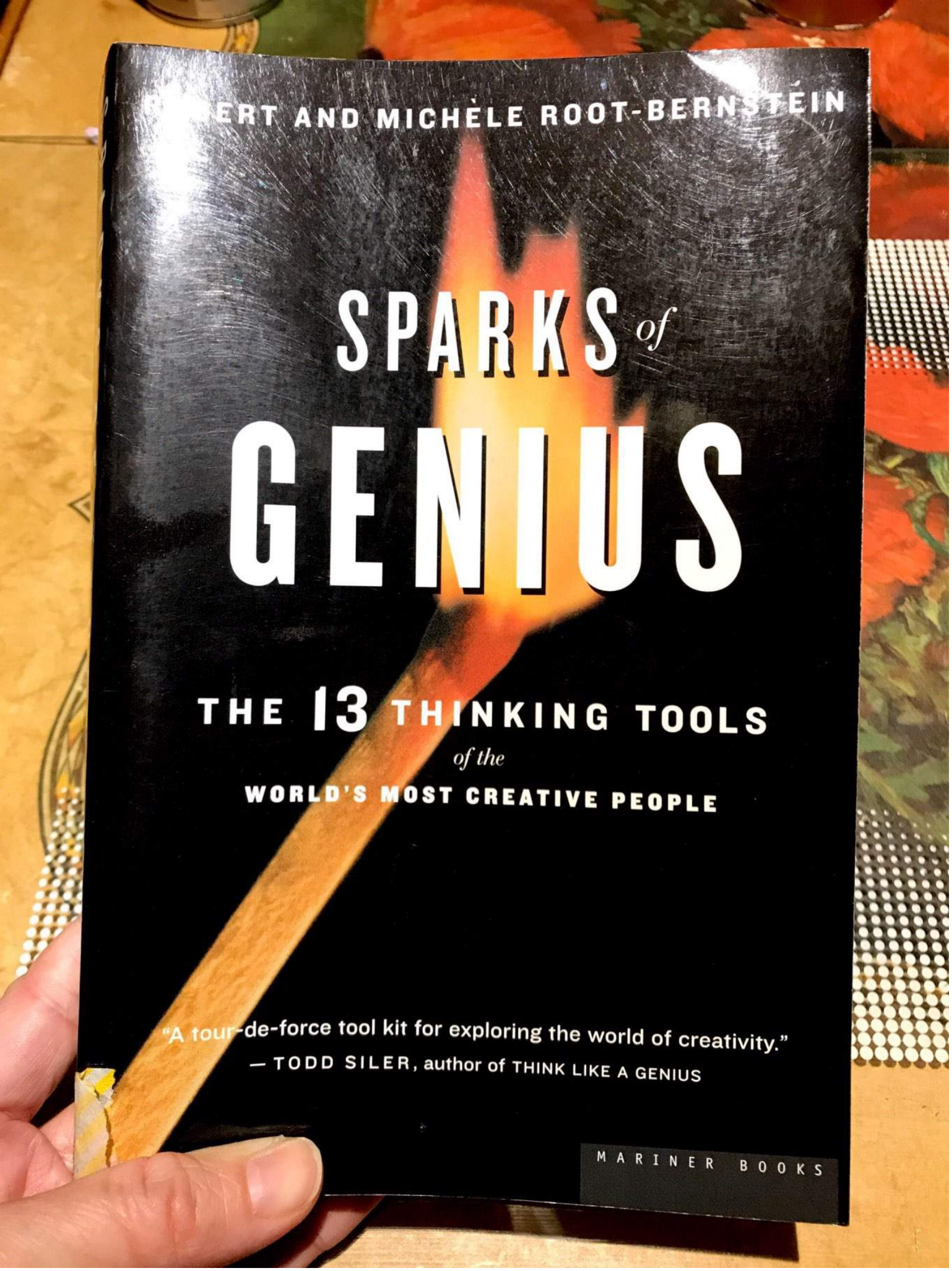

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CONTENTS

16

Synthesizing Education

WE HAVE NOW TEASED APART the threads of creative thinking and rewoven them into a synthetic understanding of innovation that, in turn, requires a new kind of transdisciplinary, synthetic education.

Our foray into the hearts and minds of inventive individuals demonstrates that imagination can be encouraged and trained through the exercise of thinking tools and a desire for synosic understanding. Clearly these elements are lacking in most curricula today. Implementing thinking tools and synosic lessons in our schools will not, however, require major alterations in curricula. We need not change *what* we teach. A synthetic education requires only that we change *how* we teach, bearing eight basic goals in mind.

First, we must emphasize the teaching of universal processes of invention in addition to the acquisition of disciplinary products of knowledge. The purpose of education should be understanding rather than simply knowing; its focus should be the active process of learning and creating rather than the passive acquisition of facts. As we pointed out in Chapter 2, it is possible to know about principles of literature or physics without being able to use them. However, it is not possible to use them without also understanding how they function in nature and human affairs. Active understanding subsumes passive knowledge and builds upon it. Students must not only analyze the products of creative understanding, such as novels, poems, experiments, theories, paintings, dances, and songs, they must copy and imitate them, thereby learning the sensual and synosic processes of their invention.

Second, it follows that we must teach the intuitive and imaginative skills necessary to inventive processes. As we have shown, creative thinking in every

field begins in nonlogical, nonverbal forms. To think is to feel and to feel is to think. Everyone should receive early and continuing stimulation of visual, aural, and other body senses and learn how to imaginatively recreate sense images. Everyone should be schooled in the mixing and melding of synesthetic imageries. Everyone should explore the feelings and emotions of the body. Everyone should learn to abstract, analogize, and empathize; to transform one to the other; and to translate intuitive forms of knowing into words, numbers, plastic images, movement, sound. In some cases, sensing and feeling are most naturally communicated as visual, literary, or musical expressions. Indeed, the arts in a liberal arts education are important because they provide the *best* and in some cases the *only* exercise of many thinking tools, both in imagination and in expression. This leads to our next point.

Third, we must implement a multidisciplinary education that places the arts on an equal footing with the sciences. Arts and sciences constantly interact in very fruitful ways that are often overlooked. Beginning with kindergarten and progressing through college, *every* student should study the arts as thoroughly as the sciences, the humanities, and mathematics. This means reversing the marginalization of the arts in colleges and secondary schools across the country and making the aRts the "fourth **R**" of everyone's education. The arts are not merely for self-expression or entertainment. They are, as we have shown, disciplines as rigorous as medicine or mathematics, with their own bodies of knowledge, techniques, tools, skills, and philosophies. Moreover, because the imaginative tools used in the arts are critical to the humanities and the sciences, they deserve support not just for their own sake but for the sake of education as a whole. Math, science, and technology have flourished in the past only when and where all the arts have flourished. They will flourish or fail together in the future.

Fourth, we must integrate the curriculum by using a common descriptive language for innovation. There is no point in teaching a liberal arts and sciences curriculum that continues to fragment knowledge and creates specialists who cannot communicate across disciplinary lines. Education must focus on the trunk of the tree of knowledge, revealing the ways in which the branches, twigs, and leaves all emerge from a common core. Tools for thinking stem from this core, providing a common language with which practitioners in different fields may share their experience of the process of innovation and discover links between their creative activities. When the same terms are employed across the curriculum, students begin to link different subjects and classes. If they practice abstracting in writing class, if they

work on abstracting in painting or drawing class, if they abstract relevant information from a history text or a biology experiment, and if, in all cases, they call it abstracting, they begin to understand how to think beyond disciplinary boundaries. They see how to transform their thoughts from one mode of conception and expression to another. Linking the disciplines comes naturally when the terms and tools are presented as part of a universal imagination.

Fifth, we must emphasize the transdisciplinary lessons of disciplinary learning. A common creative language is not enough. A century of educational studies has shown that students are far more likely to remember and apply what they have learned if information and skills are taught as generally useful rather than as unique solutions to unique problems. Teachers should downplay tags such as "art," "music," or "science" that place knowledge in insular boxes and focus instead on how the same material can be used flexibly in many disciplines. The object is to help everyone think simultaneously as artist *and* scientist, musician *and* mathematician, dancer *and* engineer. An education that trains the mind to imagine creatively in one field prepares the mind for creative application in any other, for thinking tools as well as flexible knowledge are transferable.

Sixth, we must use the experiences of people who have successfully bridged disciplines as exemplars of creative activity within our curricula. The best way to learn is to watch others and then model their techniques, insights, and processes. This book is filled with examples of people who have integrated knowledge in new ways, with descriptions of how they learned their imaginative skills and how they created. Such examples should be used in every class in every subject at every curricular level as spurs to inventive imitation and innovation. Until students see the human face of the creative process that underlies the disembodied products of their world, they cannot realize that they, too, may participate in creating their own vision of the future. And when they see that so many innovators in every discipline have been innovative precisely *because* they melded tools and concepts from numerous fields, they will understand and desire a synthesizing education.

Seventh, to reach the widest range of minds, ideas in every discipline should be presented in many forms. There is no one single imaginative skill or creative technique that is adequate for all thinking needs. The intuitive approach is as valuable as the logical one; the analytical, algebraic mind is no better than the geometric, visual mind or the kinesthetic, empathic one. Every idea can and should be transformed into several equivalent forms, each of which has a different formal expression and emphasizes a different set of

thinking tools. The more ways students can imagine an idea, the better their chances of insight. The more ways they can express that insight, the better their chances that others will understand and appreciate it.

Finally, we must forge a pioneering education, whose purpose is to produce the imaginative generalists who can take us into the uncharted future. Every novel idea takes us into new territory, and creative people are, by necessity, pioneers. The tools and skills that pioneers take to the frontiers are not specialized or narrow. They are basic, general-purpose tools that can be adapted to the need at hand. Pioneers of the creative imagination must have adaptable minds, too, and all-purpose toolboxes of inventive skills that enable them to make new knowledge.

What this new knowledge may be, we can only guess, but much remains to be known and invented. As Aldous Huxley noted shortly before his death, what we know now is a small part of what we can and will know in the future. "The purified language of science, or even the richer purified language of literature," he asserted, "[will] never be adequate to the givenness of the world." To expand our conceptions in keeping with this givenness will require manifold acts of the creative imagination, as biologist John Rader Platt cogently speculates: "Our verbal and musical symbols scarcely represent the whole field of possible sound; painting, sculpture and architecture scarcely scratch the surface of the organization of visual space; and I am not sure that mathematical symbols represent all the forms of biological logic. What new kinds of symbols," he asks, "are we preparing to manipulate, color organs, Labanotation for the ballet, or a dozen others, calling for new talents and developing new types of youthful genius?" What kinds indeed? One thing is certain. The new symbols will be unexpected and surprising, and in Huxley's view they will emerge only when the humanities and the sciences, the arts and technologies, "advance together."

To advance together means, said C. H. Waddington, whose book *Tools for Thought* inspired this one, "a very much more profound generalism than is usually considered." It means, as Waddington's colleague, biologist Chandler M. Brooks has written, that "in our educational endeavors, we may be compelled to think of specialization in breadth rather than specialization in minutiae." We must resist the pedagogical tracking of different kinds of learners. We must reverse the trend toward early and narrow specialization of student interest and activity. For when we look closely at the formative years of productive artists, scientists, and inventors we find that although the strong enthusiasms of youth shaped their future contributions, *they did not lead to them in any direct, disciplinary fashion.* Consider the following four

people, who showed strong early proclivities but whose adult achievements would have been crippled by early specialization and constriction of interests and activities.

