All I Really Need to Know (About Creative Thinking) I Learned (By Studying How Children Learn) in Kindergarten*

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ABSTRACT
This paper argues that the "kindergarten approach to learning" – characterized by a spiraling cycle of Imagine, Create, Play, Share, Reflect, and back to Imagine – is ideally suited to the needs of the 21st century, helping learners develop the creative-thinking skills that are critical to success and satisfaction in today's society. The paper discusses strategies for designing new technologies that encourage and support kindergarten-style learning, building on the success of traditional kindergarten materials and activities, but extending to learners of all ages, helping them continue to develop as creative thinkers.

INTRODUCTION
Kindergarten is undergoing a dramatic change. For nearly 200 years, since the first kindergarten opened in 1837, kindergarten has been a time for telling stories, building castles, drawing pictures, and learning to share. But that is starting to change. Today, more and more kindergarten children are spending time filling out phonics worksheets and memorizing math flashcards [5]. In short, kindergarten is becoming more like the rest of school.

In my mind, exactly the opposite is needed: Instead of making kindergarten like the rest of school, we need to make the rest of school (indeed, the rest of life) more like kindergarten.

As I see it, the traditional kindergarten approach to learning is ideally suited to the needs of the 21st century. In a society characterized by uncertainty and rapid change, the ability to think creatively is becoming the key to success and satisfaction, both professionally and personally [2]. For today's children, nothing is more important than learning to think creatively – learning to come up with innovative solutions to the unexpected situations that will continually arise in their lives [17].

Unfortunately, most schools are out-of-step with today's needs: they were not designed to help students develop as creative thinkers. Kindergartens (at least those that remain true to the kindergarten tradition) are an exception. The traditional kindergarten approach to learning is well-matched to the needs of the current society, and should be extended to learners of all ages.

What do I mean by the kindergarten approach to learning? In traditional kindergartens, children are constantly designing, creating, experimenting, and exploring. Two children might start playing with wooden blocks; over time, they build a collection of towers. A classmate sees the towers and starts pushing his toy car between them. But the towers are too close together, so the children start moving the towers further apart to make room for the cars. In the process, one of the towers falls down. After a brief argument over who was at fault, they start talking about how to build a taller and stronger tower. The teacher shows them pictures of real-world skyscrapers, and they notice that the bottoms of the buildings are wider than the tops. So they decide to rebuild their block tower with a wider base than before.

This type of process is repeated over and over in kindergarten. The materials vary (finger paint, crayons, bells) and the creations vary (pictures, stories, songs), but the core process is the same. I think of it as a spiraling process in which children **imagine** what they want to do, **create** a project based on their ideas, **play** with their creations, **share** their ideas and creations with others, **reflect** on their experiences – all of which leads them to **imagine** new ideas and new projects (see Figure 1).

In going through this process, kindergarten students develop and refine their abilities as creative thinkers. They learn to develop their own ideas, try them out, test the boundaries, experiment with alternatives, get input from others – and, perhaps most significantly, generate new ideas based on their experiences. In reality, the steps in the process are not as distinct or sequential as indicated in the diagram. Imagining, creating, playing, sharing, and reflecting are mixed together in many different ways. But the key elements are always there, in one form or another.

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* Apologies to Robert Fulghum (1986). Fulghum's best-selling book *All I Really Need to Know I Learned in Kindergarten* focused on *what* children learn in kindergarten, and why those lessons remain important for the rest of their lives. This paper focuses on *how* children learn in kindergarten, and why kindergarten-style learning serves as a useful model for learners of all ages.

Some of the most creative artists and inventors of the 20th century credit their kindergarten experiences with laying the foundation for their later success [1].

If this learning approach has been so successful in kindergarten, why hasn't it been applied in other parts of the educational system? One reason, I believe, is a lack of appreciation for the importance of helping young people develop as creative thinkers. Another reason has to do with the availability of appropriate media and technologies. Wooden blocks and finger paint are great for students working on kindergarten projects and learning kindergarten concepts (like number, shape, size, and color). But as students get older, they want and need to work on more advanced projects and learn more advanced concepts. Wooden blocks and finger paint won't suffice. If older students are going to learn through the kindergarten approach, they need different types of tools, media, and materials [12].

