyond this rote level.

While content in educational apps should be meaningful, this does not rule out a role for fantasy. Children can learn more effectively with fantasy than realistic materials in stories (Weisberg et al., 2015). Many apps present children with the opportunity to pretend or to engage in dramatic play. Pretend play helps children to develop creative thinking skills and promotes executive function (see Weisberg, 2015 for a review). As long as the content promotes drawing meaningful connections between their actual lives and the pretend context, it may be more effective than disembodied content that does not link to children’s prior learning. For example, the app Alien Assignment asks children to help a family of green aliens who are visiting the planet to become oriented to life here by taking pictures of various objects. While the story line may not be directly related to real life, the premise of helping someone and thinking about what they might know and do not know is very meaningful to young children. However, given that research is mixed regarding the benefit of reality over fantasy or pretense (Richert, Shawber, Hoffman, & Taylor, 2009; but see Hopkins, Dore, & Lillard, 2015; Weisberg et al., 2015) one should keep in mind that depending on the age of the child, he or she may need more support to draw the conclusions between fantasy/pretend and real life.

17.2.3.2 Context

Beyond content, it is important for children to learn within a meaningful context and to extend this meaning into their everyday lives. Apps must go beyond the flash-card model to promote meaningful learning. In fact, recent work suggests that children begin to prefer meaningful contexts as early as infancy. Before their second birthday, infants are more successful at a categorization task when they learn about the function of the objects to be categorized. In other words, they learn more when they understand how an object works and this meaningful information is even more useful than the name of that object for younger (14 month old) infants (Booth & Waxman, 2002). Later in childhood, this same benefit of meaningfulness is evident with children learning more vocabulary words when those words are embedded in a meaningful narrative or expository text relative to when words were not exposed in a meaningful text (Nagy, Herman, & Anderson, 1985). Crucially, learning was equivalent when children were exposed either to the narrative or the expository text suggesting that children were able to learn just as much from context that is not explicitly attempting to teach them (the narrative text) than when it is (the expository text). Children used contextual meaning to learn. When adults provide extended instruction about vocabulary that is embedded within a story, children learn and retain even more (Coyne, McCoach, & Kapp, 2007). Helping children find meaning results in better learning.

One way to inspire meaningful learning is to provide contexts that help children to see the connection between what they are learning about and their everyday lives. For instance, children ages 4–7 years are more likely to remember story events when they hear a familiar narrative versus a more novel narrative (Hudson & Nelson, 1983). Given the fact that children can and do learn from pretense (Hopkins et al., 2015), it is likely that this benefit may not necessarily be about familiarity but about drawing meaningful connections, which is admittedly easier in reality or in familiar contexts. This type of meaningful learning actually appears to help children stay engaged (not distracted) and active in the learning process. Perhaps it makes what is new stand out, thereby making it easier for children to focus on what is to be learned. Recent work has found that when children were "rewarded" with meaningful information (such as how an object worked), they were more likely to continue on-task than when meaningful information was not offered or children were given a sticker (Alvarez & Booth, 2014).

Not surprisingly, meaningful contexts benefit adults' learning as well. One area that has recently begun to adopt this approach is healthcare (Hinyard & Kreuter, 2007). Recent work suggests that when doctors hear a narrative about a patient, they are better able to remember guidelines for prescribing opioids compared to doctors who are simply instructed about these guidelines. Despite the transparency of this explicit instruction, when guidelines are embedded within a meaningful context, even adults show better learning and more appropriate application (Kilaru et al., 2014).

When thinking about designing educational apps, it is important to consider whether the context created by the app allows children to make meaningful connections to their lives *outside* of the app. For instance, helping children to see that the triangle shapes that they are identifying within an app are just like the triangles they see when a parent cuts a sandwich or serves them a slice of pizza will result in true learning.

17.2.4 *Socially Interactive: Learning Is Maximized When Supported by Social Relationships (Either in-Person or Virtual)*

The final pillar that emerges from the Science of Learning is social interaction. Decades of evidence suggest that children learn best when working with others on joint tasks. At first glance, this appears to be the pillar that is the least easily applicable to the app environment as children often sit alone when engaging with apps. In fact, apps on most devices are designed for single-person viewing. However, some principles of social interaction may be attainable and even promoted via the use of apps.