In 1894 a young man climbed to the top of Scotland's highest peak, Ben Nevis. It was the kind of misty, translucent day when rainbows form in perfect circles around the sun and the shadows it casts. The young man thought these sights were the most beautiful he had ever experienced. "The wonderful optical phenomena shown when the sun shone on the clouds surrounding the hill top," he later wrote, "and especially the coloured rings surrounding the sun (coronas) or surrounding the shadow cast by the hill top or observer on mist or cloud (glories) greatly excited my interest, and made me wish to imitate them." Later, he did.

In 1895 another highly sensitive individual explained her creative aspirations. From a very young age, she recalled, "I loved poetry with a passion. Its very form, its very rhythm delighted me. I greedily devoured every excerpt from Russian poets that caught my eye and, I have to confess, the more high-flown the poetry the better I liked it. . . . The very beat of poetry enchanted me so much that I began composing at the age of five. . . . By the age of twelve, I was unshakably convinced I was going to become a great poet." Indeed, nothing seemed more divine to her than to create new worlds with poetic imagination.

At about the same time, another young man discovered that geometry was "the process that sets the truth before us. We start from a brilliantly-lighted spot and gradually get deeper and deeper into the darkness, which, in its turn, becomes self-illuminated by kindling new lights for a higher ascent. . . . It is assuredly a majestic enterprise, commensurate with man's immense ambitions, to seek to pour the universe into the mould of a formula and submit every reality to the standard of reason. . . . It is superb. You feel as if you were witnessing the creation of a world." Moved by the immense beauty of reason, he, too, aspired to illuminate new worlds.

Finally, listen to the words of a contemporary of these young people, whose love was the social sciences. "Different studies gave me practice in 'abstract' thinking, in learning to penetrate into fundamental questions," he wrote. "Aside from my chosen specialty (economics . . .), I was powerfully attracted, sometimes successively, sometimes simultaneously, to other different fields: Roman law . . . criminal law . . . the history of Russian law and peasant law . . . ethnology . . . all these claimed my attention and helped me to think in an abstract manner." This young man's goal was to alter fundamentally the conditions of humanity.

Who were these people? One might expect the young man who wanted to capture the coronas and glories of Ben Nevis to have become a painter; the young girl who loved poetry to have become a poet; the schoolboy who loved geometry to have become a mathematician; and the youth who loved the social sciences to have become an economist or politician. In our modern schools, they might have been pushed in these directions. None of these identifications is accurate, however. Each of the four used his or her unique blend of talents, training, and passion in unexpected ways.

"He who has once seen the intimate beauty of nature," Konrad Lorenz once said, ". . . must become either a poet or a naturalist and, if his eyes are good and his powers of observation sharp enough, he may well become both." C. T. R. Wilson, the young man so inspired by glories and coronas in the Scottish highlands, returned to his Cambridge laboratory and invented the cloud chamber with the poetry of physics in mind. Cloud chambers, as we discussed in Chapter 5, allowed scientists to visualize subatomic particles for the first time. But as Wilson revealed in his Nobel Prize lecture many years after the fact, his first concern had been a purely visceral and aesthetic one. His cloud chamber truly embodied both art and science, not only for himself, but for future generations, too. "I have seen the glory effect, and have made a Wilson cloud chamber when I was a youth," wrote chemist William Lipscomb some eighty years later. "Both effects are beautiful indeed."

The woman who was sure she would become a poet did so, and became an internationally recognized playwright as well — but only in her spare time. Sofya Kovalevskaya is remembered mainly for her outstanding contributions to mathematics. "You are surprised at my working simultaneously in literature and in mathematics," she wrote in her autobiography. "Many people who have never had occasion to learn what mathematics is confuse it with arithmetic and consider it a dry and arid science. In actual fact, it is the science which demands the utmost imagination. One of the foremost mathematicians of our century says very justly that it is impossible to be a mathematician without also being a poet in spirit. . . . The poet must see what others do not see, must see more deeply than other people. And the mathematician must do the same." Indeed, one of Kovalevskaya's teachers, Karl Weierstrass, proclaimed that "a mathematician who is not somewhat of a poet, will never be a perfect mathematician." Kovalevskaya took these words to heart, writing the poetry of numbers.

The schoolboy who loved geometry did not become a mathematician or a physicist or even an engineer. Rather, Henri Fabre earned for himself the sobriquets "poet and prophet of the insect world" and "prose Homer of the

wasps and spiders." His writings inspired thousands of young people to become entomologists in the first half of this century and gave pleasure to millions of readers. Nevertheless, geometry was never far from Fabre's creative imagination. "If it has ever fallen to my lot to write a page or two which the reader has run over without excessive fatigue," he once wrote, "I owe it, in great part, to geometry, that wonderful teacher of the art of directing one's thought. . . . It arranges what is confused, thins out the dense, calms the tumultuous, filters the muddy and gives lucidity, a superior product to all the tropes of rhetoric." Fabre would undoubtedly have agreed with Edna St. Vincent Millay, had he known of her then unpublished poetry, that "Euclid alone has seen beauty bare," for to him geometry was beautiful, in the same way that a poem or narrative was beautiful when its words, rhythms, and structure led toward illumination.

Finally, the young social scientist was Wassily Kandinsky, considered to be the first artist to paint nonrepresentational pictures. His love of abstract concepts and his desire to reform the conditions of mankind did not lead him into economics but into painting, where he reinvented perception and representation itself. To say, however, that Kandinsky "changed fields" is to miss the unity of his vision. "Painting is a thundering collision of different worlds," he wrote, "intended to create a new world in, and from the struggle with one another, a new world which is the work of art. . . . The trunk of the tree does not become superfluous because of a new branch: it makes the branch possible." Someone like Charles Ives understood this, too. He worked in the insurance industry his whole life and not only was proud of his business experience but felt that it contributed in fundamental ways to his music: "You cannot set art off in a corner and hope for it to have vitality, reality, and substance. The fabric weaves itself whole. My work in music helped my business and my work in business helped my music." Out of youthful enthusiasms and mature interests, the creative individual interleaves vocations and avocations that together stimulate imagination and innovation.

The point of these examples is simply put: these were whole people, not specialists. They made contributions to particular disciplines because of, not in spite of, their broad interests. They were pioneers, generalists, who bridged areas of expertise and pulled together disparate areas of knowledge. They met the challenges of their time and place and expanded the human imagination by being polymaths. And it is polymaths such as these to whom we will owe the great synthetic breakthroughs of the future.

The word *polymath*, derived from the Greek words meaning "to know

much" or "very knowing," has come to mean in common parlance a person of encyclopedic learning. Polymaths are not to be confused with dilettantes, who take up new subjects for amusement or pleasure. Polymaths master their activities to a significant degree and perceive the fundamental connections between them. The greatest polymaths of all, like the "Renaissance men" Leonardo da Vinci, Vesalius, and Michelangelo, seem capable of encompassing all that is known. Of course, no one has ever had truly encyclopedic knowledge, and that is not what we are calling for here. But it has long been observed by psychologists that people who are innovative tend to participate in a wider range of activities and develop a higher degree of skill in those activities than other people. Certainly that has been the case for virtually every artist, scientist, inventor, and humanist discussed in these pages, nearly all of whom can be called polymaths.

One need not be a genius to be a polymath. Everyone can develop hobbies, arts, crafts, intellectual interests, and challenging physical pastimes. Everyone can draw connections between an amateur avocation and a professional vocation. And everyone should, for the practical payoff is tremendous. Recent studies have found that the best predictor of career success in any field is not IQ, grades, or standardized test scores but participation in one or more mentally intensive leisuretime activities or hobbies — anything from painting, composing music, or writing poetry to programming computers, creating videos, or playing around with scientific ideas or mathematics. This is true for professionals of all kinds; it is true for business entrepreneurs and CEOs; it is true for artists, academics, and entertainers.

Some polymaths develop their multiple interests and activities so thoroughly that they achieve dual careers, for example, mathematician-poet Kovalevskaya, composer-chemist Aleksandr Borodin, poet-physician William Carlos Williams, and painter-biologist Desmond Morris. Others simply adapt the tools and knowledge of their avocational interest to their vocational field in the various ways we have discussed throughout this book. They conceptually integrate their many interests into "activity sets" or "networks of enterprise" that focus energy and nurture imagination by concentrating on the common skills and ideas that transcend any single avocation. As composer Robert Schumann stated, "The cultivated musician may study a Madonna by Raphael, the painter a symphony by Mozart, with equal advantage. Yet more: in sculpture, the actor's art becomes fixed; the actor in turn transforms the sculptor's works into living forms; the painter turns a poem into a painting; the musician sets a picture to music."

e. e. cummings provides another exemplar. He thought of himself as primarily a painter and wished to make a name for himself in that field. Yet it was not in visual art but in poetry that he made his most important contributions — not in spite of his love of painting but *because* of it. cummings tackled the transformation from painting to poetry quite literally. As a painter he used chiaroscuro, contrasting shades to highlight and give depth to images, and explored cubism, which contributed to what he called "seeing around" things. By direct imitation, in poetry he invented the concept of "knowing around" ideas, which he achieved by pairing words with their opposites, as in "big little," "glad sorry," "foolishwise" or "proudhumble." His innovation could not have come through training in literature courses; it could come only from sources manifestly outside that discipline.

Nobel laureate Georg von Békésy also believed in the cross-fertilization of knowledge and skills. When he wanted to understand how to do the best biology, he turned to art, where by diligent study he learned that the elements that characterize the greatest art — imagination, surprise, consistency, skill — also characterize the greatest science. As painter and Pulitzer Prize–winning novelist Paul Horgan has written, "Profoundly to understand one art is to be able to articulate principles — though not necessarily techniques — applicable to all arts. Form in one art can never convincingly be imitated in another; but analogies are possible — and not only from one art to another, but from science to art, and *vice versa*."

Some creative people take this cultivation of transdisciplinary, transferable skills to extremes. Poet Gary Snyder, for instance, has argued that an excellent mechanic or chef has as much to teach about the making of poetry as a master poet. "You learn how to use your mind in the act of handling parts and working," he has said. "You learn how things go together. . . . It's a *true* analogy. A master is a master. . . . Say you wanted to be a poet, and you saw a man that you recognized as a master mechanic or a great cook — you would do better, for yourself as a poet, to study under that man than to study under another poet who was not a master." Kurt Vonnegut also values mastery of the creative process over mastery of specific material. He has argued that it is pointless to look for the next generation of innovative writers in English and creative writing classes. They will, he believes, be found in the sciences and medicine, for mastery of those crafts will provide not only the basis for writing great fiction but the unusual experiences needed to enrich it.

Polymath- and imagination go hand in hand. Multiply trained individuals transform experience, synthesize knowledge, and lead us toward synosia,

the understanding that, in the words of physiologist Claude Bernard, "everything in nature is connected with everything else." Some part of this synosic understanding is within everyone's grasp. The same impulse that motivates the best art, the best literature, the best science can be harnessed to provide the best schooling, as innovators and their teachers have been doing for centuries. In Japan, people who perform the tea ceremony have always been trained synthetically. The method, based on the teachings of Zen Buddhism, reached its peak when Kobori Enshû built the Bosen (final attainment) tearoom in the seventeenth century. Enshû was a painter, poet, architect, gardener, and tea master. The room he designed for his tea ceremony integrated all that he knew into one harmonious whole. Tea masters today are expected to attain an equivalent synthesis of talent and experience. Shinichi Suzuki imbued his Talent Education program with a similar philosophy, based on personal observations of Einstein and other musically talented scientific friends. "I believe sensitivity and love toward music and art are very important things to all people whether they are politicians, scientists, businessmen or laborers," Suzuki wrote. "We are not teaching . . . children to make them professional musicians. . . . Talent education is life education." Education is meant to open many doors, leading to many rooms.

