Creativity

Understanding Innovation in Problem Solving, Science, Invention, and the Arts

Robert W. Weisberg
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In my last book on creativity, written over 10 years ago, I noted in the preface that it was an exciting time to be studying creativity, and I think that that statement is even more true today. The study of creative thinking has undergone what one might call a mini-boom in recent years, with an increasing stream of important work, both empirical and theoretical, being produced. We have accumulated an ever-expanding database of information that can serve as the foundation for thinking about the processes underlying creativity and the characteristics of creative people. In addition, the field has taken steps toward maturity, as evidenced by the increasing numbers of sophisticated models that have attempted to integrate and explain findings across disparate areas.

These recent advances have been presented in several recent edited handbooks, by Sternberg (1999), by Runco (1997), and by Shavinina (2003), which present cutting-edge chapters on various aspects of creativity written by experts. However, those developments have not been summarized and evaluated in an overall manner for students and researchers. There is thus a real need in the study of creativity thinking: There has been a growth in research without a comprehensive review of that research that will be useful for advanced students and scholars. The present book is designed to meet that need; it provides a comprehensive historically based review of research and theory concerning creative thinking, at the level of an advanced undergraduate or graduate-level course. I also believe that the presentation of material is comprehensive enough to make the book useful for scholars and researchers.

My plan in writing this book, as noted, has been to present a broad-
Preface

ranging historically based survey of research and theory concerning creativity. There is also a second purpose behind this project. I take what can be called a “cognitive” perspective on creativity—a view advocated also by Perkins (1981) and Simon and his coworkers (Newell & Simon, 1972; Simon, 1986), among others—which proposes that creative products of all sorts are brought about by our ordinary cognitive processes, such as those involved in our day-to-day problem-solving activities. From the point of view of the researcher studying creativity, there may be no difference in the processes that bring about a great scientific or artistic advance and those underlying someone’s making a new salad from leftovers in the refrigerator. Much of the mystery that we sometimes feel about creative thinking and creative people is the result of our ignorance about the phenomena in question. When one examines creativity from the perspective of the cognitive psychologist, one finds that many groundbreaking creative advances are comprehensible without assuming that anything ordinary is occurring in the way of thought processes. This conclusion can be contrasted with views that propose that there are extraordinary aspects of the person who is able to produce significant new works. Those postulated extraordinary aspects vary from theory to theory, but they include ways of thinking (“divergent” thinking, or leaps of insight, or unconscious thinking) or personality characteristics (“openness to experience”; psychoticism).

I have tried to be even-handed in my presentation of the facts, but I have not been reluctant to inform the reader of the interpretation of those facts that I felt was most useful. I saw my first responsibility as an unbiased presentation of the relevant information. That presentation could then be followed by the presentation to a now informed reader of possible interpretations of that information. The reader can then assess any theoretical claims from a knowledgeable position. I have tried to use my overall orientation to structure the presentation of the material while at the same time giving competing views a fair hearing and allowing readers to decide for themselves which interpretation to accept for the present. I have also criticized what I see as various shortcomings in my own view, again to assist the reader in making an informed independent judgment as to what to believe.

One unique aspect of this book concerns the “data” that are presented concerning creativity. In my own research, in addition to carrying out traditional laboratory studies of undergraduates solving simple problems, I have also examined historical case studies of the development of creative products (e.g., Weisberg, 2006). Examples have included the development of the double-helix model of DNA, the invention of the airplane and the lightbulb, and the development of Guernica, one of Picasso’s most famous paintings. I believe that case studies provide readers with compelling ex-
amples of how creative thinking functions at its best, and that they can provide us with “data” relevant to the scientific study of creative thinking, including creative thinking in the arts. I have used case studies as an important source of information concerning how the creative process works when it is functioning at the highest levels. In this book I present a wide range of case studies to which I constantly refer as I work my way through discussions of various phenomena. As noted earlier, this tactic allows the reader to approach material from a knowledgeable perspective, which allows him or her to play a more active role in the learning process.