17.2.4.1 Content

Although research on apps is so new that the existing literature is not yet abundant, research with another type of screen media, television, has uncovered ways to promote social interaction through content—even when children are the sole user of the app. Research on children's learning from television suggests that the characters themselves are important. Children have a tendency to form "parasocial" relationships with familiar characters on the screen. These relationships contain a strong emotional bond on the child's part, and children perceive themselves as interacting meaningfully with the character (Strommen, 2000; see Calvert & Richards, 2014; Chap. 9, Richards and Calvert, 2016; Chap. 10, Simensky, 2016 for a review).

Importantly, when children view content presented by familiar characters, they tend to learn more. Research from Lauricella, Gola, and Calvert (2011) presented identical math content to all children, but manipulated whether children learned from Elmo or DoDo (a character popular in Taiwan but not in the USA). Toddlers who saw Elmo on the screen learned to seriate nesting cups, but children who saw DoDo did not. Similar effects of familiar characters have also been associated with improved expressive vocabulary (Linebarger & Walker, 2005), literacy skills (Piotrowski, Linebarger, & Jennings, 2009) and healthier food choices (Kotler, Schiffman, & Hanson, 2012). While parents should be aware of the concerns about consumerism and marketing to children via apps (Common Sense Media, 2013), it may be that at least some familiarity with characters may serve an important role in helping children learn.

17.2.4.2 Context

Apps do have an advantage over television in that they provide a natural context for interaction and contingency. Research shows that social contingency, in which there is a back-and-forth reciprocity between speakers, is a powerful tool for children's learning (Goldstein & Schwade, 2008; Reed, Hirsh-Pasek, & Golinkoff, submitted for publication; Tamis-LeMonda, Bornstein, & Baumwell, 2001; Tamis-LeMonda, Bornstein, Kahana-Kalman, Baumwell, & Cyphers, 1998; Tamis-LeMonda, Kuchirko, & Song, 2014). Investigations of children's ability to learn from television have long suggested that learning language from the screen is limited during children's first 3 years of life (Wyss, 2008; DeLoache et al., 2010; Krcmar, Grela, & Lin, 2007; Kuhl, Tsao, & Liu, 2003; Scofield & Williams, 2009), termed the "transfer deficit" (Anderson & Pempek, 2005; Barr, 2010). Additionally, research is clear that live human interactions trump electronic "interaction" when it comes to children's language learning (Krcmar et al., 2007; Kuhl et al., 2003; Reiser, Tessmer, & Phelps, 1984; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009). Yet recent work suggests that if screen media were able to incorporate the natural back and forth that happens in face-to-face interaction, as is the case in Skype or other video chatting programs, children can learn new words. In work by Roseberry and colleagues, toddlers learned new words through video chats just as they did in live interactions with the experimenter, but the children who viewed traditional video showed no evidence of learning (Roseberry, Hirsh-Pasek, & Golinkoff, 2014). When it comes to language development of young children, this reciprocity appears to be especially important (Dunst, Gorman, & Hamby, 2010; Goldstein & Schwade, 2008; Gros-Louis, West, & King, 2014; Tamis-LeMonda et al., 2014; see also Chap. 15, McClure & Barr, 2016).

One technique that children's television shows have used successfully to increase social interaction and learning is for a character to pose questions to the unseen audience, wait for an answer, and then respond (Anderson et al., 2000; Fisch & McCann, 1993). For example, a character on the show might look into the camera and say, "What else is orange?", pause for a few seconds, and then say, "That's right! The carrot is orange!" (see also Chap. 7, Linebarger, Brey, Fenstermacher & Barr, 2016). This contingency is a powerful tool and can result in increased learning (Troseth, Saylor, & Archer, 2006).

Apps allow for a remarkable degree of contingency that was never available in television. While television programs might have a character ask a question and then insert some "blank" time meant for children to respond, these responses are only contingent in that they are time-locked to allow for a child's response. The character responded the same whether the child remarks that apples or carrots are orange. Apps have the increased ability and flexibility to respond contingently and immediately to a child's response. If the app asks the child to point to another object that is orange, and the child taps on the apple, the app can then respond by saying "Try again! Apples are red!" This represents another degree of meaningful contingency that was unavailable without a real-life social partner within the medium of television. However, apps are not yet at the point where they are as flexibily contingent as a real-life social partner.