Many Western teachers have also striven for integration of sense and reason, emotion and analysis, the widest range of knowledge and understanding. Pestalozzi, Montessori, and other educators have insisted on using visual and proprioceptive modes of thinking to teach analytical material. At the Bauhaus in the 1930s, teachers strove to integrate daily life, art, and technology by ranging over an enormous number of disciplines. For a single painting course on human form, Oskar Schlemmer covered biology, ethics, anthropology, and theater as well as nude and figural drawing. His fellow teacher Paul Klee presented his classes with a chart of fields relevant to painting that included natural history, philology, literature, philosophy, and mathematics. Elsewhere, Merce Cunningham's dance and choreography teacher, Nellie Cornish, of Seattle's Cornish College of the Arts, also had her students study all of the arts. By the same token, poet Amy Lowell wrote that no subject should be "alien" to the poet, "and the profounder his knowledge in any direction, the more depth there will be to his poetry." For composer-architect-engineer Iannis Xenakis, "The artist-conceptor will have to be knowledgeable and inventive in such varied domains as mathematics, logic, physics, chemistry, biology, genetics, paleontology (for the evolution of forms), the human sciences and history; in short, a sort of universality, but

one based upon, guided by and oriented towards forms and architectures." Charles Steinmetz encouraged his engineering students at Union College in Schenectady, New York, "to study Greek, Latin, history, philosophy, and other subjects offered in the Liberal Arts College. The classics open the world of art and literature to the student. A neglect of them is one of the most serious mistakes. Technical training alone is not enough to fit a man for an interesting and useful life."

This advice is certainly as valid today as it was in Steinmetz's day. We need polymaths and pioneers who know that imagination thrives when sensual experience joins with reason, when Illusions link to Reality, when intuition couples with intellect, when the passions of the heart unite with those of the mind, when knowledge gained in one discipline opens doors to all the rest.

Everything in your life ends up in your act.

Addressing a conference on art, science, and creativity, comedian Aaron Freeman recently boiled it all down to that single punch line. We couldn't agree more. Every example in this book demonstrates Freeman's conclusion. You are all that you can do, and all that you can do is mirrored in what you create. The wider your range of knowledge and feeling, the greater your range of imaginative possibilities and the more synthetic and important your work will be.

The point of education must be to create whole people who, through their wholeness, can focus the accumulated wisdom of human experience into illuminated patches of splendor.

I live to buy in every mart;
To try the hand at every art;
In every science take a part;
With every passion prove the heart. . . .

So wrote the young Sir Ronald Ross, physician, scientist, musician, composer, and poet many years before he was honored with a Nobel Prize for his discovery of the mode of transmission of malaria. His aspirations could not be more worthy in our fragmented world. For, as Robert Frost said so eloquently in "Two Tramps in Mud Time," to fuse emotion, intellect, and purpose into one universal imagination is the greatest joy and greatest resource of the individual and of humankind:

But yield who will to their separation,
My object in living is to unite
My avocation and my vocation
As my two eyes make one in sight.
Only where love and need are one,
And the work is play for mortal stakes,
Is the deed ever really done
For Heaven and the future's sakes.

A synthesizing education strives for nothing less.

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MINDS-ON RESOURCES

THINGS FOR ALL AGES TO PLAY WITH

Art to Zoo: News for Schools from the Smithsonian Institution. Office of Elementary and Secondary Education, Washington, D.C. 20560. An educator's guide to materials, games, and other exercises associated with the Smithsonian's exhibits. Covers every possible tool for thinking in the most multicultural way.

Beeswax for Modeling. Stockmar Wax in many different colors is available from Hearth Song, P.O. Box B, Sebastopol, CA 95473. 1-800-325-2502.

Dymaxion World Puzzle, Buckminster Fuller Institute. 1987. Available from Pacific Puzzle Company, 378 Guemes Island Road, Anacortes, WA 98221. A puzzle-map illustration of one of Fuller's basic structural ideas.

Dimensional Man. (David Pelham, 1999). New York: Simon and Schuster. A life-sized, 3-D cutaway model of the human body with moving parts.

Edmund Scientific Catalog. Edmund Scientific Company, Consumer Science Division, 1101 East Gloucester Pike, Barrington, NJ 08007-1380. 1-800-728-6999. The home source for everything from models, motors, and gears to electronics and cameras you can build yourself. Covers the range of tools for thinking.

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Ernst, Bruno. 1992. *Optical Illusions.* Cologne, Germany: Taschen. Describes how to make Penrose impossible staircases and tribars. Also covers Escher's geometric impossibilities and cognitive aspects of perception.

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Froebel Blocks (Friedrich Froebel, 1831). Museum of Modern Art. Mail Order Department. 11 West 53rd St., New York, NY 10019-5401. 1-800-447-6662. The 3-D building game that stimulated the likes of Frank Lloyd Wright, Buckminster Fuller, and Wassily Kandinsky.

Gardner, Martin. 1978. *Aha! Insight.* San Francisco: W. H. Freeman. Any book by Gardner is great, and this is one of the best. Pattern recognition and forming 2-D and 3-D puzzles, and much more.

Geodesic Dome Model Kits, Avionics Plastics Corporation, Farmington, NY 11735. Build Buckminster Fuller geodesic domes and much more.

Haab, Sherri, and Torres, Laura. 1994. *The Incredible Clay Book.* Palo Alto, Calif.: Klutz Press. A gem for building 3-D and manipulative skills.

Klutz Catalogue, 455 Portage Avenue, Palo Alto, CA 94306-2213. 1-800-558-8944. The best hands-on books around for building body thinking, imaging, patterning, and related skills.

Kohl, MaryAnn F. 1989. *Mudworks: Creative Clay, Dough, and Modeling Experiences.* Bellingham, Wash.: Bright Ring Publishing. The title says it all.

Long Jump Preceded by a Run: A Chronophotograph by Etiennes-Jules Marey. Optical Toys. P.O. Box 23, Putney, VT 05346. A flipbook recreating Marey's studies of motion.

Making Music. (Morton Subotnik. 1995.) Voyager CD-ROM (www.voyager.com). A visual-pattern approach to composing music on computers.

Mindware. 2720 Patton Road, Roseville, MN 55113. 1-800-999-0398. One of the best general catalogues of 3-D games, puzzles, building toys, tessellations, and much more.

Ninomiya, Yasuaki. 1980. *Whitewings, Excellent Paper Airplanes.* AG Industries, 3832 148th Ave. NE, Redmond, WA 98052. 1-206-885-4599. Some of the best paper airplane designs around. Good for dimensional and modeling skills.

One Milk Drop. (Harold "Doc" Edgerton, 1996.) Optical Toys, P.O. Box 23, Putney, VT 05346. A flipbook recreating Edgerton's stop-motion photography.

Origami. You'll find many good books on origami at your library or bookstore. Refer to the articles by Barry Cipra listed in the Bibliography for the mathematical basis of origami.

Parola, René. 1996. *Optical Art: Theory and Practice.* New York: Dover Publications. Hands-on examples of how to make moiré patterns, optical illusions, Vasarely– and Bridget Riley–style drawings, and more, with examples from pros and teenagers.

Pentagram. 1989. *Puzzlegrams.* New York: Simon and Schuster. Puzzles using many tools for thinking.

Pentagram. 1990. *Pentagames.* New York: Simon and Schuster. Games using many tools for thinking.

Prairie Style Building Blocks and Guggenheim Architecture Blocks. Frank Lloyd Wright Collection. P.O. Box 64412, St. Paul, MN 55164-0412. 1-800-735-2587. Different block styles for building 3-D skills.

Roef, Kerry. 1992. *The Private Eye: Looking/Thinking by Analogy.* Seattle: Private Eye Project. Exercises for analogical thinking across the curriculum.

Schattschneider, Doris, and Wallace Walker. 1977. *M. C. Escher Kaleidocycles.* Corte Madera, Calif.: Pomegranate Press. Escher prints that you cut and paste to form geometric solids and kaleidocycles, a novel 3-D geometric form invented by the authors, a mathematician and an artist, respectively.

Sculpstone. T&M McCurry, Box 372, Philo, CA 95466. 1-707-895-2291. Sculpting material for learning basic 3-D techniques and manipulative skills.

Set. (Marsha Falco, 1991.) Game of pattern recognition and, equally important, nothingness perception for people of any age. Widely available in retail stores.

Seymour, Dale, and Jill Britton. 1989. *Introduction to Tessellations.* Palo Alto, Calif.: Dale Seymour Publications. Ever wonder how Escher actually made his tessellations? Hands-on exercises show you.

Skwish (1991). Pappa Geppetto's Toys Victoria, Ltd. Box 3567, Blaine, WA 98231-3567. A Kenneth Snelson tensegrity model in the form of a squishable toy for kids of all ages.

Sunprint Kit. Lawrence Hall of Science, University of California, Berkeley, CA 94720. 1-415-642-1016. Available at Natural Wonders stores. Makes photographic prints using sunlight and water as a developer. Great for thinking about how 3-D maps onto 2-D.

Tangrams. The ancient Chinese puzzle is available in many forms in most hobby and toy stores. Teaches pattern recognition and pattern forming.

Tensegritoy. Tensegrity Systems Corporation. Tivoli, NY 12583. 1-800-227-2316. A building system based on Kenneth Snelson's tensegrity principle.

The Magic Mirror: An Antique Optical Toy. 1979. New York: Dover Publications. Anamorphic pictures that use a cylindrical mirror (included).

The Magic Moving Picture Book. 1977. New York: Dover Publications. Recreates the kinds of images Muybridge and Marey made popular.

Tree Blocks. Von Oppen Toy Company, 2022 Cliff Drive, Suite 292, Santa Barbara, CA 93109. 1-818-992-4569; e-mail: elves@treeblocks.com. These, the most unusual blocks we have come across, provide a very different approach to 3-D building than do geometric shapes.

SELECTED VIDEO AND AUDIO SOURCES

"Alexander Calder." *An American Masters Special* (WNET, 1998). WNET, P.O. Box 2284, South Burlington, VT 05407. 1-800-336-1917.

Behind the Scenes. Ten half-hour episodes with Penn and Teller, directed and produced by Ellen Hovde and Muffie Meyer. WNET, P.O. Box 2284, South Burlington, VT, 05407. 1-800-336-1917. This introduction to how creative people work illustrates all of the thinking tools. Particularly good for children and teens.

From the Earth to the Moon. Part 3: Spider (1999). Directed by Tom Hanks. An excellent example of transformational thinking, recreating the development of the lunar lander from sketch through model to functional machine.

"Georgia O'Keeffe," *American Masters* Series. Directed by Perry Adato. WNET, P.O. Box 2284, South Burlington, VT 05407. 1-800-336-1917.

Helen Keller in Her Story. American Foundation for the Blind, 11 Penn Plaza, Suite 300, New York, NY 10001. Original film interviews with Keller, revealing her incredible intelligence.

"Innovation and Imagination." Robert Haas, recorded 26 Feb. 1997 by CSPAN2 for "About Books." Available from the National Association of Independent Schools, 1620 L Street NW, Washington, DC 20036.

Lorenzo's Oil (1992). Directed by George Miller. A factually accurate reconstruction of the Odones' attempt to find a cure for their son's mysterious disease; pattern recognition and modeling play major roles.

