Chapter 1
Blueprints for a Creativity Curriculum

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Abstract Decades of cognitive research have arrived at a consensus: all children have creative potential; creativity depends as much on exposure and opportunity as on hereditary factors; and it can be improved through instruction and practice. Yet cultivating creativity has increasingly become a matter of equity. As industrialized countries move towards greater automation and human labor shifts towards jobs requiring flexible thinking, millions of children are being disadvantaged. How to design a curricular framework at the necessary scale? Building it around divergent thinking has a host of advantages. The concepts are straight-forward and easy to define. They are well-established in the literature, making it easier to persuade school boards and state legislatures. They are trans-disciplinary, as applicable to STEM fields as to the arts. Successful exemplars exist, with objective ways to measure them. Finally, the concepts are open-ended: they don't dictate how to accomplish the goals, only what the goals are. For our children's benefit, researchers need to band together around a shared framework, with curricular reform itself treated as a divergent thinking problem: the aim not to find one right answer, but to speak with one voice about values and goals, and present as many viable solutions as possible.

Keywords Creativity · Education · Divergent thinking · Equity

1.1 Introduction

A child entering kindergarten in 2022 won't graduate from a 4-year degree program until 2039. What will the labor market look like then? While there is vigorous debate about whether the effects will be harmful or benevolent, few dispute that industrialized countries are advancing towards ever increasing automation: tasks that can be delegated to a robot or computer will be (McAfee and Brynjolfsson 2016).

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Especially for repetitive or dangerous tasks, human performance is no match for a tireless, relentless, fast-moving machine. By the time today's youngsters start looking for work, many jobs will be manned by robots. Some studies estimate that close to 50% of the United States labor force will be supplanted (Frey and Osborne 2017).

Are we preparing our children for that economy? Current public school education has invested heavily in achieving measurable outcomes in literacy, rote learning, and calculation. But there is a critical piece missing. As Corazza (2016) writes:

> There should be no doubt that the centrality of humans in the future will depend fundamentally on their… cognitive flexibility, capacity to take decisions based on incomplete information, intuition, problem solving ability, artistic and aesthetic sense: in a word, on their creativity (p. 259).

Many see a creative economy as humanity's best bet for future employment (Frey and Osborne 2017). Yet fostering creativity in our young seems less and less of a priority. The scale of the problem is daunting: there are currently over 50 million children in American public schools. The majority suffer from lack of opportunity, with "exposure to innovation during childhood" having "significant causal effects on children's propensities to invent" (Bell et al. 2019, p. 647). Obstacles to improvement are considerable: overflowing classrooms; limited budgets and time; restrictive curricula (Makel 2009). As a result, efforts to bring more creativity into classrooms largely depend on the initiative of individual teachers, often receiving little institutional support. For those who value creativity in the classroom, there are lots of reasons to be discouraged.

Yet in spite of the obstacles, educating our children for the world they will live in should be an endeavor that is too big to fail. Here, cognitive science has an important role to play. As Makel (2009) writes: "The greatest impact creativity researchers could have on society (and where I hope the field is headed) is helping schools foster creative development in our youth" (p. 38).

Similarly, Corazza (2016) asserts that:

> all creativity researchers share a very important social responsibility:… the education of both younger and older generations in the subject of creative thinking and its practical application in all domains of knowledge…Given this sense of urgency and necessity for action…it is of utmost importance to resolve any fragmentation (p. 259).

But how to mobilize a determined effort? There are competing models of the creative process. Open questions abound: the degree to which creativity is domain-general or domain-specific, whether there is "far transfer" between disciplines, whether creativity can be taught, even whether children can be considered creative. Makel and Corazza have issued a call to arms—but can a field whose subject matter celebrates novel thinking and alternative viewpoints and has so many unresolved issues coalesce around unified guidance?

The answer may be hiding in plain sight. From the earliest days of creativity research, *divergent thinking*—the proliferation of multiple options—has been a common denominator in models of the creative process. Torrance (1970), Guilford (1984), Urban (1997), Cropley (2001), and Vincent, Decker & Mumford (2002) are among the many who have argued for its relevance. Whether it is referred to as ideation, brainstorming, or blind variation and selective retention, *divergent thinking* captures the diversification of options that propels human ingenuity. Reviewing the literature, Runco and Acar (2012) conclude: "divergent thinking is not synonymous with creativity but…there is great value in the concept" (p. 9). Historically, a multitude of creativity training programs in both education and industry have shared divergent thinking as a common foundation (Scott et al. 2004). It is the area of greatest consensus.

Building a creativity curriculum around divergent thinking has a host of advantages. First, its terms are straight-forward and easy to define. Second, it has been extensively studied: there are literally decades of research investigating it. It is solidly mainstream, making it easier to persuade school boards and state legislatures. Third, it is trans-disciplinary, as applicable to STEM fields as to the arts. Fourth, abundant exemplars exist (Scott et al. 2004). Fifth, there are objective ways to measure it. Finally, and most crucially, the concepts are open-ended: they don't dictate how to accomplish the goals, only what the goals are.

Still, a tipping point in which creativity becomes a widespread instructional mandate has yet to be reached. If anything, it is slipping backwards. If we fail to meet this moment, we may undermine generations of children. How can what we've learned about the brain and education help to achieve the necessary progress?

1.2 What Is Creativity?

In advocating for creativity in schools, one big stumbling is that the word itself can mean different things to different people. Are we talking primarily about the arts? Is something only creative if it is judged so by experts? Are failed ideas creative?

