The Orchid and the Dandelion

New research uncovers a link between a genetic variation and how students respond to teaching. The potential implications for schools—and society—are vast.

Laurence Holt

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Marinus van IJzendoorn, one of the world's leading experts in child psychology, is telling me about dandelions. This is unexpected, since I reached him via Zoom at his home in the Netherlands to talk about a breakthrough he has made that has far-reaching implications for school intervention. But his analogy is leading somewhere.

He's 60 and speaks in the flawless, softly accented English that is universal in Holland. When I first saw him, his resting face seemed severe, but as soon as he spoke, he smiled. It's easy to imagine him telling a mother in gentle but assured tones that her troubled child is in fact rather bright.

Dandelions are remarkable organisms. They somehow survive in almost any ecological niche, not by being incredibly hardy but by altering their biochemistry on the fly. Their defining characteristic is adaptivity.

Orchids, not so much. They do badly in most environments, but, in certain conditions, they bloom spectacularly.

Most children are like dandelions, explains van IJzendoorn (the 'J' is silent: *ee-zen-dorn*). They grow to function surprisingly well regardless of their environment. But other children have a harder time. They are prone to tantrums and oppositional behavior, say, or they are constantly distracted. Van IJzendoorn likens them to orchids. They do badly in most environments. But with the right structure, the right support, they do well. In fact, in those circumstances, they do better than the dandelions.

That's a recent view, and one still seen as radical by many in psychology. More typically, oppositional behavior, ADHD, and other cognitive traits such as dyslexia are seen only as deficits, to be identified, accommodated, and treated. Proponents of the orchid theory—which experts refer to by the rather less memorable name of *differential susceptibility,* meaning that people differ in their susceptibility to a particular environment—argue that these traits wouldn't have survived evolution if they only had downsides. That suggests there must be circumstances in which people with these traits, like orchids, have an advantage over dandelions. The metaphor appears to have originated with W. Thomas Boyce, a pediatrician and professor at the University of California, San Francisco, who wrote the 2019 book *The Orchid and the Dandelion* (Knopf). Van IJzendoorn notes it may be imprecise shorthand but has caught on.

In the early 2000s, van IJzendoorn and his colleagues began to wonder if this idea might explain the yawning gaps in children's response to schooling. Perhaps students who do poorly in school are orchids in the wrong environment.

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The question of what to do to help students who are falling behind their peers gnaws away at teachers. "By middle school, a single class could include students whose abilities spread across six grade levels," says David Geary, a professor in the Department of Psychological Sciences at the University of Missouri. Teaching to such a wide span is a challenge. But in elementary school, and especially in reading, where mini-assessments are frequent, catching students as they fall has become a science.

The idea is to gauge students' ability levels and organize them into tiers with increasing degrees of support. For most students, tier one, the regular classroom, is sufficient. For those who need additional support, teachers provide a second tier of more intensive, higher dosage instruction. And for a few students, a third tier of instruction might be needed, adding daily small-group work or one-on-one tutoring. Implementing this three-tier model seamlessly requires coordination and extra staff. But there is evidence that it works for many students.

And that's the funny thing. Whatever intervention is used at the higher tiers, it works—just not much. Reading leveled books works a little, as does learning individual letter sounds or using a reading app on a tablet. The same is true for interventions in mathematics and at any grade level. In the language of the effectiveness literature, 0.1 standard deviations is considered a small impact, 0.3 is okay, and 0.8 is strong. What Works Clearinghouse, a federal database, lists 155 interventions for mathematics with an average effect of 0.1. Academic labs and education vendors create new interventions each year and excitedly commission studies of their effectiveness only to discover that if a new program works at all, it does not work much.

The Dutch researchers studying orchid children thought they knew why. A colleague of van IJzendoorn, Adriana Bus, who earlier in her career authored some of the most influential papers in early literacy, dug into the data. She looked at interventions that gave a student-by-student breakdown. Almost universally, those interventions didn't show what you might expect. Instead of every student improving a bit, they showed some students improving a lot and others not at all. Some even experienced a negative effect—they would have been better off not getting the patterns intervention. When you average across all those students, you wind up with a small positive effect masking a much bigger one for a subset of students. The interesting question isn't "does the intervention work" but "for *whom* does it work?"

Bus reasoned if you could figure out ahead of time which students would respond well to an intervention and only put those students into it, then you would have transformed a weak effect into a stronger one.

But how can you figure out who is going to respond to an intervention before delivering it? This is a bit like the old joke that it is prohibitively expensive to put seatbelts on every train in the country, so let's just put them on the trains that are going to crash. Van IJzendoorn and his colleagues at the University of Leiden thought they could identify which trains would crash: which students would respond best to a specific intervention.

The conventional wisdom was that the wide differences in individual student outcomes in an intervention were essentially random noise. Students (and teachers) have good days and bad days. If you re-ran the intervention, the same students might get different outcomes.

Van IJzendoorn and Bus challenged that. They thought, instead, that genetics could help predict which children would respond strongly to a reading intervention, to find the orchids among the dandelions.