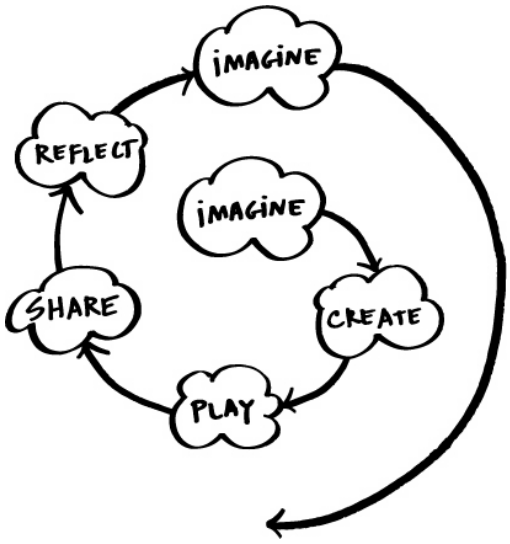

Figure 1: The kindergarten approach to learning

This is where, in my opinion, digital technologies can play a transformational role in education. I believe that digital technologies, if properly designed and supported, can extend the kindergarten approach, so that learners of all ages can continue to learn in the kindergarten style – and, in the process, continue to develop as creative thinkers.

My focus here is on what researchers have called "little c" creativity – that is, creativity within one's personal life – not "big C" Creativity that transforms the boundaries of an entire discipline or domain. The goal is not to nurture the next Mozart or Einstein, but to help everyone become more creative in the ways they deal with everyday problems.

The rest of this paper is organized around the different aspects of the kindergarten learning approach: Imagine, Create, Play, Share, Reflect, and back to Imagine. Each section discusses strategies for designing new technologies that encourage and support kindergarten-style learning, building on the success of traditional kindergarten materials and activities, but extending to older learners, in hopes of helping them continue to develop as creative thinkers.

IMAGINE

Consider the most popular kindergarten materials: blocks for building, crayons for drawing, dolls for role-playing, tiles for making geometric patterns. All of these materials are designed to encourage a child's imagination. The materials do not over-constrain or over-determine. Children with different interests and different learning styles can all use the same materials, but each in his or her own personal way.

In developing technologies for older learners, we try to achieve a similar effect. Our guiding principle is "many paths, many styles" – that is, to develop technologies that can be used along many different paths, by children with many different styles. Too often, educational technologies are overly constrained, such as tutoring software for teaching algebra, or simulation software for modeling planetary motion in the solar system. Our goal is to provide tools that can be used in multiple ways, leaving more room for children's imaginations.

When my research group developed Cricket technology, for example, we explicitly tried to broaden the range of projects that children could create [15]. Crickets are small programmable devices, small enough to fit in the palm of a child's hand. Children can plug motors, lights, sensors, and other electronic blocks into a Cricket, then program their creations to spin, light up, and play music. Children have used Crickets to make a wide range of imaginative creations. For example, a group of girls at an after-school center in Boston used Crickets and craft materials to create an interactive garden, with flowers that danced and changed colors when you clapped your hands. At a workshop in Hong Kong, a 12-year-old boy created a wearable jukebox that played different songs when you inserted different coins, and an 11-year-old girl added lights to her boots and programmed them to turn different colors based on the pace of her walk, as measured by sensors that she attached to her boots (see Figure 2).

Cricket kits are similar, in many ways, to the Mindstorms robotics kits developed by the LEGO toy company, in collaboration with my research group. But there are important differences. While Mindstorms kits are designed especially for making robots, Cricket kits are designed to support a diverse range of projects combining art and technology. Cricket kits include not only LEGO bricks and motors but also a collection of arts-and-craft materials, colored lights, and a sound-box for playing sound effects and music. By providing a broader range of materials, we hoped to encourage a broader range of projects – and spark the imaginations of a broader range of children. In particular, we aimed to encourage broader participation

among girls. Even with strong efforts to increase female participation, only 30% of the participants in LEGO robotics competitions are girls [9]. In Cricket activities at museums and after-school centers, participation has been much more balanced among boys and girls [16].

As we develop new technologies for children, our hope is that children will continually surprise themselves (and surprise us too) as they explore the space of possibilities. When we created Crickets, we didn't imagine that children would use them to measure their speed on rollerblades, or to create a machine for polishing and buffing their fingernails. To support and encourage this diversity, we explicitly include elements and features that can be used in many different ways. The design challenge is to develop features specific enough so that children can quickly learn how to use them, but general enough so that children can continue to imagine new ways to use them [14].

Figure 2: Projects from a Cricket workshop

CREATE

Create is at the root of *creative thinking*. If we want children to develop as creative thinkers, we need to provide them with more opportunities to create.

Friedrich Froebel understood this idea when he opened the world's first kindergarten in 1837. Froebel filled his kindergarten with physical objects (such as blocks, beads, and tiles) that children could use for building, designing, and creating. These objects became known as Froebel's Gifts. Froebel carefully designed his Gifts so that children, as they played and constructed with the Gifts, would learn about common patterns and forms in nature.

In effect, Froebel was designing for designers – he designed objects that enabled children in his kindergarten to do their own designing. Froebel's work can be viewed as an early example of Seymour Papert's *constructionist* approach to education [11], which aims to engage learners in personally-meaningful design experiences.