Creativity can be understood as the production of novel output whose viability and lifespan will depend on perceptions of its value, usefulness, intelligibility, and originality. The weightings of these often subjective judgments can vary from work to work, person to person, field to field, and over time. Da Vinci's *Mona Lisa* is a case in point: in the nineteenth century, it was considered one of the Louvre's lesser holdings. When the painting was stolen off the wall of the museum in 1911, Parisians "lost a masterpiece they didn't really know they had" (Sassoon 2001, p. 12). Impelled in part by the publicity surrounding its theft and safe return, the *Mona Lisa* gradually became the most prized and talked-about painting of all time (Sassoon 2001).

Kaufman and Beghetto's 4C model of creativity (2009) compares the reach and impact of creative work. Mini-c and little-c creativity involve output that is personally meaningful but has limited exposure. Pro-c refers to creative work that receives professional approval; and Big-C creativity refers to achievements that stand the test of time. The 4C model makes the case that creativity is not just represented by the peaks: it is the full mountain range, from the foothills to the summits, covering a vast landscape of human behavior.

Novelty too comes in varying degrees. “Sustaining” creativity refers to output that perpetuates existing standards. For instance, in many artistic traditions, an individual performer adds their own flourishes to inherited melodies, stories, visual art, or dance: the goal is not to improv, upend or replace traditional practices but rather to keep them viable. A sequel is another example of “sustaining” creativity: it takes inventiveness to keep a story going; but that continuation lives comfortably within an existing framework, such as Sherlock Holmes’ London or the “Star Trek” universe. Often, chronology is less crucial: for instance, you can read Sherlock Holmes stories out of order.

“Incremental” creativity refers to gradual improvements or evolution: making a car safer or more fuel efficient, building a faster CPU, creating a new spin on crime fiction. Links to the past are palpable: you know you’re getting a next-gen product or version 2.0. Here the arrow of time matters more: you’re less likely to trade backwards for a more dangerous car or slower computer; a forensic detective can’t be backdated to the nineteenth century.

Finally, “disruptive” creativity refers to work that is radical and norm breaking. At its most extreme, there is a clear dividing line of “before” and “after:” before and after Einstein’s theory of relativity, Picasso’s *Les Demoiselles d’Avignon,* and the world wide web.

Humans generally prefer gradual transitions to sudden overhauls. That’s why software developers populate our devices with digital bookshelves, trash cans, and camera shutters; they keep us tethered to the familiar (Brandt and Eagleman 2017). Indeed, as Henrich (2020) argues, the premium Western industrialized societies place on disruptive creativity is largely an outlier in human history. For many cultures past and present, “novelty” is a refresh, not a restart: they’re not looking for the next Silicon Valley. Furthermore, disruptive innovations often take flight after a long runway: for example, the electric car has been under development since the birth of the automobile (Høyer 2008). There’s no doubt innovation has accelerated in the digital age; but sudden breakthroughs are the exception, not the rule. Most creativity tills the soil of the familiar, replenishing and reinvigorating it.

What does this all mean for educators? First, human creativity is far-ranging: there’s almost nothing in our interests and behavior we don’t apply it to; it is a hallmark of our species (Brandt and Eagleman 2017). Second, active imaginations generate creative output that ranges from the unviable and short-lived to the cultural treasured and long-lasting. Some ideas are left unrecorded, like a night of theater improve; others leave their mark on history. Some are readily dismissed, even by the person who thought them up; others continue to stir hearts and minds centuries after they were conceived. Vagaries of time and place play an outsize role in how work is received: something treated as irrelevant in one context may be viewed as groundbreaking in another; judgment can be provisional and consensus hard to reach (Brandt 2021). As a result, we need to prepare students to be responsive to a whole range of social and cultural situations. If we only train them to be innovators, they may stumble in more constrained situations; on the other hand, if we only train them to be incrementalists, they may fall short in challenges that demand more radical re-thinking.

All of this points to divergent thinking as a fundamental educational goal: it is through idea diversification that students gain the flexibility and resilience to respond to a complex, ever-changing world.

1.3 Creative Thinking in the Brain

Brains operate in a perpetual tug-of-war between automation and innovation: either streamlining for efficiency and accuracy, or networking for greater flexibility. When we need a fixed outcome, our neural processing is consolidated into dedicated networks, enabling us to reliably do everything from eating and breathing to spelling and math tables (Eagleman 2011). In contrast, when engaged in creative tasks, functional connectivity between brain regions is enhanced and neural networks become less stable (Beaty et al. 2018). Crosstalk between neural regions is how the brain does R&D: the brain accepts a loss of speed and accuracy for the opportunity to surprise.

We now know that our brains are in a perpetual state of remodeling throughout our lifetimes (Bagarinao et al. 2019). Furthermore, neural networks are in a "chronic and unforgiving competition" (Eagleman 2020, p. 45)—because the greater the amount of territory devoted to a task, the better the performance. As far as the brain is concerned, *we are what we do*: for instance, the brain regions involved in spatial navigation are enlarged in London taxi drivers; and the same is true of the motor cortices of musicians, who need fine motor control to play their instruments. What about creativity? Longitudinal studies are rare: however, initial indications are that the same principle holds. For instance, Sun et al. (2016) imaged participants before and after a 20-session course in divergent thinking. The researchers found that improved originality and fluency were correlated with changes in functional connectivity and gray matter volume.

