The Curiosity Cycle: Preparing Your Child for the Ongoing Technological Explosion

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Preface

Technology is rapidly changing our society, and this dynamic environment will provide opportunities for those with the flexible and adaptive thinking that come with curiosity. Creating curiosity is about creating anticipation. Novelists know this; they foreshadow events by giving hints of what is to come. Sports producers also know the value of curiosity. During the hype before the big game, they talk about the history of the teams and players, and they analyze how the players on the opposing teams match up to each other. Like novelists and sports producers, we have the ability to spark curiosity in our children. We can get them excited about the topics that will ensure their success and define their future.

In addition to being curious about the external world, children must understand how their internal emotional states affect their thoughts and behavior. They need to know that their own thinking is sometimes flawed and that impressions of the outside world can be distorted in their minds. Children also need to understand the social environment in which they are enveloped, and they must be able to recognize and predict the thought patterns of those around them. Compounding this complexity, our culture is increasingly being inhabited by smart machines, and our little social and emotional creatures must be adept at interacting with computers, which have alien thought patterns that are neither emotional nor social. Computers are becoming increasingly skilled at performing simple computations on the events and objects of real life, but they still need human creativity and curiosity to guide them. This book will help you to prepare your child to be mentally, emotionally, and socially ready for this environment.

Kids are under pressure to excel in school, and I believe that they spend too much time in the classroom learning how to do well on tests. The principles presented here will help your child achieve an intelligence that is broader than test scores. The goal is not to push kids harder, but to create a curiosity within them so that they are intrinsically and internally motivated to go out and acquire knowledge. The title of this book references curiosity instead of success or intelligence because the goal is to give children internally driven curiosity. Everything else follows naturally.

Is it even possible to teach a child to be curious? A recent book titled *Freakonomics* pointed out that activities such as taking kids to museums and reading to them are not enough to improve academic progress. The authors suggest that raising intellectually successful children is based on who you are, not what you do. I agree that taking kids to museums is not enough; I propose that it is *how* you take them to museums that matters. Vince Lombardi said: "Practice doesn't make perfect. Perfect practice makes perfect." It is not just about exposing your child to culture—it is *how* you expose your child to new ideas and *how* you interact with your child. The Curiosity Cycle points the direction toward that "how."

You will find that the approach I offer is different from most books about raising intellectual children. The principles presented here were developed while I was researching the question of how to build smart robots. My Ph.D. research was an interdisciplinary effort between robotics and developmental psychology, and I worked toward enabling robots to learn about the world in the same way that human children do. This research took me deep into the current literature on developmental psychology with the goal of developing a set of *actionable* principles that could be articulated and implemented on a robot. These principles form the foundation of this book. Children are not robots, but they both face the same problem of learning in complex environments. Viewing the minds of our children as computation machines provides insight that can make us better teachers.

This book targets parents of young children (from birth until about 10 years old), but my hope is that anyone interested in either human or artificial cognition will enjoy reading about the principles covered here. Where there was a trade-off to be made between scientific rigor and understandability, this book errs on the side of understandability.

I love thinking about our origins and watching the world change toward our unknown future. As our children move into this future, both the world and their roles within it will be constantly changing. This constant change means that the ability to learn will be more important than intelligence. My goal in this book is to show how children can become lifelong learners.

Chapter 1

Introduction

We learn by building models. Models enable us to understand the world and act within it, and our early models form the foundation upon which subsequent knowledge and skills are learned [87, 20, 70]. For example, after a child has mastered the skill of walking, that child soon learns the model that door knobs must be rotated to open doors. This model consists of the identified door knob and the rotation action needed to work it. On the way to mastering the skill of opening doors, the child will first learn an incomplete model that specifies only that door knobs are involved in opening doors without saying how. With this incomplete model, the child won't be able to reliably open doors, but the child will have just enough knowledge to be fascinated by them. It is these incomplete models that lead to curiosity.

Incomplete models are what motivates agents to explore and learn about the environment in computational theories of developmental learning [84]. If you know everything about a situation, there is nothing to learn and nothing about which to be curious. Conversely, if you know nothing about a situation, you can't make any sense of it and so will ignore it. When children ask why fire engines have sirens, we explain it to them, but they still only partially understand, and their models improve but remain incomplete. These incomplete models lead to a whole series of new questions, such as, "Why do the other cars need to get out of the way? Why do they have to get to the fire fast? Why? Why? Why?"

This book uses incomplete models to build a framework for thinking about curiosity called *the curiosity cycle*. In the curiosity cycle, children individuate concepts from the environment, such as door knobs and fire engines, and they use these concepts to build models, such as the model that door knobs open doors. Children then test these models to see how well they predict the environment, and through this process of testing, children learn new models and concepts leading to the next round of the cycle. For example, a child may try to open a door and find that it does not budge. This experience will lead to the new concept of a locked door. Further experience will show that a locked door can be opened if Mom or Dad has the key. In this way, new concepts lead to new models, and new models, by virtue of often being incomplete, lead to more curiosity.