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On Chromosome 11, beyond the supercluster of genes for smell, gliding over a great variety of genes linked to autism and depression, past the famous insulin gene (one of the first discovered), and just before reaching the telomere, or the end of the chromosome, lies one of the most interesting of all genes, named, in the inimitable style of biochemistry, DRD4. It's an unassuming name for an unassuming thing: just a string of DNA letters and then a repeating pattern. These are the instructions to make a receptor, a piece of biomechanical machinery designed for a particular molecule to lock into. DRD4 makes receptors for dopamine, the pleasure molecule.

Not everyone has the same repeating DRD4 pattern. For most people, the pattern repeats four times. For some, it only repeats twice. Still others have three, four, or six repeats, all the way up to 11, though that is vanishingly rare. One in five Americans, and far fewer Asians, has a DRD4 gene with seven repeats, according to a study published in *Human Genetics* in 1996 based on a worldwide sample of 1,300 people. That difference, tiny though it is from the standard four repeats, can make for a very different arc of life. Ellen Greenberger, a professor at the University of California, Irvine, School of Social Ecology, and her team combined genetic data with evidence of ancient migrations. A clear pattern emerged: "The populations that remained near their origins showed a lower proportion of long [seven-repeat] alleles of DRD4 than those that migrated farther away," says Greenberger.

One conclusion is that seven-repeat people are better explorers. Researchers have shown an association between seven repeats and traits including novelty-seeking, risk-taking, and hyperactivity. Perhaps people with seven repeats were more likely to embark on a long, harsh migration. Given the choice between a new experience and a familiar one, seven repeaters tend to prefer novelty. They have learned that, occasionally, they will discover a new experience that beats the old. It may be that the ancient willingness to be more active and to take risks, which were advantages on a 6,000-mile journey 20,000 years ago, expresses itself in modern people as higher activity and a tendency to have your attention diverted—perhaps even ADHD.

Marinus van IJzendoorn

Why would a few extra repeats at the far end of Chromosome 11 make you more easily distracted? No one knows for sure, but it could be that the seven-repeat recipe makes receptors that are less good at binding to dopamine than the four-repeat recipe. Dopamine feels like a reward. So seven-repeat people have to work harder to get the same amount of dopamine rewards as four-repeaters. They need more stimulation to get the same good feeling.

The orchid theory put forward by van IJzendoorn and his colleague Marian Bakermans-Kranenburg had already suggested that owning a genome with seven repeats in DRD4 should not be viewed solely as a problem. The first study to show this appeared in *Development Psychobiology* in 2006. Van IJzendoorn and a colleague videoed 47 10-month-old infants at home with their mothers. While the infants played, the experimenters gave the mother a distracting task to see how the child—and the mother—handled the situation. Then they sequenced DNA from each child. They found that, for seven-repeat children, behavior is much worse than average—they are disruptive and defiant—when they are treated insensitively. But they behave better than average when they are treated sensitively, for instance when parents were trained to give feedback in the form of praise for wanted behaviors rather than frequently calling out unwanted behaviors. For four-repeaters, the form of feedback still makes a difference, but not much. The seven-repeaters are orchids; the four-repeaters are dandelions.

Perhaps, thought Van IJzendoorn, orchid children learn differently, too. In the wrong environment, perhaps they learn at a much slower rate than their dandelion peers. That gets noticed in school and is considered a deficit. In the right environment, they learn as well as their peers, but better. If that were true, these children are falling behind because school was designed by the dandelions for the dandelions. It's like letting a plot of land grow wild. Dandelions will do well;, orchids will struggle. Should we conclude that orchids are simply less successful plants than dandelions, destined always to shrivel? No; we would find a better environment in which to grow them. School is one big, wild field made for dandelions.

Van IJzendoorn recruited Bus to help prove this theory correct.

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The experiment Bus and her colleagues designed was straightforward. She took a mixed group of dandelion-children and orchid-children (four-repeaters and seven-repeaters) and gave them an early reading intervention designed to deliver a dopamine rush: computer-based lessons with instant feedback. In a typical kindergarten classroom, when a child reads a word, there is likely no -one close enough to give feedback, except when a teacher calls on them specifically. In the Leiden experiment, every single word a child read generated feedback. The hypothesis was that this might give orchid-children as much dopamine as dandelion-children get every day. Presumably, the dandelions would get even more,; but there's a limit to how much dopamine has an effect at any one time. Bus's prediction was that orchids would do worst in the classroom but best, better even than the dandelions, in the high-dopamine computer-based program.

The life of a researcher is to spend many months planning and running an experiment, followed by weeks of carefully sorting data, until the day you plot the result as a few bars on a computer screen. Most of the time, the bars are roughly the same height, but occasionally they are not. It's like coming across a brightly colored flower in a junkyard. The Leiden team's bar for orchid-children was much taller than that for dandelion-children.

