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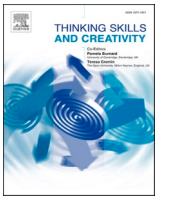

Creativity and diversification: What digital systems teach

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ABSTRACT

Creativity is everywhere. Diversity is everywhere. Digitization is everywhere. This present article gives a new perspective on my and my laboratory's work over the last decade, explaining why creativity, diversity, and digitization go everywhere together.

A, B, C, … there are some thirty letters to the alphabet, more than a million to this volume of *Thinking Skills and Creativity*, and an unknown number in the range of quadrillions of letters has been written down since the alphabet was invented, only three thousand years ago. What may have at first been a handful of edgy and curvy symbols has become a world of limitless possibilities.

There's an interesting twist to this edgy and curvy story of writing. Early alphabets were edgy, with many straight and few curved lines. The Latin letters, which came later, have a much more even distribution of straight and curved lines. Roughly half of the letters are composed of straight lines, while the other half also contains curved lines. One could decide to replace the curved lines with zeroes, and the straight lines with ones; and one could rewrite all letters of the alphabet with just zeroes and ones. Well, one would then get an alphabet of just zeroes and ones, which—one must admit—is something of a digital computer code. Computer codes are binary alphabets of zeroes and ones.

Some people picture computers as rigorous machines that cannot make errors and are therefore different from humans. In reality, computers cannot be separated from humans (Bejan 2020), and both computers and humans know how to work with digital systems, which is what makes them powerful. Digital systems, such as the binary 0/1 computer code and the human alphabet, have one truly empowering characteristic. That's the characteristic we have already observed. With only a handful of symbols, digital systems open up worlds of limitless possibilities. It's easy to see. With only the fingers on one hand, one can count, count, and count, and we haven't yet grown tired of counting. This opens up room for creativity and diversification. One can learn to count new types of numbers.

Maybe this phenomenon, namely that digital systems open up room for creativity and diversification, is best illustrated with the genetic code. With just two base pairs—one could have decided to call them zero and one—the genetic code encodes for any genetic information. Uncountable zillions of genetic base pairs have been written since the beginning of life on earth, and we haven't yet grown tired of life all together. Life keeps writing and rewriting genes and translating them into proteins, and it does that with stunning sophistication. The creativity and diversity of biological life will convince any doubter that systems of just zeroes and ones have limitless potential.

And there is more. Genetic base pairs and proteins are chemical compounds, which are combined out of atoms. These atoms, when it comes to their type and properties, are determined by their kernels, which are combinations of protons and neutrons. In turn, the protons and neutrons are combinations of only two types of quarks: up and down quarks. One could have decided to call these quarks zero and one-quarks. They make up the binary code of the universe. The universe that we live in is a digital universe. This digital

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universe has opened up endless possibilities for creativity and diversification. Think just how diverse ecosystems and cities are. They are oases of diversity, all rooted in binary codes.

In my research over the last decade, I have introduced the replicator-mutator equation to the humanities and the sciences of the city (Baciu, 2015, 2016, 2017, 2018, 2019, 2020, 2021; Baciu & Birchall, 2021; Baciu & Della Pietra, 2021). This equation is important in the context of this present article because it explains why digital systems, creativity, and diversification go everywhere together. You can see the equation, playfully annotated, in Figure 1. The equation states that new culture is the reproduction of past culture, transformed by creativity and interplay. Interplay is very important because it may lead to diversification. To emphasize this distinctive outcome, I took the liberty to write that new culture is the reproduction of past culture, transformed by creativity, and by "diversification."

Let me now explain why this equation goes hand in glove with digital systems. First, digital systems start with just a handful of symbols. This economy of means makes reproduction easy, and reproduction is part of the equation. The easier it is to reproduce past culture , the better. Next, digital systems make it possible to creatively combine and recombine symbols, which gives rise to creativity. Creativity, once again, is part of the equation. Finally, digital systems open up limitless worlds of possibilities. Diversification is necessary to broadly explore what is possible. Take it this way: In order to explore things as vast as the ocean, you need multiple ships to sail in multiple directions. Figuratively, that's what diversification is. Diversification is necessary when broadening one's horizons and exploring oceanwide worlds of possibilities. It is evident, then, that our boundless universe makes space for countless digital systems, for life's creativity and diversity, and for further digital systems, creativity, and diversification.

