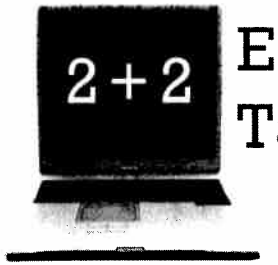


Euclid Would Have Taught Math This Way

Observation A: Schoolchildren in the United States (and several Western European countries) are consistently outperformed in international comparison tests of mathematical ability. Teachers complain that many students appear uninterested in the subject and are unmotivated to make the effort necessary to progress in developing computational skills, problem solving ability, or an understanding of basic mathematical concepts. "They simply do not seem willing to put in the effort to learn some skills that could be of real use in their adult lives," is an often-heard remark.

Observation B: The vast majority of schoolchildren in the United States and those same countries—97% according to the Pew survey—spend many hours each week playing video games. (So too do over 50% of adults, according to Pew, but my present focus is on schoolchildren.) During the course of that game play, they may acquire a vast amount of knowledge about the imaginary world portrayed in the game, they will often practice a skill many times until they are fluent in it, and they will perform a particular action (such as manufacturing an artifact or killing a particular kind of beast) repeatedly in order to complete a quest and thereby advance in the game.

If you were put in charge of reorganizing education to solve the problem highlighted in Observation A, what would you do? If you don't immediately connect Observations A and B, and think, "Use video game technology to teach basic school mathematics," then you probably have not played any good video games, and you almost certainly have a wildly inaccurate conception of what the best and most popular of those games involve.

In this book, I am trying to convince you that the solution to the problem of unsuccessful and unmotivated students of mathematics is to make extensive—and yes, I mean extensive—use of video games in mathematics education. In fact, I am going to claim much more than that. Video games are not just a way of resolving a current crisis in mathematics education. Nor does their use in mathematics education amount to "selling the subject short," "dumbing down the material," or "pandering to the latest technology craze." Rather, for a whole range of reasons I enumerated in Chapter 2, immersive virtual worlds are in fact the ideal medium for developing basic mathematical skills and understanding, and video games are an ideal way to make use of those environments to help students learn mathematics.

Just as the invention of the printing press in the fifteenth century made it possible for everyone to acquire basic literacy, so too future generations will recognize the development of video game technology in the early twenty-first century as the time when a technology appeared that enabled everyone to acquire basic mathematical ability. Recall that by "everyday math" or "everyday mathematical ability" I mean, in general, the mathematics that is taught—or *should* be and is *supposed* to be taught—in the elementary and middle grades of schools to children 5 through 14 years old. This includes basic number concepts, arithmetic, arithmetical relationships, multiplicative and proportional reasoning, numerical estimation, elementary plane geometry, basic coordinate geometry, elementary school algebra, quantitative reasoning, basic probability and statistical thinking, logical thinking, algorithm use, problem formation (modeling), problem solving, and sound calculator use. (For reasons I will make clear later, I believe that video game technology is completely unsuited to teaching more advanced mathematics—though it can play a significant role in education at that level. My present focus is exclusively on everyday math.)

I would note that if you have managed to get along in life well enough without mastery of this everyday math, then that may simply reflect other strengths you have, but in the future faced by today's children, everyday math is going to be even more important for good citizenry than it is today.

A New Approach

I have already emphasized that it's not enough to read about video games. They must be experienced. That's why I keep urging you to go out and get a good video game (e.g., my favorite game, *World of Warcraft*) and play it. One of the most difficult lessons to learn for those of us who were successful in learning primarily through books and lectures is that games are all about experience; they can be understood only by playing them. Good video games present the player with a considerable intellectual challenge. In the true sense of the word, they are all about

learning. It's just that the learning process involved in playing a good video game does not resemble what we traditionally think of as "education." Using games to teach mathematics is not about combining longstanding pedagogy of mathematics education with game technology; it is about using games to teach mathematics in an entirely different way. Admittedly, not all parts of elementary mathematics lend themselves naturally to learning in a game environment, and more advanced aspects of the subject definitely do not. But most of the mathematics typically taught in grades one through eight can, I believe, be learned faster and better with the aid of a properly constructed game than by more traditional methods.

I claim that using video games is the way Euclid would have taught basic mathematics had that technology been around in ancient Greece. This is not to say he would not have written *Elements*. For the benefit of my non-gamer readers, I should observe that many video games incorporate lots of on-screen text that the player must read to progress, and rapid advancement in many games requires the player to read pages of printed supplementary material as well. I suspect that Euclid's video game would have been no exception. Good video games do not replace reading; they supplement it, and often depend on it. And they don't replace the teacher either. Rather, they add a fourth leg to the existing educational support stool of teacher, textbook, and family and friends.