While it is impossible for an author to judge the quality of his or her work, there is no doubt that this is my biggest book on creativity. There is a larger set of topics covered in this book than in my earlier ones. For example, the coverage of invention has been expanded, with information about various aspects of Edison’s career, and the material on scientific creativity is also covered more broadly and deeply. Musical creativity is also covered in more detail. There is also much more known about creativity, which requires more coverage. Beyond my own perspective, a number of other theories of creativity are covered in detail, research relevant to each theory—positive and negative—is discussed, and the relative merits of the various theories are evaluated, using what one might call a “compare and contrast” method. In conclusion, I believe that this book represents a unique addition to the literature on creativity. It presents an integrated review of recent research and theory, from a perspective that enables a fresh look at many phenomena. That viewpoint is supported with research findings, including case studies that are intrinsically interesting as well as not presented elsewhere. Finally, the presentation allows a comparison of several theories that have attempted to explain creative functioning.

The first chapter of the book presents a general introduction to my perspective on creativity. Rather than going directly to a relatively abstract discussion of issues of definition, I then present two case studies of creative thinking at the highest level—Watson and Crick’s discovery of the double helix and Picasso’s creation of the painting Guernica—which will illuminate the best way the functioning of creative thinking, and provide the beginnings of a database from which the reader can assess theoretical proposals that will be presented later. Chapter 2 then serves to provide a general orientation to the area. It presents an overview of the study of creativity, including my particular definition of the relevant terms, which is a bit different from that typically used in the literature. The broad range of research methods used to study creativity is also critically examined. The chapter concludes with a brief introduction to some of the major theoretical perspec-
tives—including my own—that have been used to explain and understand creativity, and which will be discussed in detail throughout the book.

Chapters 3–5 present the details of the cognitive perspective that serves to organize my presentation. Chapter 3 discusses problem solving as an example of creative thinking and introduces many of the concepts used by the cognitive perspective to discuss problem solving, such as searching of problem spaces and the role of analogical transfer in problem solving. Chapter 4 examines the role of expertise in problem solving and in creative thinking more generally. Proposing that expertise is important in creativity immediately raises the question of the role of talent in creativity, and this issue is considered. Recent findings may require us to rethink the notion of talent. Chapter 5 presents a number of case studies from various domains—the arts, invention, and science—to provide support for the cognitive view presented in the earlier chapters. Throughout Chapter 5, the case studies are used as data to test specific aspects of the cognitive view as well as to provide examples of application of the concepts underlying the cognitive perspective.

Chapters 6–11 examine various aspects of the competition to my view; that is, those chapters examine other ways of understanding creativity. Chapter 6 examines the notion of insight in problem solving (and by implication in creative thinking): the idea that solutions to problems sometimes come about as the result of processes that bring about sudden changes in the way the problem is perceived. Those processes are different from those postulated by the cognitive view presented in the earlier chapters. The notion that creative advances come about through a sudden leap of insight has been in psychology for more than 100 years, and I review its development and the current status of its empirical support. Chapter 7 examines the question of genius and madness, the idea that psychopathology may play a role in fostering creative production. This too is an idea that has been around for a long time, and I again examine its history. In addition, this is an area in which increasingly nuanced work has taken place in recent years, and I examine those developments in some detail, since they allow us to move away from the simple idea that madness does (or does not) support genius. The issues are much more complicated but (to me at least) much more interesting.

The cognitive perspective outlined in Chapters 1–5 assumes that creative thinking is the result of ordinary conscious thought, which raises the question of the possible role of the unconscious in creativity. Chapter 8 examines various aspects of the unconscious that have been postulated by researchers as playing a role in creative thinking, and also examines empirical support for those components. Chapter 9 is the first of two chapters examining the psychometric perspective on creativity. This is the general idea that one
can use tests to ascertain important aspects of creative individuals, and thereby determine what it is that allows them to do what they do. Chapter 9 examines tests that have been developed to measure the thinking strategies underlying creative thinking, and examines the support for the idea that there is a critical type of thinking underlying creativity and that one can measure that thinking type using “creativity tests.” Chapter 10 examines research that has used tests to isolate critical features of people’s personalities that play a role in creative accomplishment. Finally, Chapter 11 critically reviews three theories that have been proposed to explain creativity. Each of them provides an alternative to the cognitive perspective underlying my presentation, which will allow readers to determine, based on the evidence presented earlier as well as new evidence presented in Chapter 11, which view they believe is most reasonable at this time. The last chapter provides a summary of the discussion in the book and presents suggestions for where we might go in the future.
Acknowledgments