I believe that this insight should be relevant for the teaching of creativity. What I propose is a view of creativity that is digitally informed and fit for a century of digitization—and it is an inclusive view of creativity. I should say that the alphabet is a digital system because any and every human language is a digital system. Any and every language is composed of a smaller set of sounds, "phonemes," that are combined into prefixes, suffixes, word roots, words, sentences, and entire stories (Nowak & Komarova, 2001; Nowak, Komarova, & Niyogi, 2001). In turn, languages are digital systems because they are part of culture, and cultures more generally are digital systems: Music is composed of smaller sets of musical notes; art is composed of artistic motives; feelings and complex personal experiences are composed of more basic emotions; and urban environments are composed of architectural types. When we study the universe, genetics, languages, cultures, and urban space, we find multiple, nested digital systems. These digital systems are like matryoshkas, or like sets of parentheses one nested in the other. Everyone and everything is part of this world.

This perspective on creativity that I have now proposed may be particularly useful because it is a scientific perspective. I say a "scientific perspective" because the replicator-mutator equation is best used in scientific research, as I and my collaborators have done in abundance. Analytical solutions to the replicator-mutator equation explain and interconnect many empirical observations about human culture, including the rise and fall of fashions, and the formation of linguistic, cultural, and urban diversity. And my work only expanded on an outstanding body of previous science. Indeed, the replicator-mutator equation is a heart-piece of mathematical modeling in the life sciences. What I called creativity is there known as variation-selection process, or as evolution (Eigen 1971; Domingo, & Schuster 2016), while diversification is equivalent to frequency dependent selection or, in one word, ecology (Lotka 1910;

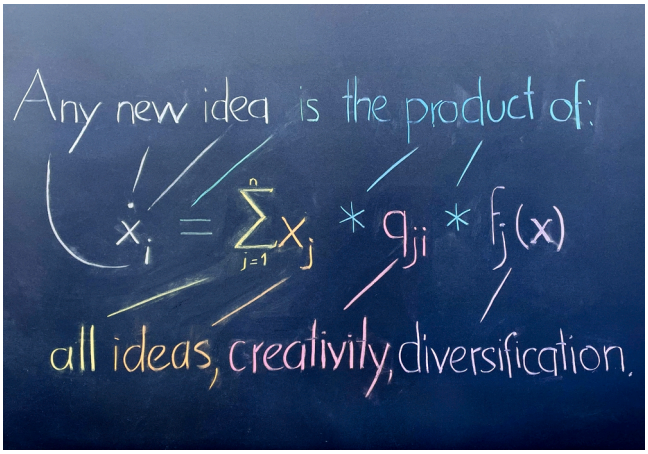

Fig. 1. Any new idea is the product of all past ideas, creativity, & diversification. Technically, the term q_{ij} stays for any creativity matrix, mutation matrix, or association matrix. This term is also used in variation-selection processes as modeled with the quasispecies equation. The term $f_i(\mathbf{x})$ stays for interplay between diverse variants and between the variants and their environment (frequency dependent selection). It is also used in the replicator equation, which is mathematically equivalent to generalized Lotka-Volterra equations. The replicator-mutator equation unites these two terms—q_{ij} and $f_i(\mathbf{x})$—into an overarching equation. The equation models a universal process that may be best called "creative interplay," or, considering that interplay may result in diversification as a distinctive outcome, "creative diversification."

Hofbauer & Sigmund, 1998). The replicator-mutator equation was obtained by multiple researchers who united these two ubiquitous processes into one formula (Bomze & Burger, 1995; Hadeler, 1981; Page & Nowak, 2002; Stadler & Schuster, 1992). Along the way, the equation itself has gradually changed, and it acquired new applications in a process of "creative diversification."

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