In creating his Gifts, Froebel was limited by the materials available in the early 19th century. With today's electronic and digital materials, we can create new types of construction kits, expanding Froebel's kindergarten approach to older students working on more advanced projects and learning more advanced ideas. With Mindstorms and Crickets, for example, children can create dynamic, interactive constructions – and, in the process, learn concepts related to sensing, feedback, and control.

I view Mindstorms and Crickets as Froebel's Gifts for the 21st century, using new technologies to extend the kindergarten approach to learners of all ages. Unfortunately, they are the exception rather than the rule in today's toy stores. Most electronic toys are not in the spirit of Froebel's Gifts, since they do not provide children with opportunities to design or create. Most of today's electronic toys are pre-programmed by the toy company. Children cannot design or create with these toys, they can only interact with them; for example: hold the doll's hand and its mouth turns to a smile, sing to the doll and it starts dancing. I am sure that designers and engineers at the toy companies learn a great deal while creating these toys, but I doubt that children learn very much while interacting with the toys.

PLAY

Piaget famously proclaimed that "Play is the work of children." Certainly, play has been an integral part of the traditional kindergarten approach to learning, and most adults recognize the importance of providing young children with opportunity to play. But as children grow older, educators and parents often talk about play dismissively, referring to activities as "just play," as if play is separate and even in opposition to learning.

In my mind, play and learning can and should be intimately linked. Each, at its best, involves a process of experimentation, exploration, and testing the boundaries [19]. Unfortunately, many recent attempts to link play and learning are at odds with the kindergarten approach to play and learning. Consider the recent focus on "edutainment" products. Creators of edutainment products tend to view education as a bitter medicine that needs the sugar-coating of entertainment to become palatable. They provide entertainment as a reward if you are willing to suffer through a little education. Or they boast that you will have so much fun using their products that you won't even realize that you are learning – as if learning were the most unpleasant experience in the world.

I also have a problem with the word "edutainment" itself. When people think about "education" and "entertainment," they tend to think of them as services that someone else provides for you. Studios, directors, and actors provide you with entertainment; schools and teachers provide you with education. Now, edutainment companies try to provide you with both. In all of these cases, you are viewed as a passive recipient. If we are trying to help children develop as creative thinkers, it is more productive to focus on "play" and "learning" (things you do) rather than "entertainment" and "education" (things that others provide for you).

Spurred by the extraordinary popularity of video games in youth culture, a growing number of researchers have begun examining how and what children learn as they play video games [4]. There is no doubt that children learn many things when they play video games, and children exhibit a deep sense of engagement that is all too rare in school

classrooms. But, with a few notable exceptions, such as the Sim series games and Shaffer's "epistemic games" [18], currently-available video games do not support kindergarten-style learning. Even games that engage children in strategic thinking and problem solving provide few opportunities for children to design and create, a key ingredient in the kindergarten approach to learning.

How can we use new technologies to integrate play, design, and learning? One way is to provide children with the opportunity to design their own games. In her book *Minds in Play*, Yasmin Kafai [7] documents how elementary-school students become more creative thinkers as they design their own games. More recently, my research group teamed up with Kafai to develop a new programming language, called Scratch (http://scratch.mit.edu), that enables children to create not only games but also interactive stories, animations, music, and art [13]. In designing Scratch, one of our key goals was "tinkerability" – that is, we wanted to make it easy for children to playfully put together fragments of computer programs, try them out, take them apart, and recombine them. To create programs in Scratch, you simply snap together graphical blocks, much like LEGO bricks or puzzle pieces (see Figure 3). You don't need to worry about where to put semi-colons or square brackets: the blocks are designed to fit together only in ways that make sense, so there are no "syntax errors" as in traditional programming languages. You can even add new blocks as the program is running, so it is easy to "play with your code," testing out new ideas incrementally and iteratively.

Figure 3: Scratch programming blocks

SHARE

At an educational-technology workshop a few years ago, participants were asked which of the following learning experiences had been most difficult for them:

- Learning to ride a bicycle
- Learning to write a computer program
- Learning to share

An overwhelming majority selected "learning to share."

Sharing has always been an important part of the creative process in kindergarten, but the ability to share and collaborate has generally received less emphasis in later years of schooling. That has started to change recently, as a result of several independent but converging trends, all of which are pushing schools to pay more attention to sharing and collaboration:

- Business leaders and policy makers, noting that teamwork is more important in today's workplace than ever before, have encouraged schools to put more emphasis on collaboration to help prepare students for their future jobs
- Educational researchers, building on foundational work of Vygotsky, have focused more attention on the social nature of learning and strategies for supporting communities of learners [8]
- The proliferation of interactive technologies and widespread access to the Internet has led to a flourishing of what Henry Jenkins [6] calls a "participatory culture" – in which people actively create and share ideas and media with one another on blogs and collaborative websites like Flickr (for photographs) and YouTube (for videos).