This book has benefited from the influence of many people. Students and colleagues over the last several years have helped me shape my ideas and have introduced me to new ways of thinking about things. Among those people are my present and former students Joe Buonanno, Anthony Dick, Lila Chrysikou, Jessica Fleck, Rick Hass, John Rich, Pamela Shapiro, and Liza Zaychik. My colleagues Nora Newcombe, Bill Overton, Larry Steinberg, and Diana Woodruff-Pak have lent sympathetic ears and critical minds to discussions over the years and have stretched my ideas in directions in which I never would have gone alone. Cynthia Folio and Aleck Brinkman have led me through some of the intricacies of music theory with a kind and supportive hand. The folks at John Wiley, beginning with Dennis Layner, and including Tisha Rossi and Isabel Pratt, were enthusiastic about the project from its inception, and that enthusiasm, especially Tisha’s support for the way I wanted to organize the book and present the material, played an important role in the book reaching completion in the form that it did. Several anonymous reviewers for John Wiley are also deserving of thanks. Preparation of the manuscript was supported by a Temple University Summer Research Fellowship, for which I am grateful.
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This book is dedicated to the memory of my father, who first taught me how to think; to my mother, who keeps me on my toes and who never ceases to amaze me; and to Alana, who is teaching me to wonder all over again.
CHAPTER 1

Two Case Studies in Creativity

Creative thinking brings about new things—innovations—ranging from solutions to simple puzzles and riddles to ideas and inventions that have radically altered our world. Creative people are those who produce such innovations, and the creative process consists of the psychological processes involved in bringing about innovations. Figures 1.1A and 1.1B give examples of some of the more impressive products of creative thinking. In Figure 1.1C are some simple exercises that might result in creative thinking on your part. If you had never seen those puzzles and riddles before, and if you solved one or more of them, then you were thinking creatively when you did so—you produced something new. In this book, we will consider the full range of creativity, ranging from solving simple puzzles to producing the seminal innovations shown in Figures 1.1A and 1.1B. We will examine a wide range of recent research on creativity, as well as theories that have been developed to explain the processes involved when people produce innovations.

There are many reasons why creativity is a critically important topic for psychologists to understand. First of all, our world has been shaped by the products of creative thinkers. All of our modern conveniences—the telephone and other modes of communication, the automobile, the airplane, computers, and so forth—have been brought about through the creative work of inventors and scientists. Our healthy existences and our ever-longer lives are the result of scientific and medical advances, which are the result of creative thinking on the part of scientists in many domains. Much of the richness of our lives—art, music, drama, literature, poetry—is the result of artistic creativity. Society values greatly the products of creative thinking;
Figure 1.1 Examples of creative thinking (1937): A, DNA: The double helix; B, Picasso’s Guernica; C, Examples of problems
we bestow honors, such as Nobel Prizes, on those who have produced such things, and the stories of their lives and accomplishments fill our history books and encyclopedias. By understanding how creative products are brought about, we may be able to increase the likelihood that innovations will occur, thereby making life better for us all.

In addition, creative thinking is also big business. Our largest and most prestigious corporations, as well as the largest government agencies, are constantly searching for ways to be more innovative, and they pay handsome fees to consultants who will help them achieve new levels of innovation from their employees. Institutions of higher education also take interest in teaching creative thinking. Many university business schools offer courses that are designed to provide business leaders—both those of the future and present-day ones who return for a refresher—with skills that will enable them to solve on-the-job problems. At the grassroots level, one constantly

Figure 1.1 (continued)
reads accounts of debates concerning the best way to structure our educational system so that children come out as young adults who are able to think creatively. It is therefore important that we have some idea of how creativity comes about, so that we can make decisions concerning how individuals might be helped in dealing with situations that demand creativity.