The curiosity cycle, through the process of individuating concepts, building models, and testing models, allows children to construct a *web of knowledge* that encodes everything they know about the world. We can think of knowledge as a bunch of individuated concepts and a set of models that define the relationships between them. With the curiosity cycle, knowledge forms a web because the concepts are linked to each other through models, and the models are linked to each other through concepts that exist in multiple models.

A benefit of having knowledge organized in a web is that new knowledge can build on previously learned knowledge. Once children learn one thing, they can use that idea to learn other things. For example, a child quickly learns that the ringing of a telephone means someone is there waiting to talk. When this child moves into an office environment, the now young adult can build on that concept of ringing to learn that a ringing of the telephone that repeats two short rings indicates an outside call, and a ringing that repeats one long ring means an inside call. This model cannot be learned without first knowing the concept of ringing and then building on that concept to distinguish between repetitions of two short rings and one long ring. Trying to predict who might be calling raises a question that is partially answered by learning to distinguish between these two types of rings.

Using models to predict the environment is crucial to the curiosity cycle because testing improves models. Beyond improving models, the mindset of seeing the world through prediction has the benefit of allowing your child to view knowledge as tentative. Knowing that you might be wrong is the first step toward undoing an assumption and finding the right solution to a problem. Considering knowledge to be tentative cuts down on mistakes from not realizing that things could be another way. It leaves your child open to learning new things, and this can continue throughout life. Children must always be aware that some of what they know could be wrong—probably is.

A consequence of learning through prediction is that even an *incorrect* model is better than no model. We need models to predict the environment because models give us hypotheses to test, and the results of these tests allow us to learn. Of course, Mark Twain once said, “It ain’t what you don’t know that gets you into trouble. It’s what you know for sure that just ain’t so.”[1] I believe this is true. When it comes to *decisions*, it is crucial to know that your model may not always be correct and to take that into account. But when it comes to *learning*, an incorrect model can be a useful place to start. We will also see in Chapter 3 that incorrect and incomplete models are also a good place to start when problem solving.

Another consequence of accepting incomplete models is that learning a little about something goes a long way. We have a tendency to avoid learning only a little about a topic, maybe because it makes us feel ignorant. But if we do learn even a little, we will have concepts and partial models that can keep accumulating over time as new information arrives. Without these partial models and concepts, we just ignore that incoming information and opportunities for learning are wasted. The result of the curiosity cycle is that the more your child knows, the more curious he or she becomes.

Learning through curiosity leads to adaptive thinking because your child is constantly trying to improve his or her models, and new ideas become embedded in the knowledge that your child already has. This type of learning means that your child doesn’t just know facts by rote; he or she has models for why things are true and sees how they relate to everything else that he or she knows. These models can then be adapted when the situation changes. There is an old story [88] about a group of people in India who would trap monkeys using

[1] `http://marktwainblog.org/`

an emptied-out coconut filled with rice. The coconut had a hole that was large enough for a monkey to put its hand into but was too small for the monkey to pull its hand out with a fist full of rice. The trappers would attach this coconut to a stake. The monkey would come, put its hand into the coconut, and as the people came to capture it, the monkey would be trapped by its own brittle thinking. Its thinking was not adaptive enough to reevaluate the situation and realize that it should let go of the rice.

To further illustrate this idea of adaptive thinking, assume that x stands for the value of something in the environment that we care about, like the number of tacos in the refrigerator. Let's also say that your child and another child both know that $x = 8$. The other child has a shallow understanding and just has it memorized that $x = 8$. But if your child has a deeper understanding, he or she will have a model that determines where the value of x comes from, such as the simple model of $x = y + 3$, where y is the number of tacos delivered by truck and 3 is the number of tacos made on location each morning. Imagine that normally $y = 5$ because there are 5 tacos delivered by truck, but your child notices that the truck delivery y has increased by 1. Your child will instantly know that $x = 9$, but the other child will still think that $x = 8$. Also, your child will always be on the lookout for a better model, so if the world changes and the model $x = y + 3$ no longer holds on Saturdays, and now, on Saturday, $x = y + 6$, your child will notice and adapt his or her taco consumption accordingly.

As a more concrete example, I once took a linear algebra class in which everyone had done well on all the tests leading up to the final exam. Based only on previous experience, one would conclude that the final exam was going to be easy as well. But, by relating this information to other information, we know that not everyone can receive an A and the professor needs a separation of grades. Using this understanding, we come to the opposite conclusion: Since currently everyone is doing well in the class, and since there isn't much separation in the grades, the final exam will be especially difficult. It was.

In addition to enabling adaptive thinking, curiosity will enrich your child's life. Curiosity-driven learning makes learning more interesting because your child has a place to put new facts. Your child doesn't have to try to remember a bunch of unrelated ideas; everything fits together and is linked to what he or she already knows. Memorization is tedious, and it is easier to integrate new information when that information "makes sense" based on the concepts and models that your child already has.