One can easily imagine an app that is designed to teach children about numerosity. In this app, children are tasked with finding items on a grocery list. When the child taps on different foods, the item flies off of the shelf and into the cart. The child gets immediate responses that are linked to her taps and can get positive feedback once she completes the shopping list. However, apps are not yet at the point where they can hear her talk about the apple she ate at the grocery store yesterday or how she felt when she dropped her cookie on the ground while she was waiting in line. While some new apps (e.g., Words by Osmo) utilize reflective artificial intelligence and respond to items children manipulate in the real word, apps still are not able to mimic the second-by-second, complex, and ever-changing reciprocity of a human partner.

Again we return to the issue of within app- versus environmental-context. An additional lesson from the screen media literature is that although television (or really any activity) may not be inherently social, it has the potential to become a social activity when a social partner joins in on the experience. For television, this is termed **coviewing** and while it can involve anyone, most research has concentrated on parents coviewing television with children. While research applying this concept to apps has not yet been conducted, the results from research on coviewing with television are mixed. Parents' eye gaze, for example, has been shown to impact the likelihood that infants will gaze at a television and for longer periods of time (Demers, Hanson, Kirkorian, Pempek, & Anderson, 2013; see also Chap. 11, Anderson & Hanson, 2016). While some early research found positive results when parents coview with children (Reiser et al., 1984; Reiser, Williamson, & Suzuki, 1988; Rice, Huston, Truglio, & Wright, 1990), other more recent research finds no benefit of coviewing when it comes to learning vocabulary (DeLoache et al., 2010). It is important to keep in mind that the potential benefit of coviewing or joint media engagement when considering all forms of media, is likely highly dependent on the content being delivered, the age of the child, and his or her current conceptual understanding. In many ways, effective joint media engagement is very similar to the classic techniques of dialogic reading and as such, is likely highly dependent on the skill of the social partner. When a parent or other social partner uses techniques like dialogic reading, such as asking children to recall events in a story after viewing, or asking open-ended questions, children showed better story comprehension and increased vocabulary knowledge (Strouse et al., 2013).

Apps open up a world of possibilities with regard to utilizing what the Science of Learning has taught us about the benefits of social interaction for children's learning. From the use of parasocial relationships to engaging multiple players in a live game to the availability of social partners within the app itself, the potential of apps to harness this social interaction is unlike anything we have seen in television or video games. Further, the ability to have live experiences that parallel the social contingency and responsivity of live interactions via apps like Skype or FaceTime, children again are given the opportunity to interact with social partners from around the world.

Taken together, research in the Science of Learning suggests that children learn best in environments where they are **active** (minds-on) and **engaged** (not distracted), when the material is **meaningful**, and when they are learning in a **socially interactive** context. However, there is one important aspect of content and context that cuts across these four pillars of learning. This is whether the app has a learning goal. If it does, and if learning is supported in a flexible context in which children are scaffolded towards that learning goal in a playful, exploratory way, learning is maximized (Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009).

17.3 Scaffolded Exploration Towards a Learning Goal

> "… children can learn anything if it is properly arranged; that appropriate structuring of the very young child's learning environment with accompanying, properly calibrated materials will enable that child to learn to read, to acquire an advanced vocabulary, and to do arithmetic calculations." (Sigel, 1987, p. 212)

Sigel (1987) believed that the optimal early learning environment allows children the opportunity to learn through self-directed play and exploration but highlighted that how children's environments are structured is key. The question about how to best instruct children is not new. For decades, there has been a debate about how we can set children up for academic success (e.g., Hirsh-Pasek & Golinkoff, 2011). On one end of the spectrum are those who advocate free play in which the learning context is unstructured and not designed purposefully (Gray, 2013). At the other end of the spectrum lies proponents of direct instruction in which adults or other more knowledgeable individuals (e.g., teachers or parents) tell children what they need to know (Klahr & Nigam, 2004). A meta-analysis of 164 studies found that direct instruction works better than free play (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). However, this analysis also found that another hybrid instructional method was superior to both. The researchers noted that "assisted discovery" methods in which the learning context is designed in a purposeful way with an adult following a child's lead while supporting learning, worked best of all. Another term for this type of learning context is 'guided play' (Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Hirsh-Pasek et al., 2009; Zosh, Hirsh-Pasek, & Golinkoff, 2016).