Research has also shown that creative thought involves an intricate dance between focused and unfocussed attention, with a large share of the labor occurring behind the scenes in the unconscious. Salience, goal-directedness, and mind wandering all collaborate (Goldberg 2018). Finally, the serial order effect is well established: responses to a prompt tend to get more unusual as time passes (Beaty and Silvia 2012).

What does all this tell us about creative cognition? Just as society divides up its labor between routine and more bespoke tasks, so too do our brains. Divergent thinking results when neural networks energetically intertwine. It is too reductive to say that divergent thinking alone accounts for the creative process: the options it produces may not be unusual; other mechanisms are involved in deciding among them and making a conclusive choice; and there are times when the brain may arrive directly at a novel solution without considering alternatives. But while divergent thinking isn't the entire machinery of creativity, it is its engine. It is hard to imagine how streamlined behavior alone could regularly generate novelty, since it is designed to do the opposite. A brain that proliferates options has a much higher chance of producing an original result. Furthermore, the serial order effect and the role of undirected thinking suggest that cultivating the creative process should generally not be a sprint: when it comes to surprising ideas, it's important to give the brain *time.*

1.4 Giftedness in Children

Do our genes play a determinant role in creative ability? After all, if creativity is largely innate, can education really improve it? Comparing identical twins is an apt way to address this question: if heredity were a dominant factor, twins would perform similarly on creative tasks, even if raised apart. Yet multiple studies (Richmond 1966; Kandler et al. 2016) have found only a modest correlation: when the environment diverges, so too do twins' development. Similarly, creativity does not seem to consistently run in families: studies "have generally found little evidence for the familial aggregation of creative talent" (Waller et al 1993, p. 235).

As a result, we may be making a crucial mistake when we treat giftedness as reflected primarily in whether or not something comes easily to a child. As the "10,000 rule" suggests, professional attainment is often dependent upon the amount of attention and effort someone is willing to devote to a task (Ericsson et al 2007). For instance, Klissouras et al. (2001) found that twins rarely reach the same level of success—effort matters. Other evidence increasingly points to the environment and training playing decisive roles. For instance, Heinrich (2020) reports that 120 genes that "can potentially influence educational attainment have dropped in frequency during the 20th century"; yet "this genetically induced pushed *against* schooling. . .was rolled over by cultural evolution," (p. 482) which has significantly *raised* schooling outcomes. Natural selection can be overruled by culture.

This raises caution flags about creativity testing, especially for the very young: children have only limited experience, and different degrees of exposure, encouragement, and opportunity. Advanced programs for more precocious youth are certainly reasonable, but creative learning should be mandated for everyone. As a society, we have been too preoccupied with giftedness and not enough with equity.

1.5 Proximal Development

In the early twentieth century, the psychologist Jean Piaget developed a framework for the maturing child that viewed cognitive development as a "preordained unfolding driven by hard-wired intrinsic biological rules" (Goldberg 2018, p. 147). At the same time, Russian psychologist Lev Vygotsky proposed a contrasting model, arguing that children cannot reach their full potential without help (Wertsch 1984). For any skill, Vygotsky defined the *zone of proximal development* as the difference between what the child could accomplish on their own and “the additional expansion made possible through instruction” (Goldberg 2018, p. 147).

Vygotsky’ views were initially overshadowed by Piaget’s, but they have gradually become more mainstream. Indeed, his model is not radical: whenever parents hire an SAT tutor or send their children to band camp, it’s under the presumption that expert guidance will improve the outcomes. Yet while we readily accept proximal development in everything from learning to drive to mastering a foreign language, there is considerable skepticism about whether it is possible to train creative thinkers. For many, creativity is a gift, and imagination can’t be taught.

Moreover, we’ve come to view school as the place where creativity goes to die. In a well-known study, 1600 school children took the same divergent thinking test given to NASA scientists (Land and Jarman 1992). Ninety-eight percent of the 3–5-year-olds scored in the genius category. When the same group took the test 5 years later, “only thirty-two percent scored that high.” Five years after that, “it was down to ten percent” (p. 153). More bad news arrived in 2011, when Kyung Hee Kim’s study documenting a steady decline in creativity scores over several generations of US school children made the cover of *Newsweek* magazine.

In order to turn the tide and persuade legislatures and school boards that classroom creativity is a worthy investment, pointing to decline is not enough; evidence of positive outcomes is vital. Examples of creativity *going up* through schooling exist, but they are less well-known. For instance, a series of studies in the 1970s offered encouraging results about workbooks designed by Myers and Torrance to stimulate divergent thinking. Nevertheless, in a literature review, Mansfield et al. (1978) find the scarcity of research on the workbooks “surprising” (p. 529). In another meta-study, Scott et al. (2004) reviewed over 70 programs for children and adults and reached “an unambiguous conclusion. Creativity training works” (p. 382). More recently, a study by Sun et al. (2020) found that Chinese high school students who took a course designed to enhance divergent thinking significantly outperformed the control group in measures of creative thinking. Still, more evidence is needed, as well as louder broadcasts when positive outcomes occur. Demonstrating the value and efficacy of creativity curricula needs to become a concerted effort—another area where uniting around a common goal is necessary to make an impact. If public school administrators aren’t convinced that creativity training works, why should they try?