"Martin Gardner, Mathemagician." *The Nature of Things* (Canadian Broadcasting Corporation, 1996) (http://www.cbc.ca). Directed by David Suzuki. Mathematical art, magic, game playing, pattern forming, and everything else wonderful that Martin Gardner has always melded.

"People in Motion II." Directed by Vicki Sufian. WNET, P.O. Box 2284, South Burlington, VT 05407. 1-800-336-1917. A look at how Evelyn Glennie makes music and how other handicapped people make art or do other unlikely things. Illustrates many tools in unexpected ways.

The Race for the Double Helix (1993). Directed by Mick Jackson. A factually accurate reconstruction of the Watson-Crick discovery of the DNA double helix, starring Jeff Goldblum and emphasizing the roles of hunches, emotions, modeling, and transformational thinking.

"Race for the Superconductor," *Nova*, 1988 (WNET, Boston). Proprioceptive and transformational thinking that mixes dance with physics.

Sequencia (Susan Alexjander). CD, Logos Series, Science and the Arts, P.O. Box 8162, Berkeley, CA 94707. DNA-based music.

"Special Effects: Titanic and Beyond." *Nova*, 1999. WNET, P.O. Box 2284, South Burlington, VT 05407. 1-800-336-1917. Dimensional thinking, modeling, and an excellent segment on the electronic motion-capture technology that Marey's abstract photography has engendered.

Stomp Out Loud (Stomp, 1998). Pattern forming and proprioceptive thinking through urban primitive dance-music. Try it with a group of your friends!

Thirty-Two Short Films About Glenn Gould (1995). Directed by François Girard. Columbia Tristar Home Video. Everything from pattern forming to transformational thinking. Stunning!

Torn Notebook (University of Nebraska Television). Directed by Gene Bunge. Great Plains National, P.O. Box 80669, Lincoln, NE 68501-0669. 1-800-228-4630. A look at how Claes Oldenburg and Coosje von Bruggen created their sculpture

"Torn Notebook," from idea through models to installation. Great example of transformational thinking.

Yo-Yo Ma Plays Bach's Cello Suites (Rhombus Media with WNET, 1997). WNET, P.O. Box 2284, South Burlington, VT 05407. 1-800-336-1917. Ma collaborates with a wide range of artists, architects, dancers, and filmmakers to produce a truly synesthetic experience.

Note: The Public Broadcasting System, the Canadian Broadcasting System, and the British Broadcasting Corporation put out catalogues of their programs each year. Many valuable documentaries concerning individual dancers, artists, sculptors, and scientists not listed here are available.

INTERNET SOURCES

Because of the incredibly rapid proliferation of Internet sites, any list is out of date before it is printed. The Internet references below are limited to those cited in the text. Many museums are now putting their resources on the Web, and almost every person mentioned in the book is discussed on at least one site. A careful choice of search terms will bring up other useful sites bearing on most of our tools for thinking as well.

Art-Science Collaborations, an organization that does what it says at: http://www.asci.org.

Bee vision (empathizing) can be found at: *http://cvs.anu.edu.au/andy/beye/beyehome.html* and at *http://www.geocities.com/Athens/Oracle/5410/bee.html.*

"Dance Review: Pilobolus Dance Theatre, Old Tale Just Isn't the Same," by Linda Belans: *www.nando.net.*

DNA music can be found at Phil Ortiz's Web site, Sounds of Science: *http://www.skidmore.edu/foureyes/phil/sos/sos.htm.*

Evelyn Glennie's home page, with interesting documents, is *http://www.evelyn.co.uk/bodypg.htm.*

The Exploratorium in San Francisco is one of the world's best hands-on museums specializing in science but exploring the arts as well. See their exhibits and other educational materials at: *http://www.exploratorium.edu/ti.*

The golden section as a pattern found in art, architecture, music, poetry, biology, and so on: *http://www.mcs.surrey.ac.uk/Personal/R.Knott/Fibonacci/fib'nArt.html.*

"Innovative Visual-Spatial Powers in Dyslexics: A New Perspective!" by S. E. Parkinson and J. H. Edwards, 1997. Internet Service Dyslexia Paper Archive: *http://www.rmplc.co.uk/orgs/wellalex/adtvisuospatial.html.*

International Synaesthesia Association Index Web site: *http://nevis.sitr.ac.uk.*
Klutz products: *http://www.klutz.com.*
LEONARDO is the world's leading arts-sciences and arts-technology journal. Most of the ideas we discuss are explored here: *http://mitpress.mit.edu/e-journals/Leonardo/home.html.*
Montessori Foundation Bookstore: *http://www.montessori.org/bookstor.htm.*
Painting with atoms — the ultimate in dimensional art: *http://www.almaden.ibm.com/vis/stm/gallery.html.*
Paleomap Project. Geological pattern forming at: *http://www.scotese.com.*
Roger Penrose Web site: *http://rysy.msm.cam.ac.uk/~msms/penrose.html.*
Tensegrity Web site with information about Kenneth Snelson: *http://www.teleport.com/~pdx4d/docs.*
Visible Human Project, National Library of Medicine: *http://www.npac.syr.edu/projects/vishuman/VisibleHuman.html.*

BOOKS FOR THE VERY YOUNG

Anno, Mitsumasa. 1969. *Topsy-Turvies.* New York: Weatherhill. Dimensional thinking.

———. 1971. *Upside-Downers: More Pictures to Stretch the Imagination.* New York: Weatherhill. More dimensional thinking.

Baum, Arline, and Joseph Baum. 1989. *Opt: An Illusionary Tale.* New York: Puffin Books (Viking). Excellent introduction to visual pattern recognition, dimensional thinking, and play.

Clement, Claude, and Frederic Clement. 1986. *The Painter and the Wild Swans.* New York: Dial. A painter empathizes with the swans he paints, becoming one.

Hepworth, Cathi. 1992. *Antics!* New York: G. P. Putnam's Sons. Pattern recognition based on finding the word "ant" in other words.

Johnson, Crockett. 1960. *Harold and the Purple Crayon; Harold's ABC;* and other titles. New York: Harper and Row. Pattern recognition, pattern forming, and analogizing.

Jonas, Ann. 1983. *Round Trip.* New York: Scholastic. Every picture in this unusual book can be seen in two ways. Pattern play.

Juster, Norton. 1963. *The Dot and the Line: A Romance in Lower Mathematics.* New York: Random House. Introduction to pattern forming in art and math.

Kunhardt, Dorothy. 1970. *Pat the Bunny.* New York: Golden Books. Kinesthetic thinking for the very, very young.

Moore, Frank J. 1978. *The Magic Moving Alphabet Book.* New York: Dover Publications. As the cover says, "26 Hidden Pictures Come to Life and Move with the Magical Moiré." A truly unique book that uses moiré patterns to hide and reveal images.

Shaw, Charles G. 1947. *It Looked Like Spilt Milk.* New York: Harper and Row. Classic in pattern recognition of forms in clouds.

READING FOR THE NOVICE LEARNER IN ALL OF US

Agee, Jon. 1999. *So Many Dynamos! And Other Palindromes.* Verbal pattern play.

Anno, Mitsumasa. 1985. *Anno's Sundial.* New York: Philomel Books. A pop-up book that covers a wide range of dimensional thinking issues, linking art and science in the process. All of Anno's books combine thinking skills that transcend disciplines.

Augarde, Tony. 1984. *The Oxford Guide to Word Games.* New York: Oxford University Press. Pattern forming, pattern recognition, playing.

Bang, Molly. 1991. *Picture This.* Boston: Bullfinch Press. An introduction to principles of visual design and visual thinking.

Berry, S. L. 1994. *E. E. Cummings.* Mankato, Minn.: Creative Education. Intriguing synthesis of biography, poetry, and resonant art by Stasys Eldrigevicius.

Byrom, Thomas. 1977. *Nonsense and Wonder: The Poems and Cartoons of Edward Lear.* New York: E. P. Dutton. Verbal and visual playing; synesthesia.

Cassidy, John, and the Exploratorium. 1996. *Exploratbook: A Kids' Science Museum in a Book.* Palo Alto: Klutz Books. This book does it all.

Cassidy, John, Paul Doherty, and Pat Murphy. 1997. *Zap Science.* Palo Alto: Klutz Books. Observe, play, and imagine to your heart's content!

Cole, Allison. 1993. *Color: An Eyewitness Book.* London: Dorling Kindersley. Observing, imaging, and playing.

Elffers, Joost. 1997. *Play with Your Food.* New York: Stewart, Tabori and Chang. 3-D play.

Ennion, E. A. R., and N. Tinbergen. 1967. *Tracks.* Oxford: Clarendon Press. A masterpiece of transforming between 2-D and 3- and 4-D thinking, beginning with animal tracks.

Fleischman, Paul. 1988. *Joyful Noise: Poems for Two Voices.* New York: Harper and Row. Pattern forming resulting from syncopated readings of multiple voices.

Frayling, Christopher, Helen Frayling, and Ron Van der Meer. 1992. *The Art Pack.* New York: Alfred A. Knopf. A unique 3-D look at the processes by which artists invent and perceive.

Greenberg, Jan, and Sandra Jordan. 1991. *The Painter's Eye: Learning to Look at Contemporary American Art.* New York: Delacorte Press. Pattern forming, proprioceptive thinking, transformational thinking, and synosia.

———. 1993. *The Sculptor's Eye: Learning to Look at Contemporary American Art.* New York: Delacorte Press. Proprioceptive, 3-D, transformational thinking, and synosia.

Hall, Donald, ed. 1985. *The Oxford Book of Children's Verse in America.* New York: Ox-

ford University Press. Full of playful experiments in verbal patterning, analogizing, imaging, and other skills.

Jackson, Brenda. 1972. *Model Making in Schools.* New York: Van Nostrand Reinhold. An excellent guide to multidisciplinary projects, from very simple to quite complex, from history and cultural models to engineering and science.

Joyce, Mary. 1973. *First Steps in Teaching Creative Dance to Children.* Integrates proprioceptive thinking with imaging, analogizing, patterning, abstracting, and more.

Judson, Horace Freeland. 1980. *The Search for Solutions.* New York: Holt, Rinehart and Winston. A well-illustrated book about scientific thinking that stresses pattern forming, modeling, and so on.

Juster, Norton. 1961. *The Phantom Tollbooth.* New York: Random House. An adventure about perception, wordplay, mathematics, patterns, synesthesia, and much more.

Koch, Kenneth, and Students of Public School 61 in New York City. 1970. *Wishes, Lies and Dreams: Teaching Children to Write Poetry.* New York: Harper and Row. Combines sensual thinking, metaphors and analogies, pattern recognition and pattern forming, and more.

Koch, Kenneth, and Kate Farrell, eds. 1985. *Talking to the Sun: An Illustrated Anthology of Poems for Young People.* New York: Metropolitan Museum of Art/Henry Holt. A wonderfully synthetic and synergistic interaction between the patterns of poetry and of art.

Lankford, Mary D. 1992. *Hopscotch Around the World.* New York: Morrow Junior Books. Combines pattern recognition and proprioceptive thinking.

Lear, Edward. 1975. *A Book of Bosh.* Chosen and edited by Brian Alderson. London: Puffin Books. Verbal playing.

Loyd, Sam. 1912. *Sam Loyd's Puzzles.* Philadelphia: David McKay. Reprint, 1975: New York: Dover Books. The best transformational thinking puzzles around.

Martin, Bill, Jr., and John Archambault. 1987. *Knots on a Counting Rope.* New York: Bantam Doubleday Dell. A blind boy is introduced to the concept of "seeing" with his other senses.