The benefits of guided play have been shown across educational domains. In the case of mathematical learning, Ramani and Siegler (2008) designed a game-based intervention in which children played a linear board game designed to help them understand the relation between numbers and develop more linear mental representations of the number line. They found that when low-income preschool children played the numerical version of the board game for a total of about 1 h (four 15-minute sessions over two weeks), they showed increases in mathematical thinking and that this effect held for 9 weeks. It was not just playing a game that helped them to learn. When the same game with the same rule was played with a game board that used colors instead of numbers, no benefit remained. Furthermore, children appear to benefit when the board is organized as linear and not circular (Siegler & Ramani, 2009) as to mimic the number line. It was critical that the adults set up and designed the play situation but then allowed children the chance to play and explore.

In a study of geometric knowledge, Fisher et al. (2013) directly compared learning through free play (no guidance or assistance), guided play (a more knowledgeable play partner followed the child's lead and scaffolded their understanding through playful instruction), and direct instruction (children were directly told the key concepts). They found that those children in the guided play condition not only showed increased knowledge over the course of that play session but also demonstrated retention of these concepts a week later.

The benefits of guided play extend beyond number and shape to include language and literacy outcomes (Weisberg, Hirsh-Pasek, & Golinkoff, 2013; Zosh, Reed, Golinkoff, & Hirsh-Pasek, 2014 for a review). Han and colleagues examined reading outcomes for at-risk preschoolers and found that when instruction is paired with guided play, children show increased gains in literacy compared to those children who only received direct instruction (Han, Moore, Vukelich, & Buell, 2010). Similarly, early evidence in a large-scale, in-progress intervention-based study with preschoolers in Head Start again finds that a focused, guided play context (either child-led or adult-led) is superior to free play (Dickinson, Hirsh-Pasek, Golinkoff, Nicolopoulou, & Collins, 2013).

Unsurprising to anyone who remembers memorizing multiplication tables or chemical reactions, direct instruction can result in learning. In fact, work by Klahr and colleagues on children's understanding of experimental confounds suggests that in some cases, direct instruction can be particularly effective (Klahr & Nigam, 2004; Strand-Cary & Klahr, 2008) over both short-term and long-term timescales. It is important to note, however, that the direct instruction condition of Klahr's work has commonalities with guided play conditions (see Chi, 2009).

Why is guided play so effective? One recent explanation suggests that guided play sets the stage, or the 'mise en place,' for learning (Weisberg, Hirsh-Pasek, Golinkoff, & McCandliss, 2014). In this account, children adopt a different mindset when they are engaged in playful learning. Unlike free play and direct instruction, the adults' role in guided play is to follow a child's lead, offering him or her the right "ingredients." The child then figures out how the ingredients go together, adopting a minds-on approach. Further, it helps children to see the meaning in what they are learning while also engaging with others socially. A closer inspection of free play and direct instruction shows that these types of pedagogy do not fully engage these four pillars of learning.

Another possible mechanism by which guided play may be more effective is in promoting discovery. Bonawitz and colleagues suggests that there is a 'double-edged sword' with direct instruction. While it gives children the appropriate information, it actually decreases exploration and discovery (Bonawitz et al., 2011). When children were directly instructed about one of four functions of a novel toy, they were much less likely to discover the other functions when given the chance to play with the toy. Children who were not directly instructed about the hidden function were more likely to discover the other functions.

It appears that one way to maximize learning is to couple exploration and guided play with direct instruction. For instance, when second to fourth grade children were given the opportunity to explore potential solutions for math problems before they were directly instructed, they had better conceptual understanding of those math concepts than those were directly instructed and then given the chance to practice (DeCaro & Rittle-Johnson, 2012).

Across all of these instances, guided play helps to focus children on the dimensions that are important for solving a particular problem. It does so, however, in a context in which children are the agents of their own learning—by either setting up the environment in which children explore, or by allowing them to explore an area with adults who then extend and augment their learning by asking open-ended questions.