1.6 Does Creativity Belong in School?

Adding creativity to the curriculum risks taxing already overworked instructors. As Makel (2009) writes, “Teachers, through high stakes testing and accountability, feel increasingly forced to sprint through as much material as quickly as possible. . .(That is) not conducive for creative experiences because the creative environment is often not viewed as efficient” (p. 40). On top of that, creativity demands a level of personal attention that is challenging in overcrowded classrooms. Nor is school-based creativity necessarily a good fit for students: some psychologists have argued that the classroom may not be the proper forum for an activity that requires self-reliance and experimentation free from prying eyes (Runco et al. 2017). Addressing these concerns requires strategic workarounds: for instance, it may often be preferable to assign creative tasks as homework, where the school bell isn't an issue and there is more privacy. Students can be self-directed in choosing their projects, work in groups to reduce the teacher's load, and be mentored in how to offer constructive feedback to each other.

The arts are typically the standard-bearers for creativity in the curriculum: studies are still scant, but those that do exist have found that historically underserved populations benefit the most from high levels of arts engagement and learning (Catterall et al. 2012; Bowen and Kisida 2019). The rewards are tangible: fewer disciplinary problems; better attendance; higher college enrollment. The paucity of extant research is due in no small measure to the shortage of public school arts programs to study—a reminder of how much this is an issue of equity.

1.7 Designing a Creative Curriculum

Makel (2009) describes the "disparity between valuing creative performance in adults and not fostering creativity in children as the *creativity gap*" (p. 38). There is a paradox involved in trying to close that gap: on the hand, it demands a scalable program, capable of addressing the needs of millions of children; on the other hand, how can there be a one-size-fits-all curriculum that allows for fresh thinking, non-conformity, and an attention to individual needs and strengths?

The answer lies in designing a rigorous framework that allows for significant customization. In applying creativity research to education, *divergent thinking* asserts itself as a critical component: it is well-articulated yet open-ended. It applies to any discipline; and by exploring questions without an answer key, it is a worthy complement to standardized testing driven curricula.

1.7.1 Divergent Thinking 2.0

Certain fundamentals should underlie a creativity curriculum. First, it should not be a "one-off;" instead, it needs to be an extended program carried through all grade levels. Second, it should not be limited to the arts; rather, it should be trans-disciplinary (Sawyer 2010). Third, the more varied the creative projects, the more flexible thinkers they are likely to produce. Finally, divergent thinking should be encouraged as much as possible.

How to do that? Divergent thinking is typically described by four main attributes: fluency (the number of responses), elaboration (how well worked out they are), flexibility (how diverse), and originality (how rare or unusual) (Guilford 1968; Torrance 1995). All of these can be taught and practiced.

For instance, consider the design of a building—a task at the cross-roads of engineering and art. Fluency and elaboration involve drafting multiple models—something routine in any architectural firm. To motivate flexibility and originality, students can be prompted to develop a range of plans: some that blend in with neighboring buildings, others that include modest updates, and still others that boldly clash with their surroundings. Every aspect of this process can be mentored.

There are a host of other ways to incorporate divergent thinking into the classroom. For instance, real world problems without a solution can engage students on issues of immediate relevance. For instance, Huang et al. (2010) used computer gaming to encourage students to proliferate options in response to a chronic problem afflicting Taiwan: the hazardous debris created by landslides. The researchers found that their playful approach successfully impelled students to work out multiple solutions.

Any subject can be enriched by free-wheeling questions. Gallavan and Kottler (2012) integrated divergent thinking into the social studies curriculum, encouraging students to consider history from multiple angles, and asking them to propose economic and political innovations. Kwon et al. (2006) likewise designed open-ended problems for middle school math: in a controlled study, they found that the treatment group showed particularly impressive results in originality.

One way to stimulate divergent thinking is to alter or loosen constraints. Science fiction prototyping (Johnson 2011) and alternative worlds and histories are particularly potent ways to encourage originality and flexibility: they require students to navigate hypothetical scenarios. What if the electoral college were abolished? What if self-driving automobiles were capable of real-time coordination? What if you could add more one sense—what would it be and why (Eagleman 2020)?

Because arts classes typically don't have to "teach to the test," they have enhanced opportunities to stimulate divergent thinking. It all boils down to a simple lesson: *think in multiples*. Yet many art classes do not explicitly prioritize this. Often this is because of resource scarcity: not enough materials or time. While that's certainly understandable, it is nevertheless a missed opportunity. Furthermore, divergent thinking isn't fully leveraged if solutions are too similar. Instead, students should be prompted to explore a spectrum of solutions from the familiar to the far-out (Brandt and Eagleman 2017). Once again, the arts are an ideal laboratory, because they can be more easily unbound from practical constraints.

Take a theme and variations, Western classical music's most overt expression of *divergent thinking*: a melody, often familiar, is revisited over and over but always in a new way. The number of variations is an index of the composer's imagination: the more, the better. Crucially, as the variations progress, they tend to get further and further removed from the source (Brandt 2019).

Creating variations is readily adaptable to other media. For instance, in an undergraduate creativity course I teach at Rice University, I ask students to write a theme and variations on a poetry reading. The requirements are that they write at least four variations; the variations should be as distinct from each other as possible;

and the source should become less and less recognizable. One student based her set on Langston Hughes' "Mother to Son":

> Well, son, I'll tell you:
> Life for me ain't been no crystal stair . . . (Rampersad and Roessel 1995, p. 30)

Her final variation was a sculpture of a staircase on which lines from the poem were inscribed.