Marsalis, Wynton. 1995. *Marsalis on Music.* New York: W. W. Norton. An excellent introduction to musical patterns and the emotions they express.

Miller, Jonathan. 1978. *The Body in Question.* London: Jonathan Cape. An unexpectedly multitooled look at how the body functions, with sections on modeling, anamorphosis, and other tools.

Miller, Jonathan, and David Pelham. 1983. *The Human Body.* New York: Viking. One of the first and best pop-up books, combining science with art via dimensional thinking.

Morrison, Philip, Phylis Morrison, and the Office of Charles and Ray Eames. 1982. *Powers of Ten: A Book about the Relative Size of Things in the Universe and the Effect of Adding Another Zero.* San Francisco: Scientific American Library/W. H. Freeman. Dimensional thinking at its best.

Munthe, Nellie. 1983. *Meet Matisse.* Boston: Little, Brown. A great introduction to abstracting.

Nash, Ogden. Anything by this prolific nonsense poet will amuse and teach pattern play.

Pawson, Des. 1999. *The Handbook of Knots.* London: Dorling Kindersley. Kinesthetic imaging that is useful.

Preiss, Bryon, and William R. Altschuler, eds. 1989. *The Microverse.* New York: Bantam. A look at the infinitely small from scientific, literary, and artistic perspectives that explore dimensional thinking, empathizing, imaging, and other tools.

Rudolph, James Smith. 1999. *Make Your Own Working Paper Clock.* Transformational thinking, visual thinking, dimensional thinking.

Thurber, James. 1957. *The Wonderful O.* Reprint, 1985: New York: Dell. What would happen if all the Os were eliminated from all the words in the world? A masterpiece of imaginative play.

White, T. H. 1958. *The Once and Future King.* New York: G. P. Putnam's Sons. The young King Arthur's adventures with Merlin include many empathic explorations of animal behavior.

Winslow, Marjorie. 1999. *Mud Pies and Other Recipes.* Hands-on make-believe for creating one's own universe with dolls.

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— Desmond Morris, zoologist, artist, and author of *The Naked Ape*

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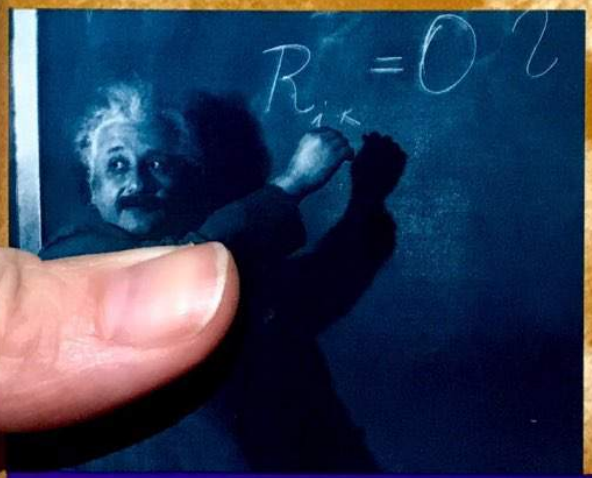

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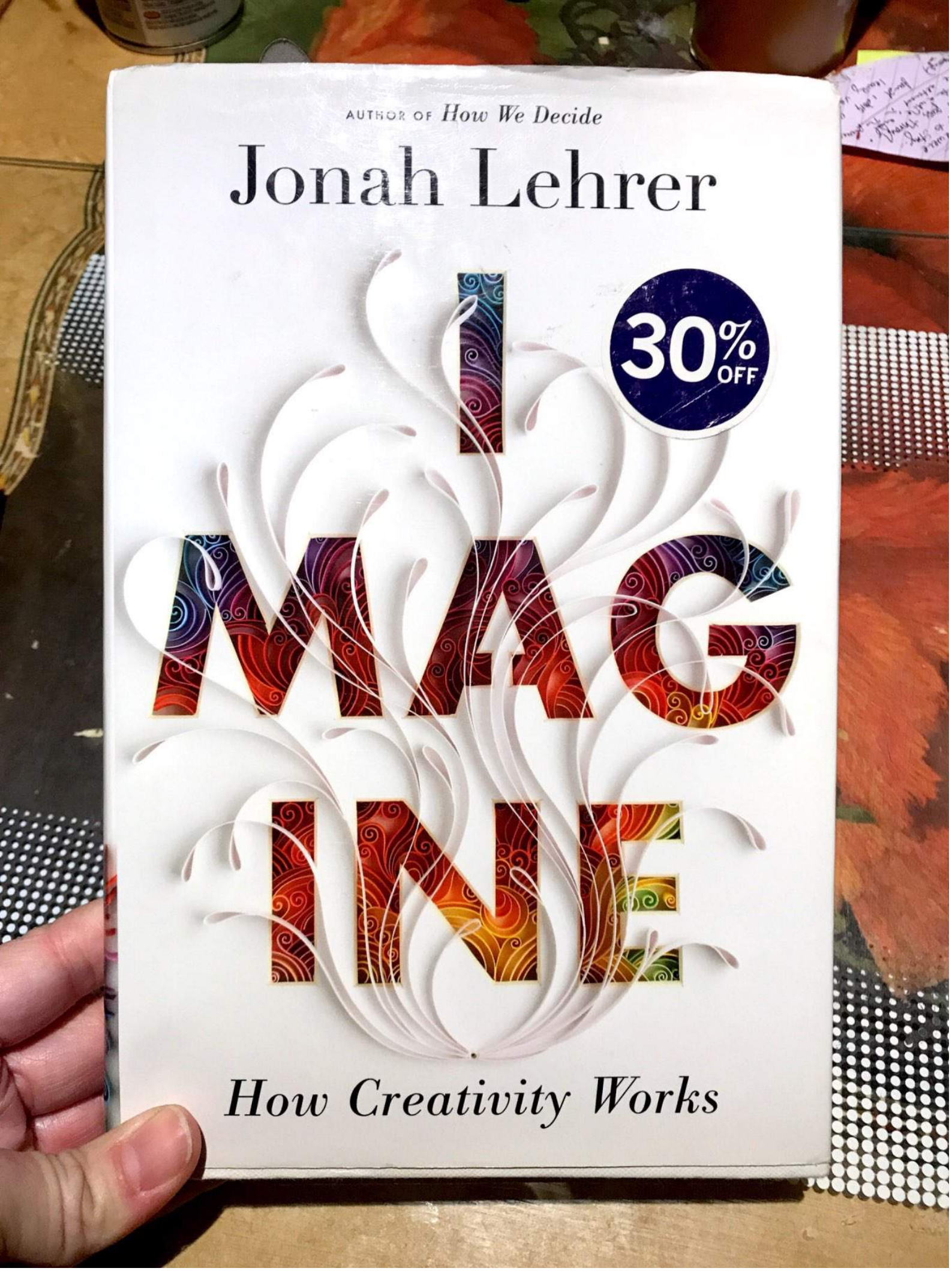

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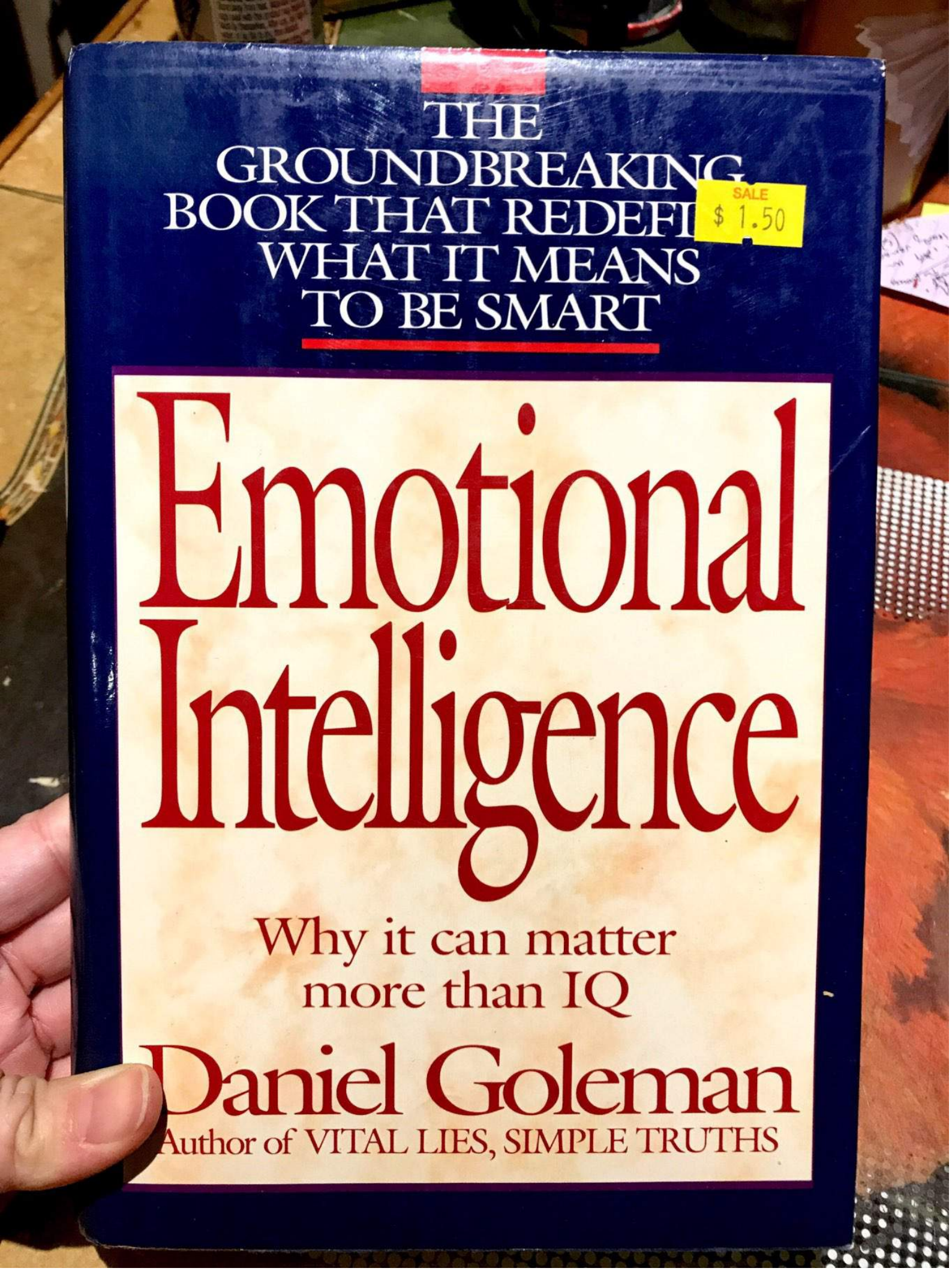

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JULIA CAMERON has taught and refined the methods of *The Artist's Way* for more than a decade. She has been a working artist for twenty years, serving in Hollywood as a film and television writer, director, and producer of independent features and documentaries. An award-winning journalist who has written for such diverse publications as the *Washington Post*, *New York Times*, *Rolling Stone*, and *Vogue*, Ms. Cameron served recently as writer-in-residence at Northwestern University where she applied her creative-unblocking techniques in teaching screenwriting and fiction in her workshop "The Vein of Gold." Ms. Cameron makes her home in Taos, New Mexico, with her partner Mark Bryan, her daughter Domenica, and three horses and four dogs.