Being careful researchers, they began immediately to plan a repeat experiment, to make sure this wasn't a fluke. The second study, this time using animated digital books, replicated the result of the first, as have several subsequent studies. The size of the effect was surprising. Orchids did 0.4 standard deviations better when learning with the high-feedback method. Dandelion-kids actually fared slightly worse than if they had received typical classroom instruction. Bus and van IJzendoorn had found a powerful way to teach the very children for whom traditional class works worst.

Once you see a classroom of students through the orchid and dandelion lens, it is impossible to miss how wrongheaded the current multitiered system of intervention is. It has the dimension wrong; it's vertical instead of horizontal. Students who fall behind are moved up to a higher tier, where they get the same instruction that failed them once, but in a more intensive way, more frequently, and in a smaller group. That is rather like a doctor who gives all his patients aspirin and, when some don't respond, recommends quadrupling the dosage. Instead of moving orchid children up, they should be moved across, to a learning environment designed for the way their brains functions.

How would that work in practice? Schools would look different than the model in which students learn in groups of 30 with a single adult. Instead, intervention teams would become specialists in matching students to learning environments.

Bus and van IJzendoorn focused on DRD4 and high-feedback environments, but researchers have found other areas of differential susceptibility—other kinds of orchids. One is how we deal with stress. Stress-orchids do poorly in environments such as taking a high-stakes test but are superior in low-stress situations such as project work. Another is introversion, which might lead to lower participation in large groups, like a classroom, but an enhanced ability to self-manage in a pandemic lockdown, say, or independent study time. Some of these may be strongly influenced by single-gene variants like DRD4. Some will be much more complex variations of multiple genes. Others will be gene-plus-environment interactions.

And we are only scratching the surface. There may be different types of orchids for learning socially rather than from books, for competing to learn rather than cooperating, or for learning from projects that give students a chance to apply new concepts before being confronted with abstract theory, or for learning from spiraling curricula, or for performing when the stakes are high. Perhaps some of these types sound like you, or someone you know.

"It would be wonderful to know which of these is true," says van IJzendoorn. It would, in fact, be a revolution. What if schools were designed to uncover each learner's inner orchid and match them with the optimal environment? The school team would think of themselves as running a portfolio of instructional approaches—computer-based, small group, project-based, whole class—and matching students with the approach that truly accelerated their learning.

Such a redesign would not be easy. It is hard to change the fundamental structure of a system as large and socially ingrown as schooling. Like any good idea in education, there are some prototypes out there—such as Kundskapskolan, a Swedish school network in which advisors help students craft and follow an academic path, a model similar to what they will do in college, and Teach to One, a way of optimizing middle-school math instruction to a portfolio of options guided by an algorithm—but they have not caught on.

A simpler starting point would be to take the existing multi-tiered system of support ("MTSS," in educator jargon) described above and turn it on its side: instead of tiers, paths, or MPSS. Path one would be traditional whole-class instruction; Path two might be computer-based, optimized for DRD4 seven-repeat orchids. Assuming there may be objections to widespread DNA testing, all Path one students could be exposed to Path two for, say, four weeks, in order to detect who advances more rapidly.

A significant bonus of this approach is that it is student-centered, something being done for and with students rather than to students, as the multitiered system sometimes appears. Students will discover whether they are orchids and, if so, which type, and how best to cultivate that strength.

The multitiered system of support, or something like it, is widely used in schools, especially for reading in earlier grades, so reorienting it should be a great deal easier to adopt than redesigning schools wholesale. Over time, one might lead to the other. But the orchid approach need not be restricted to early literacy. The Dutch researchers have already shown that the effect is at least as strong in more conceptually rich material such as vocabulary and comprehension. That suggests it will also apply in mathematics, though demonstrating that awaits further research. And, while early childhood is a time when the difference between orchids and dandelions is stark, so is adolescence.

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Pharmaceutical companies and medical researchers are working on "precision medicine" in the hope that some cancer treatments or other drugs, though they failed in broad-based clinical trials, will prove beneficial to smaller, genetically targeted populations. We have an analogous situation in education: most interventions perform poorly in broad trials. But if we can identify each student's inner orchid, and we know what environment to build for each, we can accurately target interventions. Think of it as "precision education."

Many orchid kids—those who struggle to pay attention to dull lessons, who act out, who make slower progress in academics—are today seen as problems. They are identified and accommodated, pitied, sometimes even mocked and bullied. They are considered a distraction, making the job of teachers harder, a cost to society and the rest of us.

This is a tragedy; a scandal. Orchid children are simply the victims of the one-size-fits-all approach that has pervaded school design for the last century. The dandelions created learning environments to suit themselves. Parents of orchid children sometimes talk of their being "twice exceptional," once with a behavioral disorder, say, and once as gifted. That may be comforting, but it is wrongheaded. The disorder *is* the gift. Whether it's a negative or a positive is not about how we look at it; it's about what we do to ensure a setting and an upbringing that turns the negative into a positive. The real cost is the opportunity lost to orchids and to society: they could achieve so much more in the right environment. More even than us dandelions.

Laurence Holt has spent the last two decades leading innovation teams in for-profit and non-profit K–12 organizations.

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