My remarks above were directed primarily at teachers and parents, my principal readers. But in writing this book I have a second audience in mind: the gamers themselves, for whom this book might act as a hook to draw them into the concept of video games as an educational medium. If you are a school-aged gamer, then unless you have somehow managed to survive your mathematics education so far to the point where you have a fairly good understanding of what mathematics really is, you will not be able to appreciate my claim that video games are the perfect medium to teach mathematics. "Oh no, they're going to make me play a video game where I have to keep stopping to solve math problems," you probably think. "What a drag." Well, actually, I *am* going to propose that you play games that involve solving math problems, but that doesn't mean anything like what you think it does, and you certainly won't have to stop playing the game to do the math. This is where the kinds of game I have been investigating differ dramatically from the rather dismal current crop of math ed video games on the market.

The fact is, no matter how many hours you've spent playing games—and even if you've had some experience with a video game that claims to teach math—you have not experienced a game that has been constructed to teach mathematics the way mathematics should be taught. You won't have done that for the simple reason that there are as yet no such games. Developing them, in particular, getting them right, is going to take some time. The few "math games" available today come nowhere close to achieving the potential that the medium offers. Once good

math games have been developed, however, they will change fundamentally the popular conception of what mathematics is. For my gamer audience, then, I shall in the pages that follow try to explain the nature of mathematics in a way that I hope makes clear why basic mathematics and video games were made for each other. Conversely, it will become clear how and why much of the difficulty many people have learning mathematics stems not from a lack of innate ability, but from the unsuited and therefore grossly inadequate means we have historically had at our disposal to teach mathematics (see Chapter 3).

Directing my attention back to mathematics teachers, let me come right out and say it as I see it. In my opinion, the time is not very far away when anyone in the business of teaching mathematics at school level will have a professional duty to become familiar with video games. Not to do so will soon be akin to trying to teach English without being able to read. Besides explaining why this is the case, I will also spend a lot of time in this book showing you how you will be able to use video games to help students learn mathematics. True, we are not there yet; the current generation of games is still focusing on the low hanging, basic skills fruit. But that will change, and when that change finally comes it will be significant. Admittedly, I'm taking a positive view that it will happen. I do, however, see a danger that with so many skills-focused games now being produced, there may be a backlash against any use of video games when the current crop of games is found to make little difference to the development of real mathematical thinking, as will surely happen.

Finally, a third audience I have in mind for this book comprises professional game developers who want to try their hand at a mathematics-related video game. Although I am myself not a game developer, I have learned a lot about the game development process over the past seven years, and have talked at length with some very good game designers. As a result, I have a perspective to provide you, the game developer, with knowledge and insights into mathematics and mathematics education to help you build better math-related games, should you decide to venture into that territory. There is good reason to try. The field is wide open for good games that go beyond basic skills and develop mathematical thinking. Just be prepared for a long and challenging development process. The rewards will be sweet, but there is probably no shortcut to get there.

If game development tools continue to improve at their present rate, it won't be too long before all of the audiences I just mentioned start to overlap, with teachers, students, and parents all designing, if not complete games, then mathematical activities to embed in off-the-shelf educational game platforms. The same has already happened with video production, of course, with many teachers and students now creating and editing videos, either with a camera or a drawing tool.

For this reason, some of my discussions will be directed at a reader who wants either to build a math ed video game or to design a mathematical activity to embed in a game someone else is developing. For readers who have no such intention, those discussions will amount to observations about curriculum and pedagogy. In particular, I believe, along with Gee, that we teachers have a lot to learn from what makes a good video game work. Whatever perspective and experience we bring to the design and use of video games in mathematics education, a key distinction we need to understand is between factual knowledge and knowing how to do something.

Knowing How versus Knowing That

Even I have to admit that the title of this chapter is pretty audacious. Would Euclid really have taught math using video games? This is *Euclid* for heavens sake. One of the pillars of human mathematical development. Let me explain. It comes down to the questions "What is learning?" and "What is the purpose of learning?" I'll set the scene for my answer by describing two people to you.

Alistair MacIntyre has spent most of his adult life as a paramedic working for a large oil company in Saudi Arabia. In the remote desert region where he is based, he provides the only regular medical service for thousands of square miles, and routinely finds himself having to diagnose illnesses and to perform emergency surgery, as a result of which he has become highly skilled at both.