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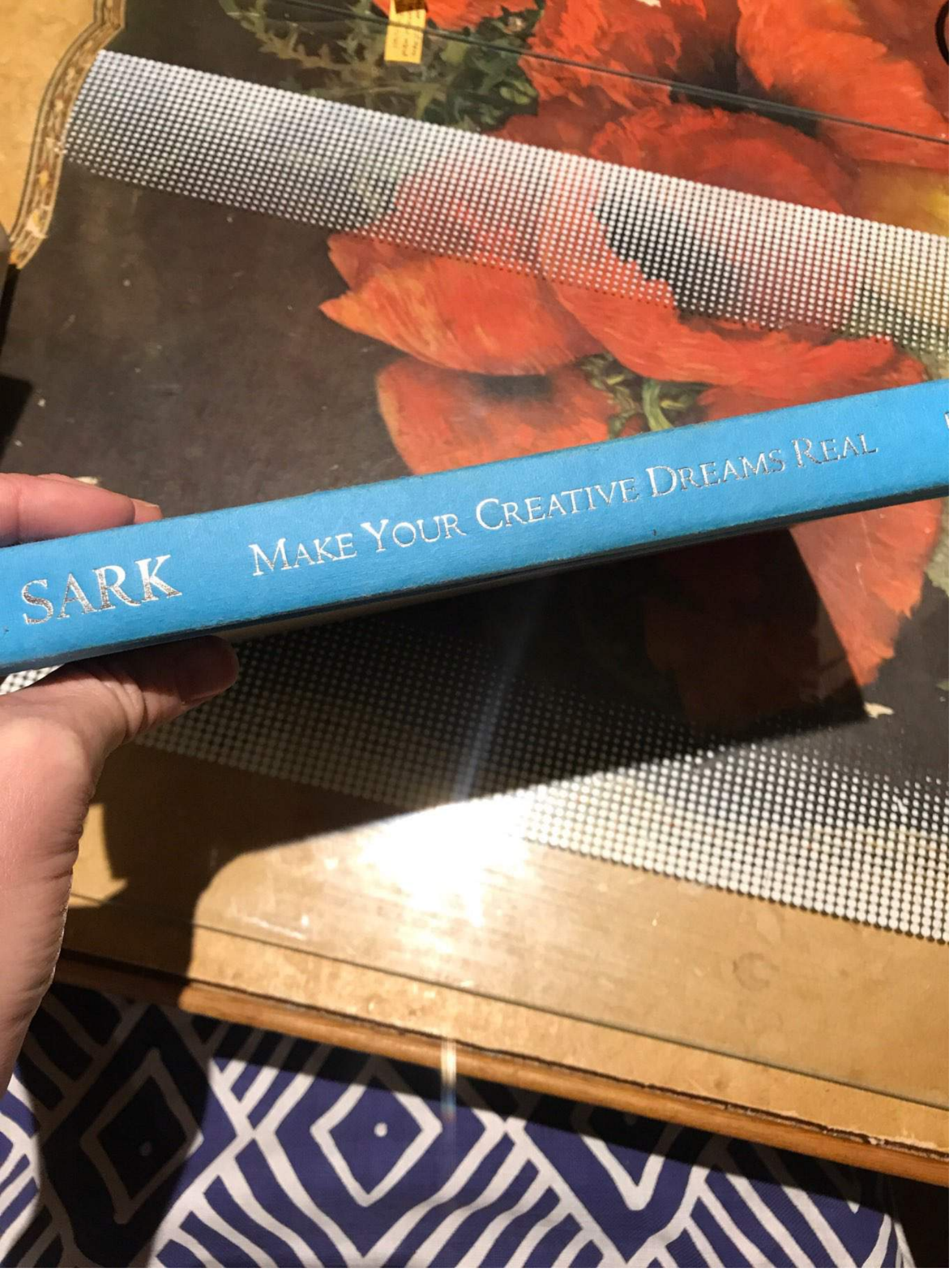

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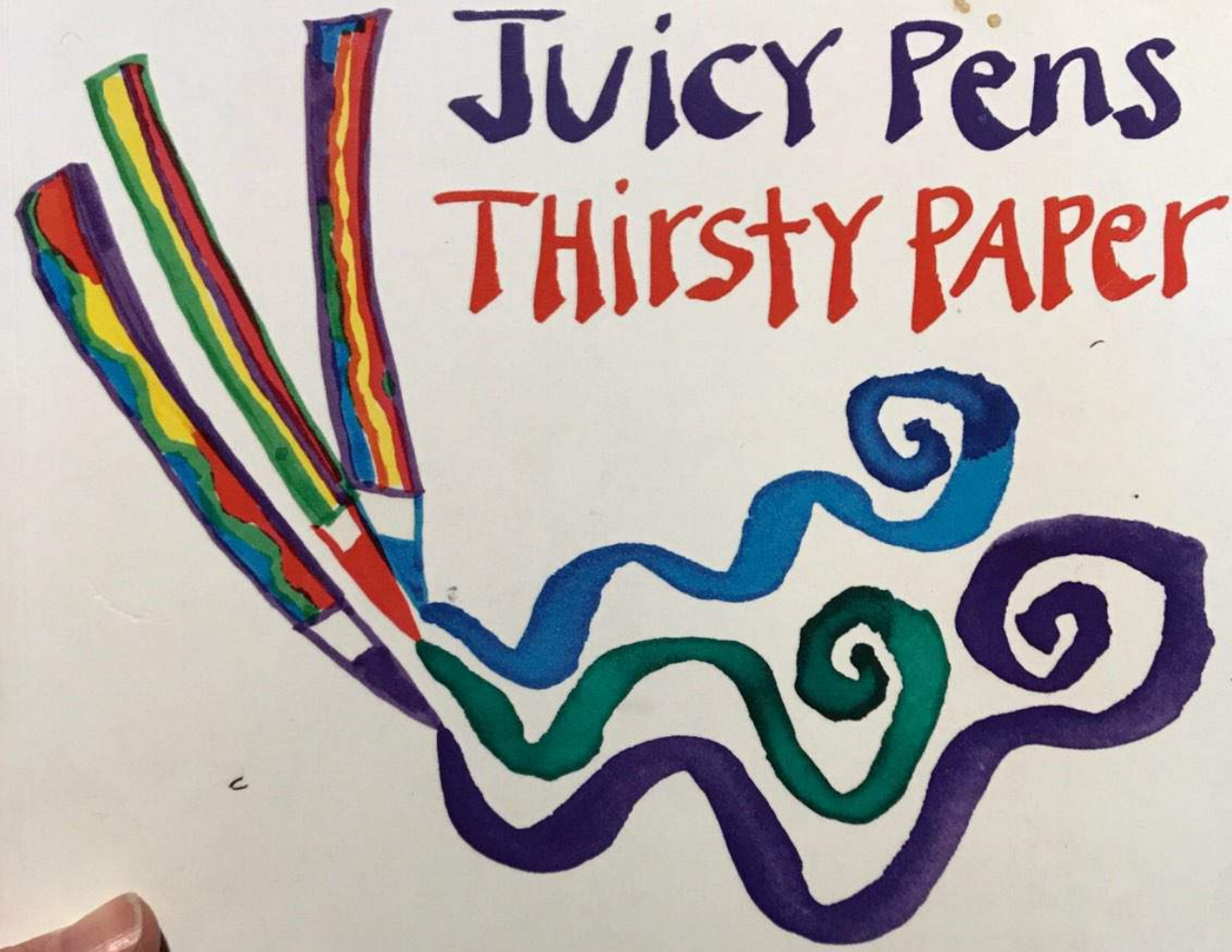

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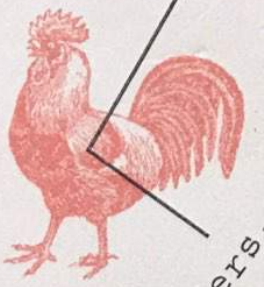

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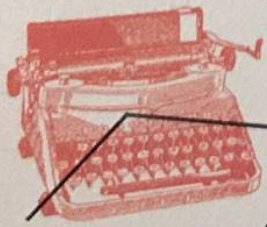

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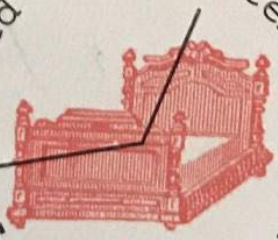

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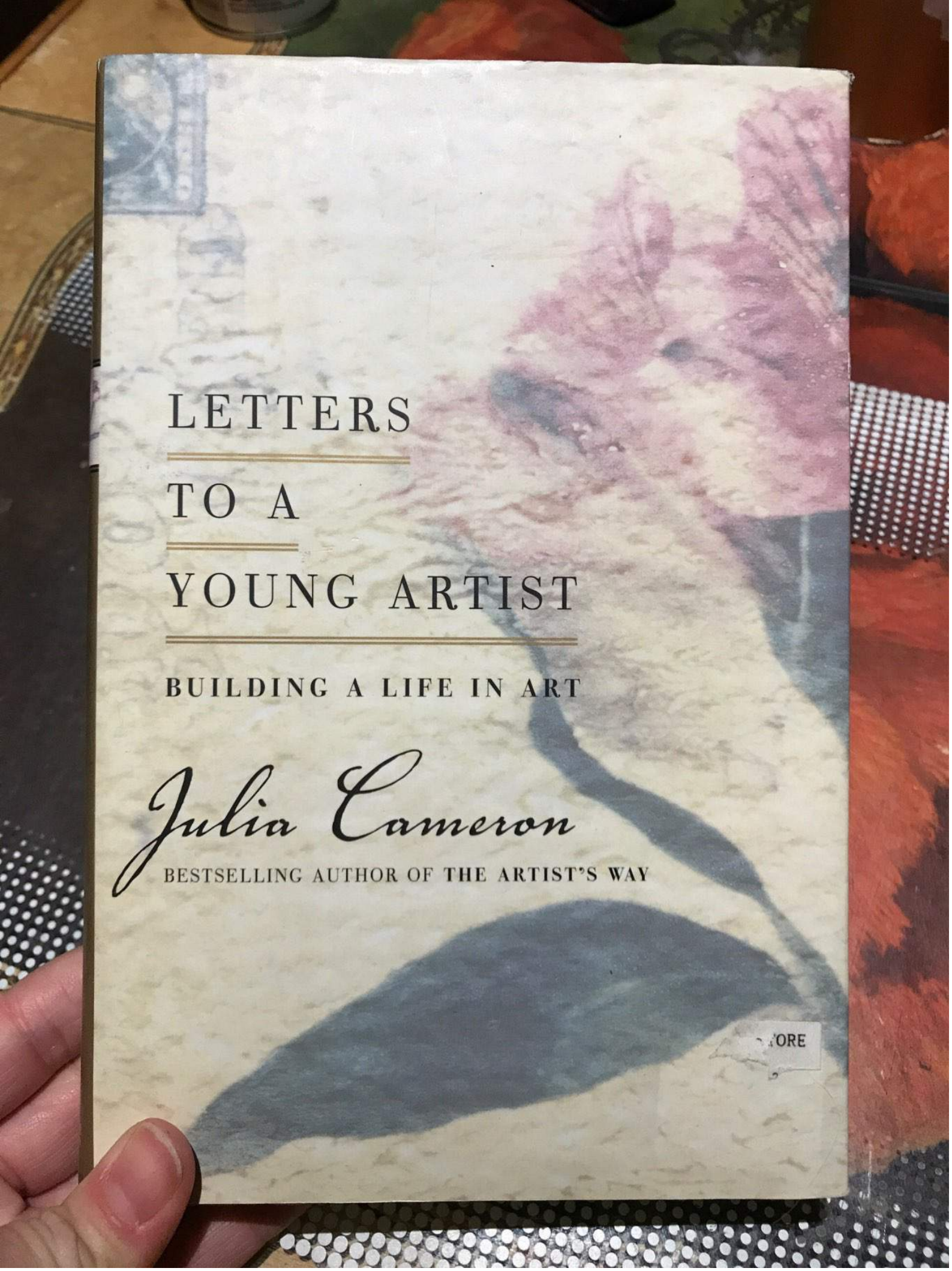

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HOWARD GARDNER is Professor of Education at Harvard University. A MacArthur Prize Fellow from 1981 to 1986, he was also the first American to receive the University of Louisville Grawemeyer Award in Education (1990).