Another based hers on a poem celebrating the search for alien life: her final variation was a transcription of the poem into chemical symbols, as is done on Voyager's golden record. In order to encourage risk-taking, students are graded solely on objective measures spelled out in advance: did they create at least four variations? Are they contrasting? Do they go different distances from the source? That way, students can try out wacky ideas without being worried about being penalized. The farther the students' sets get from their sources, the farther they tend to diverge from each other: "far" variations have ranged from audio tracks to videos, visual art, games, puzzles, even recipes—illustrating that retreating from the source encourages greater originality.

The overall goal should be a curriculum that is varied, unpredictable, increasingly challenging for higher grade levels, and personalized to the needs, values, and traditions of the students. Rather than trying to identify a single approach, aggregating a host of well-vetted ones—like a well-managed stock portfolio—is a better strategy: it will increase the number of stakeholders and minimize competition and conflict; be more adaptive to different learning styles; and, in the end, better represent the concepts it is trying to instill.

For all of its value, cultivating divergent thinking alone isn't enough: encouragement of self-expression, risk-taking, and tolerating ambiguity are all crucial (Urban 2003). As Cropley (2001) writes, "the optimum conditions for creativity exist when all of the dimensions (e.g. the properties of the person, the situation, the task, and the solution) are favorable" (p. 146). The more an entire school is involved in creative instruction, the more likely these other conditions will be met.

Implementing such a broad overhaul will be a heavy lift. The alternative is the more ad hoc approach that we have now. The risks there are that it has been hard to make creativity a priority, accountability is difficult, teacher turnover can be destabilizing, and results are almost impossible to compare.

As with any ambitious undertaking, the devil is in the details. Instructors need to be trained, and time needs to be set aside in the busy school day. There's always the risk that something designed to promote flights of fancy may be misapplied or become calcified. But the potential rewards outweigh the obstacles and drawbacks: equity for young people of all backgrounds; classrooms as incubators for tomorrow's flexible thinkers.

As we learn more about the creative brain and different teaching modules are field tested, it will be imperative to revisit curricular guidelines. But after three quarters of a century of research, it's unlikely that divergent thinking will be unseated as a core component. It will take more than these concepts alone to improve student outcomes; but it is a durable platform on which to begin to do so.

1.8 How Technology Can Help

Since the dawn of civilization, technology has given an assist to human creativity: the knife for the carver, the Bunsen burner for the chemist, the telescope for the astronomer. But nothing comes close to the digital world in its impact on creative education. First, the power and availability of computers have democratized creativity: film editing used to require a roomful of high-priced equipment; now it can be done on a laptop. Second, computers are multi-use: the same device can sequence the genetic code and run music notation software, making it an ideal tool for cross-disciplinary learning. Third, digital memory is increasingly affordable and bountiful, making it possible to preserve all drafts. That's important, because the greatest impediment to divergent thinking is having to destroy an earlier version to try out alternatives.

The computer game Minecraft is a good example of a digital platform that has found multiple uses in education. The game offers a sandbox in which players construct virtual worlds using blocks and other shapes. In the game's creative mode, players have limitless access to materials (Bos et al. 2014). There is no winning and losing, just free-form play; and, as with Legos, it is easy to tear down and redesign. Thanks to its simple premise and open-endedness, it has been used to teach math, biology, ecology, physics, and English literature (Short and Short 2012; Bos et al. 2014; Cipollone et al. 2014).

All creative tools involve trade-offs and limitations that condition their output: for instance, for all of its strengths, Western music notation cannot capture the complex pitch and rhythmic inflections of an Indian raga; in those respects, traditional Western scores are simpler. The more students rely on technology for creative work, the more essential it is that these tools are not too prescriptive: otherwise, the "guard-rails" of the software may overly limit young imaginations.

Consider Hyperscore, developed by composer Tod Machover and colleagues at MIT's Media Lab (Farbood et al. 2004). It is a graphic interface for composing that doesn't require knowledge of music notation. Instead of the traditional five-line staves, it offers a painter's palette of dots and lines for pitches, and colors for timbre. Melodies are shaped by brushstrokes, and can be layered at will. Volume is controlled by shrinking or expanding lines and shapes. A "harmony engine" adds traditional tonal harmonies, but it can also be turned off. Finally, there is real time playback. It is possible to transcribe traditionally notated music—a Beethoven Symphony is one of the demos-—but it's also possible to go well beyond that. There are constraints: for instance, the melody lines come in eight colors; polyphony beyond that becomes harder to follow. Nevertheless, the program never answers the question "What should music sound like?" Instead, it leaves it to each student to discover their own answers. Platforms such as Hyperscore that are easy to master and make it convenient to generate, test, and save alternatives have the potential to be breakthrough creative learning tools.

1.9 Assessment

As Sawyer (2010) writes, “In today’s climate of accountability, what is not assessed does not count” (p. 185). Here again divergent thinking offers distinct advantages: decades of research have been rooted in evaluating it; well-established methodologies offer guidelines for instructors. There are objective measures: a student who only creates one or two variations needs to work on their fluency; one whose answers are too similar or routine need to stretch their flexibility and originality. For a comprehensive measure, a full battery of assessments is recommended, including domain-specific testing, juried appraisals (Amabile et al. 2019), and classroom observation. That may be labor intensive, but the effort put into it will also raise the profile of creative learning at the school.