Roger Palmer is an insurance assessor, but from early childhood he has always wanted to be a doctor. In his spare time, he reads every medical textbook he can lay his hands on. Blessed with an excellent memory, by the time he was in his mid-thirties his medical knowledge was prodigious. Of course, since he does not possess a medical qualification, he has never been able to practice.

Suppose you find yourself stranded on a remote island and you become ill or need surgery. If chance were to bring one of these two individuals to your aid, which would you prefer? (Both characters are fictitious by the way, though my younger brother fits the description of Alistair.) I am pretty sure that, like me, you would much prefer it to be Alistair. You would put a much higher value on years of experiential learning than on factual book learning. Alistair might not know all the medical terminology, but over the years of actually practicing medicine, he has developed great skill as a medical practitioner. He could recognize various symptoms and know what to do. Roger's knowledge, on the other hand, is all theoretical.

Of course, it would be even better to have both present. To have Alistair treat you, but have him talk over your symptoms with Roger. And in practice, this is more or less what we get when we visit a real medical practitioner. To become qualified to practice medicine, an individual first has to take many courses and

pass a barrage of examinations, gaining Roger-type *knowledge*, and then has to spend several years as an intern, under supervision, acquiring *experience* on the job, like Alistair.

The purpose of those initial years of classroom learning that medical students undergo is to accelerate, dramatically, the length of time it takes to reach an adequate level of ability to practice medicine. Without that concentrated burst of theoretical knowledge acquisition in the beginning, it would take many years of practice, working alongside an expert, to achieve a similar level of ability. That's why we do not train doctors by an apprenticeship system, like the craftsmen of old. It would take too long. But notice that the acquisition of theoretical knowledge here is a means to an end, not the end itself. Knowing medical facts is certainly important for a doctor, but in the end what we look for when we seek medical assistance is that the doctor does something for us. Ultimately, what is important is knowing *how to do things*, not merely knowing facts.

And the same is true for any form of education. The purpose of learning a foreign language is not to accumulate a body of facts about that language, but to be able to understand it, to read it, and to speak it, in order to communicate with others or to live in a foreign country. The purpose of studying architecture is to design buildings or other spaces for living. The purpose of learning physics is to be able to do physics. And the purpose in learning mathematics is to be able to do mathematics. Mathematics is primarily about doing, not knowing. This is not to say that a person who studies architectural design or physics or mathematics has to go on to be a professional architect, physicist, or mathematician. The abilities acquired from that learning can be used in many different professions and circumstances, sometimes indirectly. But even if the only tangible benefit from taking a course in architecture is that you become more aware of the spaces you live and work in, that is of value to you, You are a different person after you complete the course than you were beforehand. Taking the course has transformed you, and you see life differently. But the transformation is a result not of your having learned some new facts, but because you have learned to look at the world differently and to think a different way. That is what education is about.

I am belaboring this point because many people seem to lose sight of the purpose of education, seeing it as a process where you spend time acquiring facts, at the end of which you take a test to see how many of those facts you have retained. I call this the "filling a bucket" fallacy, which sees education as a process of acquiring a certain amount of educational content. Five bucketfuls this term, five next term, six the next, and so on. Give the student a test to make sure that the bucket is reasonably full after each course, and send him or her on to the next.

Does this sound familiar? It should. It's what most of our current formal school educational system looks like. It's hardly surprising, then, that many people think that is what education is all about. Why have we allowed it to get like that?

Well, for all its faults, the current system does have various things going for it:

1. it can be packaged and offered in a standardized, neatly organized fashion to many students, year after year;
2. it is relatively easy to measure the performance of both of the instructors and the students (as bucket fillers and buckets, respectively)—to "maintain standards" as the politicians keep insisting;
3. it does—or at least can, if done well—provide an efficient means of acquiring and measuring factual knowledge and of acquiring and measuring certain mechanical skills (i.e., skills not requiring a lot of intellectual effort to carry out).

All of these are significant factors, both from the perspective of society and educationally. The common mistake is to think that item 3 is the goal; that education is about the acquisition of factual knowledge and mechanical skills. It is not.