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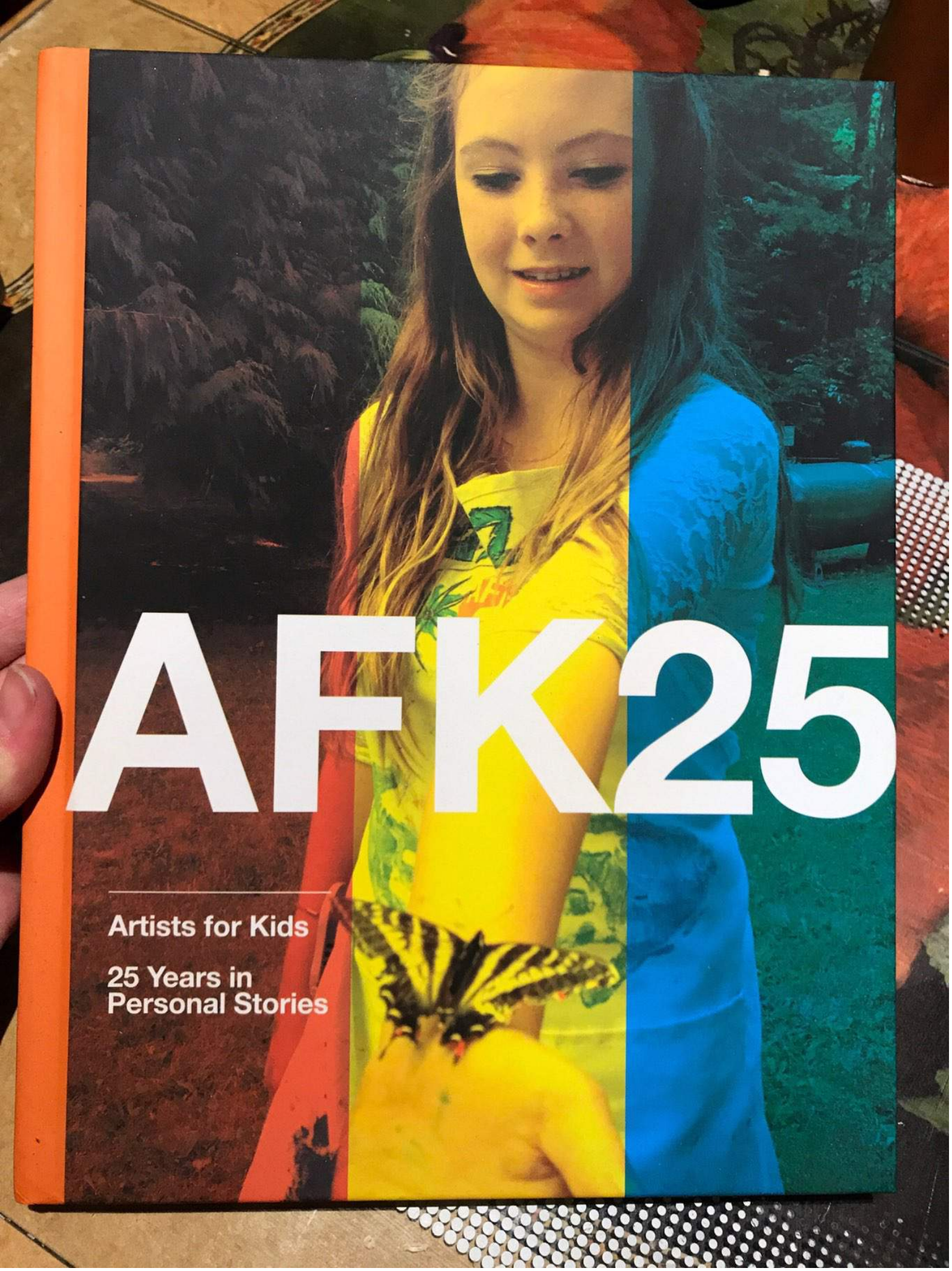

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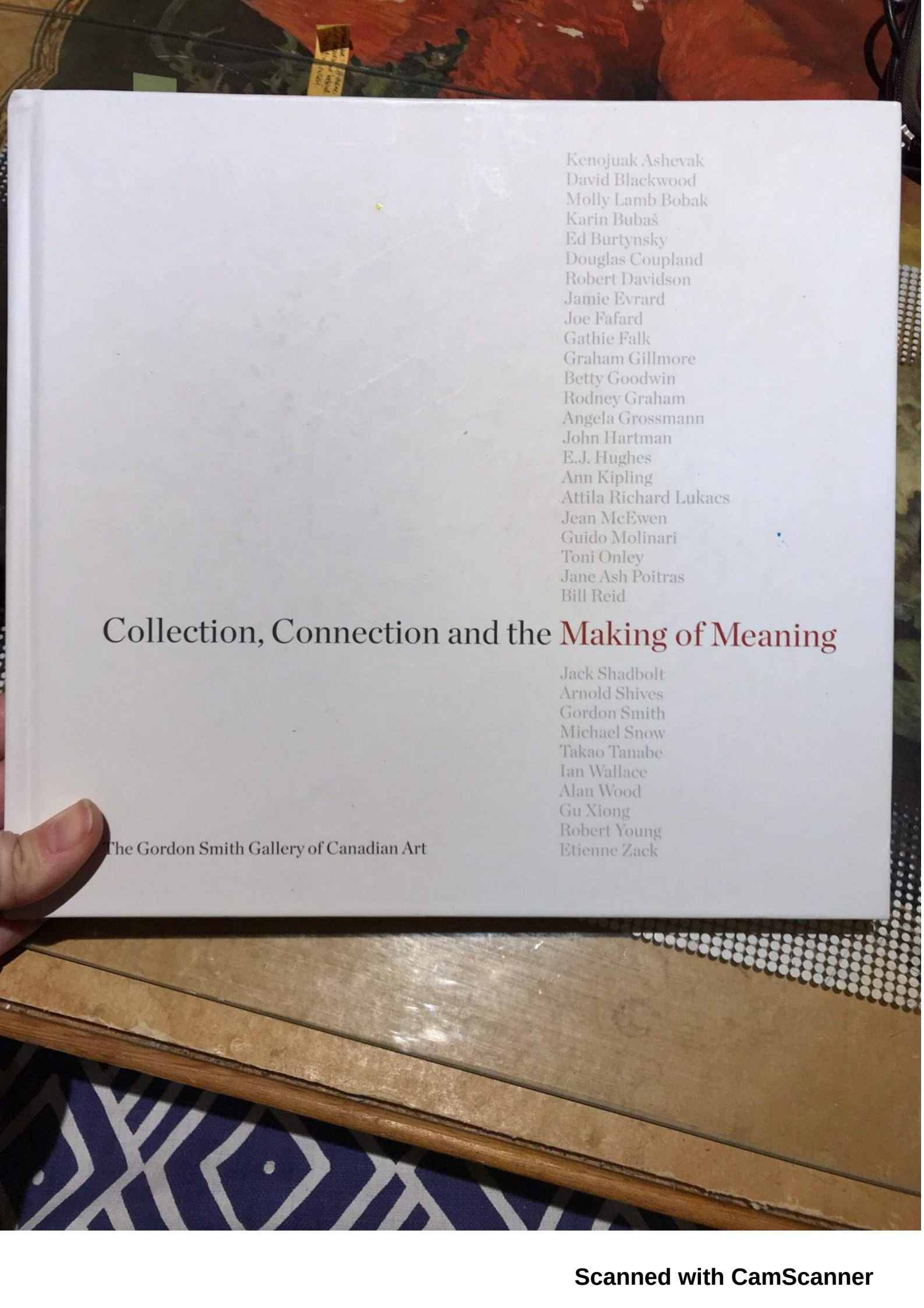

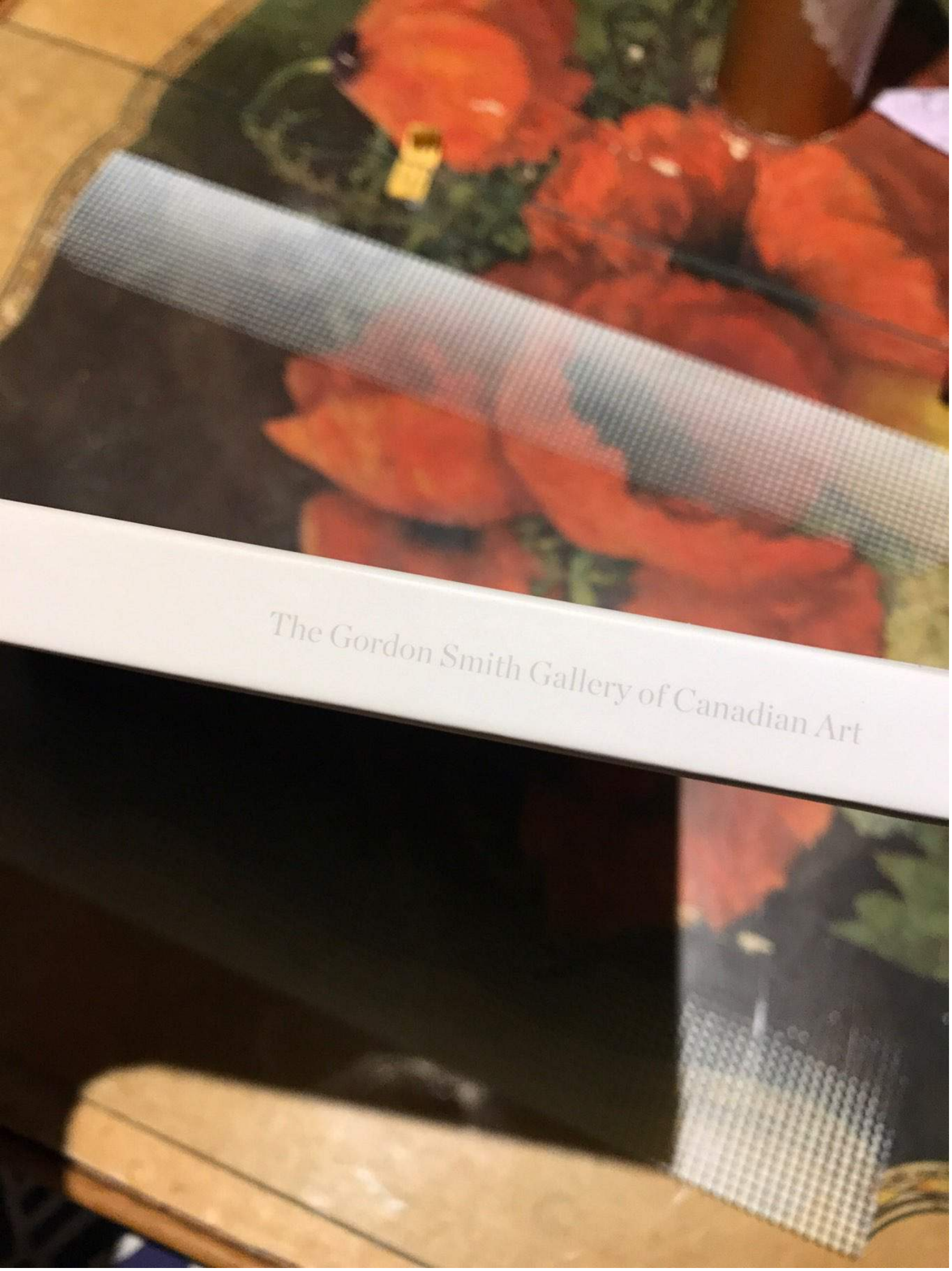

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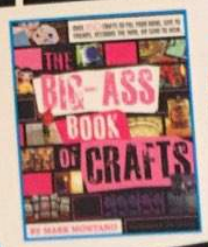