Moreover, incorporating creativity into course-based assessments may help to address long-standing issues of bias and equity. The national STEM program “Project Lead the Way” (PLTW) added measures of “transportable skills” such as divergent thinking to their standardized tests administered to over 335,000 students. They found that including the transportable skills help to mitigate the historic achievement gap for marginalized students, especially with respect to gender (Gough and Williams 2020). This further incentivized PLTW to teach these skills. Thus, a virtuous feedback loop was created between curriculum and assessment: the more creativity was reflected in both, the higher a priority it became.

1.10 The Importance of Advocacy

A recent study (Lopez Turley 2016) found that, 50 years after a landmark report laying out the inequities faced by minority students, efforts to close those gaps have largely failed. Why? More than any other factor, the study places the blame on the disconnect between researchers and policymakers. Academic faculty are generally not rewarded for engaging with the public; meanwhile, school districts are hesitant to share privileged data for fear of being maligned or misrepresented. As a result, the two communities rarely intersect.

It is not a stretch to imagine that similar problems affect creativity in education. A meta-study by Forgeard and Kaufman (2016) found that the majority of creativity studies they reviewed “offered little or no discussion explaining why readers should care” (p. 255). The authors reason that a primary reason for this may be that researchers are primarily speaking to each other. As important as basic research is, the authors argue that it is important to reach outwards, articulating creativity’s benefits to the public and explaining why and when it should supersede other priorities, especially given limited budgets and hours in the school day. If researchers don’t want schools to be creativity deserts, we need to engage with policymakers more often.

Change won't happen overnight, so it is vital to develop 5 and 10-year plans, highlighting what can be accomplished right away, and what will take longer to bring to fruition. That takes putting many heads together. Like any field, creativity research is fragmented: researchers from different institutions have few opportunities to collaborate or coordinate. On top of that, creative inquiry is multi-disciplinary, but disciplines too often remain siloed. Academic goals and incentives need to be revisited: there needs to be more interdisciplinary opportunities and greater rewards for the collective effort that real world engagement requires. We know enough now to change children's lives; the time has come to put that knowledge to good use on a bigger scale. This itself should be treated as a divergent thinking problem: the aim not to find one right answer, but to speak with one voice about values and goals, and present as many viable solutions as possible.

1.11 Conclusion

Thanks to a preponderance of evidence, scientists have coalesced around a rigorous understanding of our warming climate, and have become activists in raising the alarm, warning about imminent consequences, and working assiduously to find solutions. It is time to make the creative climate in our classrooms a higher priority. While it is never appropriate to have a party line in science, it is not hard to imagine cognitive scientists sounding similar warnings about how we are educating our children. After many decades of research, the majority would agree: all children have creative potential; creativity depends at least as much on exposure and opportunity as on hereditary factors; it can be improved through instruction and practice; and we are not doing enough. Inequities in access to innovation have increasingly become public health and civil rights issues—a shameful neglect of millions of young minds. As with environmental threats, the threats to livelihood and well-being posed by automation are looming, and waiting too long to address them may cause irreversible harm.

No one study or article on its own is likely to move the needle, no single voice enough to be a wake-up call. As with climate change, what is needed now is coalition-building, coordinated research, and broad-based advocacy based on shared data and guidelines. After many decades of research, there is enough common ground to create robust curricular guidelines. Divergent thinking may be one of the oldest concepts in creativity research, but it has withstood the test of time, offering the opportunity for varied solutions built on shared scaffolding. It is a theme capable of unending variations.

Generating multiple solutions is not the whole picture of creativity: *convergent thinking* plays a complementary and essential role (Dietrich 2015). But students get plenty of practice zeroing in on a correct answer. What's too often missing for them is even a hint of divergent thinking.

Nor is future employment the sole reason for cultivating creativity. Exercising our creative faculties is personally fulfilling and meaningful, promotes empathy and curiosity, and is both challenging and fun. A student prepared for the future economy will also have tools to express themselves, sustain long-term relationships, and raise their children.

Neuroscience and psychology are converging on a view of the brain that is largely shaped by experience and training (Eagleman 2020). The adage that teachers are "molding young minds" is turning out to be literally true: the more time and effort we spend on a task, the more brain territory is devoted to it; that, in turn, is reflected in measurable improvements and accomplishments. Given how quickly the digital economy can remake itself and how much it will intrude on human work, future adults will need to be inventive, mentally agile, resilient, and adaptable. We need to ensure that young people of all backgrounds grow into those kinds of adults. If we want to prepare our kindergarteners for the world that awaits them, the time is now to answer that call.

References

Amabile, T. M., Collins, M. A., Conti, R., Phillips, E., Picariello, M., . . . Whitney, D. (2019). A Consensual Technique for Creativity Assessment. In *Creativity in Context* (pp. 41–79). Routledge. https://doi.org/10.4324/9780429501234-3

Bagarinao, E., Watanabe, H., Maesawa, S. *et al.* (2019). Reorganization of brain networks and its association with general cognitive performance over the adult lifespan. *Sci Rep* **9,** 11352. https://doi.org/10.1038/s41598-019-47922-x

Beaty, R. E., & Silvia, P. J. (2012). Why Do Ideas Get More Creative Across Time? An Executive Interpretation of the Serial Order Effect in Divergent Thinking Tasks. *Psychology of Aesthetics, Creativity, and the Arts*, 6(4): 309–319. https://doi.org/10.1037/a0029171