Our Scratch programming language aims to build on these trends, making sharing an integral part of the programming process. Even in today's participatory culture, very few people are creating and sharing *programmable* media (such interactive characters and interactive games). While online worlds like Second Life make it relatively easy to create and share graphical objects, making those objects dynamic and interactive requires some form of programming, and traditional programming languages have had a steep learning curve. The difficulty in sharing programmable media has been one of the critical limiting factors in previous efforts to engage children in programming. In a critique of the Logo programming language, for example, Marvin Minsky [10] noted that Logo has a great grammar but not much literature. Whereas young writers are often inspired by the great works of literature that they read, there is no analogous library of great Logo projects to inspire young programmers – and no outlets where young programmers can share their Logo projects with others.

To overcome these limitations, the Scratch programming language is interwoven into a website that provides both inspiration and audience. Children can try out projects created by others, re-use and modify code from those projects, and post their own projects for others to try. The goal is a collaborative community in which children are constantly building on and extending one another's work with programmable media. We have found that construction and community go hand-in-hand in the creative process: children become more engaged in the construction process when they are able to share their constructions with others in a community, and children become more engaged with communities when they are able to share constructions (not just chat) with others within those communities.

REFLECT

The kindergartens in Reggio Emilia, Italy, are a mecca for researchers and educators interested in kindergarten. People making the pilgrimage to the Reggio schools

invariably come away impressed with the organization of the space, the availability of diverse materials for experimentation and creative expression, the support of collaborative activities. But for me, the most impressive part of the Reggio kindergartens is the way they encourage children to reflect on what they are doing. Children in Reggio are constantly producing drawings and diagrams as they work on projects. Teachers use these artifacts to engage the children in discussing and reflecting on their design process and thinking process. The classroom walls are filled with children's drawings, with teachers' annotations, providing children a way to look back at earlier stages of their work.

Such reflection is a critical part of the creative process, but all too often overlooked in the classroom. In recent years, schools have adopted more "hands-on" design activities, but the focus is usually on the creation of an artifact rather than critical reflection on the ideas that guided the design, or strategies for refining and improving the design, or connections to underlying scientific concepts and related real-world phenomena.

As we introduce new technological tools like Crickets and Scratch, we make a special effort to engage children in reflecting on the process of design. We explicitly talk about the spiral of imagine-create-play-share-reflect-imagine, and look for ways for children to use and communicate these ideas. At the end of a two-day workshop using our Cricket technology, for example, my colleague Bakhtiar Mikhak asked the 12-year-old participants to write down "tips" for children who would be starting a similar workshop the next day. The children provided the following tips:

Start simple
Work on things that you like
If you have no clue what to do, fiddle around
Don't be afraid to experiment
Find a friend to work with, share ideas!
It's OK to copy stuff (to give you an idea)
Keep your ideas in a sketch book
Build, take apart, rebuild
Lots of things can go wrong, stick with it

These tips capture some of the core elements of the kindergarten approach to learning. We see it as an important indicator of success when participants in our workshops not only practice a kindergarten approach to learning but also understand and articulate the core ideas underlying the approach.

IMAGINE

Iteration is at the heart of the creative process. The process of Imagine, Create, Play, Share, and Reflect inevitably leads to new ideas – leading back to Imagine and the beginning of a new cycle..

We try to apply these ideas to ourselves, in my research group, as we develop new technologies like Crickets and Scratch. We never expect to get things right on the first try. We are constantly critiquing, adjusting, modifying, revising. The ability to develop rapid prototypes is critically important in this process. We find that storyboards are not enough; we want functioning prototypes. Initial prototypes don't need to work perfectly, just well enough for us (and our users) to play with, to experiment with, to talk about. We'll build a prototype, play with it ourselves, watch some children play with it, talk with them about it, talk among ourselves about it – and then quickly build a new prototype.

When children use our technologies, we encourage them to go through the same process. It doesn't matter whether they are creating an animated story or building an interactive sculpture. In all cases, our message is the same: iterate, iterate, and iterate again. Time, of course, is essential in this process. If children have enough time to go through the cycle only once, they'll miss out on the most important part of the creative process.

The process of becoming a creative thinker is itself an iterative process. Historically, kindergarten has provided a good foundation for creative thinking. Think of kindergarten as the first time through the creative-thinking cycle. Unfortunately, after leaving kindergarten, children have not had the opportunity to iterate on what they learned in kindergarten, to continue to develop as creative thinkers. By extending the kindergarten approach, we hope to provide opportunities for learners of all ages to build on their kindergarten experiences, iteratively refining their abilities as creative thinkers throughout their lives.

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