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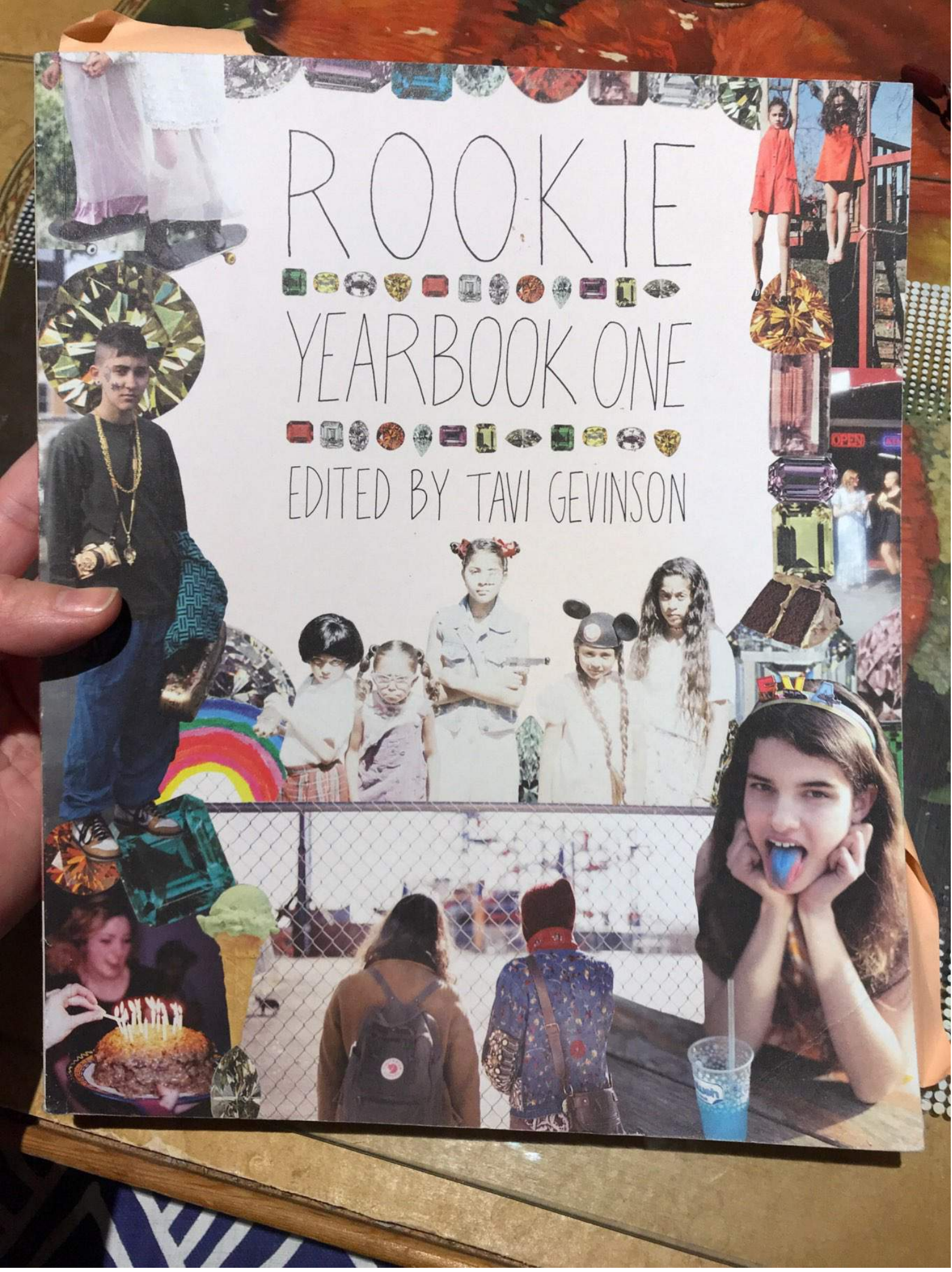

RookieMag.com is not a guide to Being a Teen or a textbook on How to Be a Young Woman. It's a publication for teenage girls intending to make the best of the cringe-worthy awkwardness and sometimes sort of beautiful pain that is female adolescence. When it becomes harder to appreciate these things, we also have good plain fun and visual pleasure. When you're sick of having to be happy all the time, we have lots of eye-rolling sarcasm. And now, what started as an online magazine is in print, too.

Within Rookie Yearbook One, *you'll find highlights from our first school year, including:*

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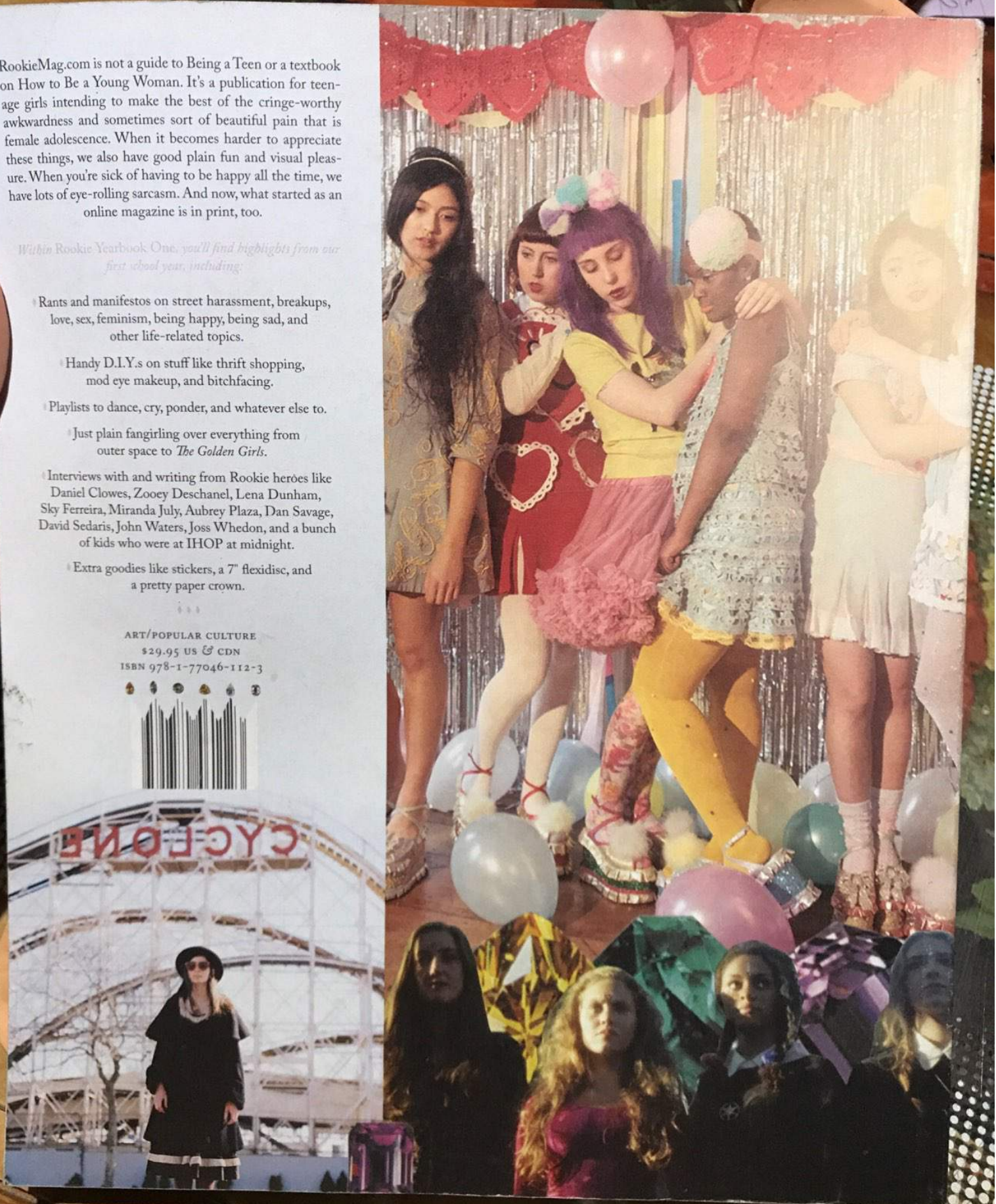

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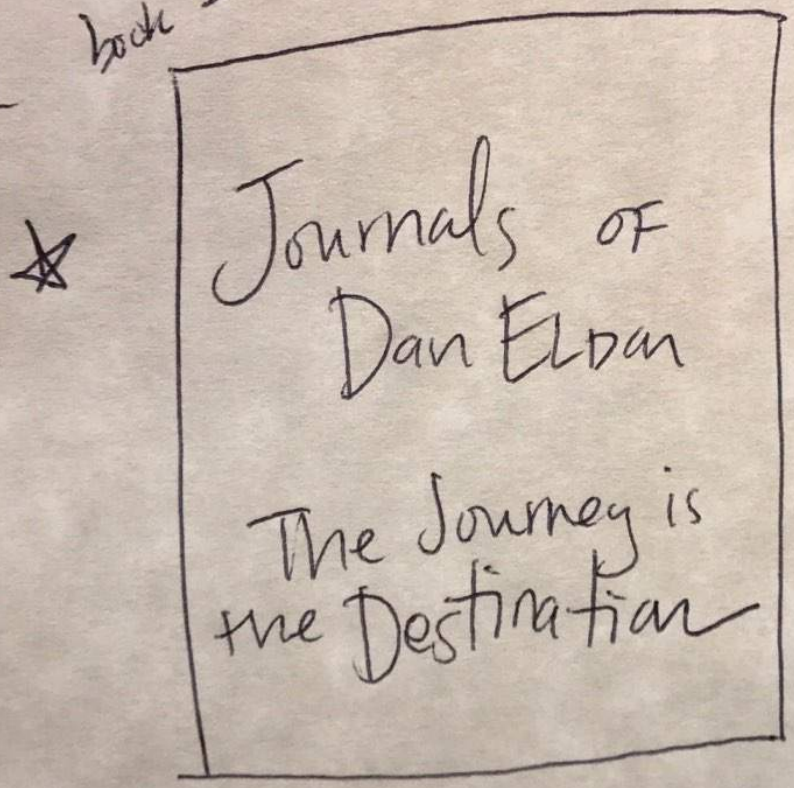

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Brad Cran is a poet, essayist, and photographer. **Gillian Jerome** is a poet and teaches in the English Department at the University of British Columbia. They are contributing editors at *Geist* Magazine and live in East Vancouver with their daughters Rory and Micah-Sophia.

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