Beaty, R. E., Kenett, Y. N., Christensen, A. P., Rosenberg, M. D., Benedek, M., Chen, Q., . . . Silvia, P. J. (2018). Robust prediction of individual creative ability from brain functional connectivity. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(5), 1087–1092. https://doi.org/10.1073/pnas.1713532115

Bell, A., Chetty, R., Jaravel, X., Petkova, N., & Van Reenen, J. (2019). Who becomes an inventor in America? The importance of exposure to innovation. *Quarterly Journal of Economics*, *134*(2), 647–713. https://doi.org/10.1093/qje/qjy028

Bos, B., Wilder, L., Cook, M., & O'Donnell, R. (2014). Learning mathematics through Minecraft. *Teaching Children Mathematics*, *21*(1), 56–59.

Bowen, D.H. & Kisida, B. (2019). Investigating Causal Effects of Arts Education Experiences: Experimental Evidence from Houston's Arts Access Initiative (Volume 7, Issueno 4).Rice University's Kinder Institute for Urban Research.

Brandt, A. & Eagleman, D. (2017). *The Runaway Species: How Human Creativity Remakes the World.* New York: Catapult.

Brandt, A. (2019). "Theme and variations as a window into the creative mind." *Mobile Brain-Body Imaging and the Neuroscience of Art, Innovation and Creativity.* New York: Springer.

Brandt, A. (2021). Defining Creativity: A View from the Arts. *Creativity Research Journal.* https://doi.org/10.1080/10400419.2020.1855905

Catterall, J. S., Dumais, S. A., & Hampden-Thompson, G. (2012). The arts and achievement in at-risk youth: Findings from four longitudinal studies. Washington, DC: National Endowment for the Arts.

Cipollone, M., Schifter, C. C., & Moffat, R. A. (2014). Minecraft as a creative tool: A case study. *International Journal of Game-Based Learning*, *4*(2), 1–14. https://doi.org/10.4018/ijgbl.2014040101

Corazza, G.E. (2016). Potential Originality and Effectiveness: The Dynamic Definition of Creativity. *Creativity Research Journal*, *28*(3), 258–267. https://doi.org/10.1080/10400419.2016.1195627

Cropley, A.J. (2001). *Creativity in Education & Learning: A Guide for Teachers and Educators.* London: Kogan Page Limited.

Dietrich, A. (2015). *How Creativity Happens in the Brain.* New York: Palgrave Macmillan.

Eagleman, D. (2011). Incognito: The Secret Lives of the Brain. New York, NY: Pantheon Books.

Eagleman, D. (2020). Livewired: The Inside Story of the Ever-Changing Brain. New York, NY: Pantheon Books.

Ericsson, K.A., Roring, R.W. & Nandagopal, K. (2007). Giftedness and evidence for reproducibly superior performance: an account based on the expert performance framework. *High Ability Studies, 18 (1)*: 3–56.

Farbood, M.M., Pasztor, E. and Jennings, K. (2004). "Hyperscore: a graphical sketchpad for novice composers." *IEEE Computer Graphics and Applications*, vol. 24, no. 1, pp. 50–54. https://doi.org/10.1109/MCG.2004.1255809.

Forgeard, M. J., & Kaufman, J. C. (2016). Who cares about imagination, creativity, and innovation, and why? A review. *Psychology of Aesthetics, Creativity, and the Arts*, *10*(3), 250.

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, *114*, 254–280. https://doi.org/10.1016/j.techfore.2016.08.019

Gallavan, N.P. & Kottler, E. (2012). Advancing Social Studies Learning for the 21st Century with Divergent Thinking. *The Social Studies,* 103:4, 165–170. https://doi.org/10.1080/00377996.2011.605641

Goldberg, E. (2018). *Creativity: The Human Brain in the Age of Innovation.* New York: Oxford University Press.

Gough, M., & Williams, A. (2020, April 30). Measuring creative thinking via holistic standardized assessments: from operationalization to impact on equity. https://doi.org/10.35542/osf.io/qp2t7

Guilford, J.P. (1968). *Creativity, intelligence, and their educational implications.* San Diego, CA: EDITS/Knapp.

Guilford, J. P. (1984). Varieties of divergent production. *The Journal of Creative Behavior, 18*(1), 1–10. https://doi.org/10.1002/j.2162-6057.1984.tb00984.x

Henrich, J. H. (2020). *The weirdest people in the world: How the west became psychologically peculiar and particularly prosperous*. New York, NY: Farrar, Straus and Giroux.

Høyer, K.G. (2008). The history of alternative fuels in transportation: The case of electric and hybrid cars, *Utilities Policy, 16 (2),* 63-71. /https://doi.org/10.1016/j.jup.2007.11.001.

Huang, C. C., Yeh, T. K., Li, T. Y., & Chang, C. Y. (2010). The idea storming cube: Evaluating the effects of using game and computer agent to support divergent thinking. *Educational Technology and Society*, *13*(4), 180–191.

Johnson, B.D. (2011) Science Fiction Prototyping: Designing the Future with Science Fiction. San Rafael, California: Morgan & Claypool.