I'll come to the question of mechanical skills in due course. For now, I want to focus on the acquisition of knowledge as a possible outcome of learning, either in mathematics or in any other discipline. The acquisition of factual knowledge—of knowing *that*—is merely a way of speeding up and making more universally available the all-important, life-transformative, knowing *how*. Whether the acquired knowing *how* is related to a career or a profession is irrelevant as far as the purpose of learning is concerned. I am not just thinking about vocational training here. Rather my focus is education and learning in the most general sense. It could be learning to paint, play a musical instrument, be a television talk show host, be an actor, to have greater appreciation of the natural world, or even just to feel more confident that you could do something if you had to—whatever that may be.

Human life is a sequence of doings—of actions performed. As a species, we *Homo sapiens* have evolved various capacities and strategies that ensure our survival, the most characteristic of which being our language facility and our abilities to modify our actions based on reflection about past events, to anticipate future eventualities, to plan future actions both individually and with others, and to collaborate. Each of these fundamental species survival capacities is enhanced by learning. In short, learning enables us to do certain things better. That, ultimately, is what learning is about. It is why (viewed retrospectively) evolution has resulted in our having the capacity to learn.

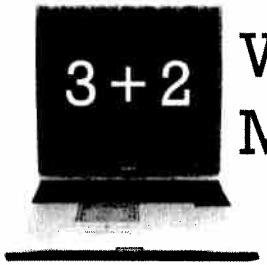
In terms of evolution and species survival, knowing facts is not in and of itself important. Knowing facts is significant only insofar as the knowledge of those facts enables us to do certain things better. After all, books contain many facts, but a book cannot do anything. Humans can know facts and can do things. We can

know something and we can know how to do something. Of the two, knowing how is what really matters to us.

In passing, I note that the aristocratic philosophers of ancient Greece elevated knowledge of facts to an intellectual status symbol. Regrettably, in certain halls of academia and in some sections of society, vestiges of that ancient culture still survive to this day, with people taking pride in seeking and possessing useless factual knowledge for its own sake. But apart from the entertainment value that factual knowledge may offer, knowing *how* is what really counts. And the Greek philosophers did have a purpose in their pursuit of theoretical, factual, and loudly proclaimed as "useless," knowledge. It was to show off to their philosopher colleagues in philosophical debate, and to demonstrate to anyone who cared—themselves for the most part—that they were different from the ordinary folk and able to pursue knowledge purely for its own sake. This is not meant as a criticism. An advanced society gains considerable value from having such individuals around.

To get back on track, knowing *that* is important only because it can help us to know *how*. A society that focused entirely on knowing *that* and paid no attention to the development of knowing *how* would quickly deteriorate. The ancient Greek society lasted as long as it did because it had a large artisan class that knew how to do things. Consequently, the development of knowing *how* should be the focus of education. I'll stress again that this does not mean that the acquisition of factual knowledge should not be part of learning. Sometimes you need sufficient factual knowledge in order to know how to do something. Moreover, knowing facts both is an efficient shortcut to knowing *how* and can be of great help in extending your knowing *how* abilities.

When we sharpen the focus from learning in general to learning in mathematics, the distinction between knowing *that* and knowing *how* becomes particularly dramatic. Mathematics is almost entirely about *doing*; in terms of factual content, the discipline hardly measures on the scale. Euclid knew that. If he had had access to a more efficient medium for teaching students how to *do* mathematics than the textbook, he would surely have used it. *Elements* would then have been at most a supplement to a video game. Hence the title of this chapter.



What Is "Doing Mathematics" Anyway?

It might seem a little odd to raise this question five chapters into a book on mathematics education. After all, doesn't everyone know what doing math is? Well, people generally think they know, but when you ask them, as I have on many occasions, you find that many don't really know, and of those that give a definite answer, those answers often differ from one another and in many cases differ from the answer typically given by professional mathematicians like me. So before I get into more specific details of how video games can be used to enhance mathematics education, we need to make sure we are all on the same page about what we are trying to achieve.

How Much Math Is There to Learn?

I have already made the case that mathematics education should be primarily geared toward *doing*, as opposed to knowing—that it's about acquiring knowing *how* rather than knowing *that*. The amount of material to know is extremely small. Take any term-long mathematics course, from elementary school through the end of high school, and you can write on a single postcard all of the key facts covered. In fact, the same is true right up through the end of the freshman year at a university. I know that from first-hand experience.

I was a high-school student and then a university mathematics major during the 1960s. In those days, every course culminated in a major performance exam, and those examinations had to be taken without any reference materials, which meant that the examinee had to know by heart all of the definitions, facts, and formulas. A typical exam question back then began by asking the student to write