To illustrate this point, consider the old experiment where both experienced chess players and novices were shown chess boards with pieces on them, and both groups were asked to later remember the locations of all the pieces [21, 94]. Experts performed better at remembering the locations of the pieces, presumably because they understood what they saw using their web of knowledge about chess. However, there was no difference between the groups in the ability to recall piece locations when the experiment used chess boards that were not from actual games (that is, when the pieces were just randomly placed on the board). In this case, the experts could not use their web of knowledge to interpret what they saw.

Each model that your child creates is like a little bet on how the world works, and these little wagers keep life entertaining. People who play fantasy football say that it adds another dimension to watching football games. You make a bet (by choosing who is on your fantasy team) and then see how it plays out. The little bets we make in life are often practical as well as entertaining, and air travel is one area where people enjoy pondering the many mysteries. For example, having an open seat next to me on flights is important so I can be comfortable and productive. I created a model that there are more open seats in the back of the plane because people generally prefer to sit up front to exit the plane faster. To test this model, I started sitting in back and found that indeed it does seem to improve the probability of having extra work space.

Besides making life richer, curiosity-based learning is internally directed and intrinsically motivated [83]. This internal focus means that we gain a sense of freedom from living this way. In school, your child will actually care about the subject being taught. Because the curiosity cycle is running, your child will want to use the subject material to help complete some of his or her models, much like a baseball card collector wants to complete a set. And because of this curiosity, it won't feel like work. Your child will feel like a free and natural human being doing what he or she wants to do.[2] This sense of freedom will continue into your child's career.

Curiosity can enrich our children's lives and endow them with adaptive thinking, but our children must also direct curiosity toward themselves as much as the outside world. Our brains are not perfect computation machines; they are organs with limited capacity for computation and memory, and they are subject to cognitive biases. Our children must learn how to properly use their brains

[2]There is a great discussion about being engaged in a subject you are learning about in school in *Zen and the Art of Motorcycle Maintenance* by Robert M. Pirsig.

so that they can recognize their biases and limitations. One of our limitations is that we are prone to cognitive laziness and reliance on instinct [49]. Going with our gut is often good enough, but our children need to learn that there are times when they must stop and think and actively use their brains. One such situation when self-reflection is called for is when we become emotional. During these times, self-awareness is critical to maintaining our equanimity.

Children also need to understand that our brains are coupled with our bodies in a unified system. The movement patterns of our bodies form the foundation of our knowledge [60], and this is partly why unstructured play is so important. Even mathematics is grounded in physical experience. We comprehend addition and subtraction as increases or decreases in the number of items in collections of objects [61]. Addition is adding items to the collection of teddy bears, and subtraction is reaching out and taking stuffed animals away.

Our children must also learn to continually examine the society in which they live and its affects on them. Sometimes, the effect of those around us is overwhelming. Later in the book, we will see that normal people like you and me are willing to administer dangerous levels of electric shock to innocent people just because an authority figure tells us to do so. In our everyday lives, companies exploit our cognitive weaknesses to sell us more and more, and fraudsters are particularly skilled at turning our own cognition against us.

To combat negative outside influences, our children need self-awareness and the ability to think for themselves. With the advance of new communication mediums surrounding the Internet, it is now increasingly difficult to shelter children from opinions that we find objectionable. Children must be able to filter the cacophony of voices in cyberspace to stay true to their own values.

Our children must also be prepared for the profound effect computers are having on our society. Unlike previous inventions, computers are more than machines that make particular tasks easier; they are general-purpose machines that can be programmed to do anything, and their usefulness is limited only by the creativity of the designer. This means that the success of our children will be determined in part by their ability to create new artifacts with computers.

The artifacts that our children create need not be physical because information is replacing physical goods as stores of value. The algorithms used to program computers are information, and even physical objects are now principally information. Prescription drugs are a good example of this. Sometimes you go to the register and it costs $4, and other times it costs $140. This disparity results because you are being charged for the information needed to make the pill, not the materials in the pill. This shift from physical objects toward information was first evident in documents. It used to be that documents were stored in filing cabinets, and electronic copies were just copies of the "real" document. But now it's the reverse; the permanent document is electronic, and we can create paper copies if we wish.[3] Continuing this trend, there are now 3D printers that can print physical objects such as bottle openers from information similar to how ink-jet

[3]Benjamin Kuipers pointed out this shift in documents to me.

printers print drafts of word processing documents.[4]

These changes brought by computers are reshaping the employment landscape. As they become more capable, computers will likely be able to do just about any job that does not require creativity. This eventuality adds extra urgency to the need for children to be able to think for themselves and become lifelong learners. On an even larger scale, these changes are reshaping how we live our lives. It is easy for us to be passive consumers because we are now bombarded with more entertainment options than ever. The ease with which we can live our lives in a perpetual state of entertainment means that our children are in danger of defining themselves as passive consumers instead of active creators. Curiosity can help your child avoid this quicksand.

[4]Last Christmas, our gift to my sister and her husband was a bottle opener printed on a 3D printer `http://www.shapeways.com/model/321931/klein-bottle-opener.html`.