When applied to apps, adopting the principle of this scaffolded exploration through guided play can be embraced in a number of ways including allowing children the opportunity to explore a problem or concept before providing a demonstration of the correct answer, creating a context that promotes active exploration and discovery, and engages children in creative thinking. One can easily imagine an app designed to teach children about the mathematical concept of addition by allowing children to drag products into a picnic basket with a target number in mind for a picnic lunch. One app might show the child an example problem where the number 7 is displayed and the app automatically shows the child four items in the basket and three additional items are added. When the problem is solved correctly, the child is shown the items on a picnic blanket and two happy children sit down for lunch. When it is the child's turn, he or she knows what to do. If the child does not correctly answer the problem, the app might play a 'buzzer' sound and then show the child the correct answer. This app demonstrates the way to play with the app and how to solve the problem. A related app might not demonstrate the "correct" way to solve the problem but instead first let children put items into a picnic basket and when the target number is reached, they hear a "ding ding ding" and a picnic party begins. In this case, children are tasked with determining what makes the bell go off. When children respond incorrectly to this app, the game might respond to an incorrect answer by demonstrating that the extra items fall off of a picnic blanket and are eaten by ants. When children are given the opportunity to explore the content and arrive at new conceptual understanding through their own exploration, learning will be maximized.

Apps represent a unique opportunity for scaffolded exploration and guided play by offering an interesting possibility. Is it perhaps possible for apps that engage children in scaffolded exploration and guided play to replace an actual, real life human? The jury is still out and this is a question ripe for investigation. Given the current limitations of even the most impressive app (e.g., even the best possible educational app is powerless when a child states he wants apple sauce for a snack!), we would hypothesize that an actual social partner would still reign supreme. However, since more experienced play partners are simply not available every second of the day—whether it is because a parent needs to make dinner or because a teacher has to share his attention with 20 students, apps represent brand new territory. It is up to researchers to find out what benefits and limitations this type of hybrid social interaction affords. It is critical that app developers keeps these pillars in mind and create contexts in which children are allowed to explore but are guided by the app towards a learning goal. Apps can be truly educational and represent a powerful learning tool that is already in many homes.

17.4 Final Thoughts

Parents are confronted with tens of thousands of apps marketed as educational. At first glance, determining which of these actually have real educational value appears to be an insurmountable challenge. By harnessing research that has been conducted under the umbrella of the Science of Learning and by abstracting four commonly agreed upon learning pillars that promote high-quality education within a context of scaffolded exploration and guided play, we developed a framework by which parents, educators, researchers and even app developers have the tools to determine what how to put the education back in the "educational" app.

Indeed, this is a first step in an as yet uncomfortable marriage between science and app developers. There is much to gain, however, by making this marriage work. A collaboration between app developers and learning scientists might herald a *second wave* of app development where apps are based on secure learning principles, here defined as the four pillars. In the first wave, the marketplace succeeded in convincing parents that content is all children need to succeed in school. Golinkoff and Hirsh-Pasek (2016) have referred to this misguided belief as the "learning illusion." Given the demands of the twenty-first century, and findings from the Science of Learning, five areas beyond ***content*** are required as well for children's success: (1) **collaboration**, or the ability to work alongside others while recognizing their differences and similarities with us; (2) **communication**, whether speaking writing or listening we must take the perspective of the other for communication to work; (3) **critical thinking**, selecting and integrating from the vast amounts of information now available that which is needed to solve the problem at hand; (4) **creative innovation**, and (5) **confidence**—the ability to persist and to take intellectual risks. In other words, ***contexts*** that are collaborative and communicative while promoting critical thinking, creative innovation, and confidence result in truly educational experiences for children. When the majority of apps no longer simply reproduce children's workbooks but create innovative approaches to facilitating children's acquisition of these 6Cs, they will be reaching their potential as instructional agents.

The power of truly educational apps is great. Utilizing what we now know about learning and applying that to a technology readily available to children across SES, we are now in a position to help level the playing field of early learning. As the Mayor of New York suggested, technology might well prove an important tool for narrowing the achievement gap (City of New York & Office of the Mayor, 2014). Preliminary evidence is promising. For example, a recent study exposed children from low-income families to a vocabulary-focused app for 2 weeks and found an increase in vocabulary of up to 31 % (Corporation for Public Broadcasting, 2011). These kinds of findings, while admittedly preliminary, show the potential impact apps may when the marriage between developer and researcher works.

Considering the four pillars within a learning context can help parents, developers and educators ride the second wave as it washes ashore. The Science of Learning has much to offer developers as we move forward. To put the education back in "educational apps" we need active, engaged, meaningful and socially interactive learning with an eye towards scaffolded exploration through guided play and a clear learning goal.

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