Kandler, C., Riemann, R., Angleitner, A., Spinath, F. M., Borkenau, P., & Penke, L. (2016). The nature of creativity: The roles of genetic factors, personality traits, cognitive abilities, and environmental sources. *Journal of Personality and Social Psychology*, *111*(2), 230–249. https://doi.org/10.1037/pspp0000087

Kaufman, J.C. & Beghetto, R.A. (2009). "Beyond Big and Little: The Four C Model of Creativity." *Review of General Pyschology,* 13, 1: 1–12.

Kim, K. H. (2011). The Creativity Crisis: The Decrease in Creative Thinking Scores on the Torrance Tests of Creative Thinking. *Creativity Research Journal*, *23*(4), 285–295. https://doi.org/10.1080/10400419.2011.627805

Klissouras, V., Casini, B., Di Salvo, V., Faina, M., Marini, C., Pigozzi, F., Pittaluga, M.,Spataro, A., Taddei, F. & Parisi, P. (2001) Genes and Olympic performance: a co-twin study, International Journal of Sports Medicine, 22, 250–255.

Kwon, O. N., Park, J. H., & Park, J. S. (2006). Cultivating divergent thinking in mathematics through an open-ended approach. *Asia Pacific Education Review*, *7*(1), 51-61.

Land, G. & Jarman, B. (1992). *Breakpoint and Beyond: Mastering the Future–Today.* New York: Harper Collins.

López Turley, R. N. (2016, September 1). Connecting research and policy to reduce inequality. *RSF*. Russell Sage Foundation. https://doi.org/10.7758/rsf.2016.2.5.13

Makel, M. C. (2009). Help Us Creativity Researchers, You're Our Only Hope. *Psychology of Aesthetics, Creativity, and the Arts*, *3*(1), 38–42. https://doi.org/10.1037/a0014919

Mansfield, R. S., Busse, T. V., & Krepelka, E. J. (1978). The Effectiveness of Creativity Training. *Review of Educational Research*, *48*(4), 517–536. https://doi.org/10.3102/00346543048004517

McAfee, A., & Brynjolfsson, E. (2016). Human work in the robotic future: Policy for the age of automation. *Foreign Affairs*, *95*(4), 139-150.

Rampersad, A., & Roessel, D. (Eds.). (1995). *The Collected Poems of Langston Hughes.* New York: First Vintage Classics.

Richmond, B. O. (1966). Creativity in Monozygotic and Dyzygotic Twins.

Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity research journal*, *24*(1), 66-75.

Runco, M. A., Acar, S., & Cayirdag, N. (2017). A closer look at the creativity gap and why students are less creative at school than outside of school. *Thinking Skills and Creativity*, *24*, 242–249. https://doi.org/10.1016/j.tsc.2017.04.003

Sassoon, D. (2001). "Mona Lisa": The Best-Known Girl in the Whole Wide World. *History Workshop Journal,* 51: 1-18.

Sawyer, K.S. (2010). Learning for Creativity. In R.A. Beghetto & J.C. Kaufman (Eds.), *Nurturing Creativity in the Classroom.* Cambridge, England: Cambridge University Press.

Scott, G., Leritz, L. E., & Mumford, M. D. (2004). The Effectiveness of Creativity Training: A Quantitative Review. *Creativity Research Journal*, *16*(4), 361–388. https://doi.org/10.1207/s15326934crj1604_1

Short, D., & Short, B. D. (2012). Teaching scientific concepts using a virtual world–Minecraft. *Teaching Science: The Journal of the Australian Science Teachers Association*, *58*(3), 55–58. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=83256656&site=ehost-live

Sun, J., Chen, Q., Zhang, Q., Li, Y., Li, H., Wei, D., . . . Qiu, J. (2016). Training your brain to be more creative: brain functional and structural changes induced by divergent thinking training. *Human Brain Mapping*, *37*(10), 3375–3387. https://doi.org/10.1002/hbm.23246

Sun, M., Wang, M., & Wegerif, R. (2020). Effects of divergent thinking training on students' scientific creativity: The impact of individual creative potential and domain knowledge. *Thinking Skills and Creativity*, *37*. https://doi.org/10.1016/j.tsc.2020.100682

Torrance, E.P. (1970). *Encouraging Creativity in the Classroom.* Dubuque, IA: Wm. C. Brown Publishers.

Torrance, E.P. (1995). *Why fly?* Norwood, NJ: Ablex.

Urban, K. K. (1997). Modelling creativity: the convergence of divergence or the art of balancing. In J. Chan, R. Li & J. Spinks (Eds.), *Maximizing Potential: Lengthening and Strengthening Our Stride* (pp. 39–50). Hong Kong: University of Hong Kong Social Sciences Research Center.

Urban, K. K. (2003). *Toward a componential model of creativity.* In D. Ambrose, L. M. Cohen, & A. J. Tannenbaum (Eds.), *Perspectives on creativity. Creative intelligence: Toward theoretic integration* (p. 81–112). Hampton Press.

Vincent, A. S., Decker, B. P., & Mumford, M. D. (2002). Divergent thinking, intelligence, and expertise: A test of alternative models. *Creativity research journal*, *14*(2), 163-178.

Waller, N. G., Blacker, D. M., Bouchard, T. J., Lykken, D. T., & Tellegen, A. (1993). Creativity, Heritability, Familiality: Which Word Does Not Belong? *Psychological Inquiry*, *4*(3), 235–237. https://doi.org/10.1207/s15327965pli0403_18

Wertsch, J. V. (1984). The zone of proximal development: Some conceptual issues. *New Directions for Child and Adolescent Development*, *1984*(23), 7-18.

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