**Beliefs about Creativity**

There are two difficulties in discussing research on creativity. Some people, even people with very deep knowledge of psychological phenomena, come to the subject of creativity with the belief that the topic is so mystical and/or subjective that it could never be captured by psychological methods (Sternberg & Lubart, 1996). In this view, we cannot even define what terms like *creativity* and *creative* mean, so as a consequence we cannot even discuss them coherently, much less study them using scientific methods. I have sometimes been asked by other cognitive psychologists—that is, people whose professional lives are involved in bringing difficult-to-study psychological phenomena under scientific scrutiny—how one could ever study creative thinking. They cannot see how one can bring creativity under scientific investigation. One purpose of this book is to demonstrate how something as seemingly difficult to pin down as creativity can be defined and brought under scientific study.

Other people, from inside and outside psychology, come to the discussion of creativity with the belief that, even if we can define creativity and begin to study it, there is no purpose in doing so, because creativity comes about as the result of almost supernatural powers. In this view, the people who bring about things like those in Figures 1.1A and 1.1B are basically different from ordinary people: They are endowed with gifts that the rest of us do not have. Learning about what they do and how they do it, even if it were possible to do so, might be of some interest in its own right, but it would not tell us much that would be useful. The differences between the creative greats and ordinary people are in this view assumed to be of two sorts. On the one hand, the greats do not think as you and I do, and the differences between “real” creativity and the activities that you and I carry out are so great as to be unbridgeable. The relatively simple problems presented in Figure 1.1C may require some creativity for solution, but those problems are so different from the situations in which great artists, inventors, and scientists work that entirely different cognitive processes must be involved. So the processes involved when you and I solve such problems would not tell us much about “real” creativity. Second, there are
assumed to be critical differences in personality structure between creative and ordinary individuals, and those differences are assumed to play a role in making some people creative.

Most psychologists who have developed theories on creative thinking and creative persons take a different perspective on these issues. Although many psychologists believe that creative thinking depends on specific thought processes, they also believe that those processes can be carried out to some degree by all of us. Those who produce great creative advances might be better creative thinkers, but the same thought processes are available to or present in all of us. Similarly, if there is a specific set of personality characteristics that are related to creative achievement, those characteristics are assumed to be present to some degree in many if not all of us; they are simply present to a higher degree in those who produce great creative achievement. According to this perspective, then, creative capacity may to some degree be present in all of us (e.g., Amabile, 1996; Csikszentmihalyi, 1996; Eysenck, 1993; Guilford, 1950; Sternberg & Lubart, 1995).

There is also a minority view in psychology (e.g., Perkins, 1981; Newell, Shaw, & Simon, 1962; Weisberg, 1980, 1986, 2003), to which I subscribe, that proposes that the thought processes underlying the production of innovations are the same thought processes that underlie our ordinary activities. From this perspective, the term creative thinking is misleading at least and perhaps a misnomer, because one thinks creatively by using ordinary thinking; one just uses that ordinary thinking to bring about innovations (see also Klahr & Simon, 1999). This does not mean that there is no such thing as creativity, however. There is no doubt that scientists, artists, and inventors, for example, bring forth innovations. It is just that those innovations are based on the ordinary thought processes that we all carry out.

One task of this book is to review a representative sample of the various theories of creativity proposed by psychologists and to examine their structure, the predictions that are derived from them, and the evidence for and against them. A further task of this book will be to show that there is a relatively close relationship between creative thinking and other forms of cognition, such as problem solving, reasoning, and the use of memory. That is, the view motivating the presentation in this book is that creative thinking is not different from ordinary thinking—the thinking that we use in carrying out our day-to-day activities. I will show also that the differences in personality and other psychological characteristics between creative individuals and ordinary people may not be very large, and, furthermore, those differences may not be crucial in making creative people creative.
Two Case Studies in Creativity

In this first chapter, I will discuss two examples of creative thinking at its highest: Watson and Crick’s discovery of the double-helix structure of DNA, the genetic material (Figure 1.1A), and Pablo Picasso’s creation of Guernica, his great antiwar painting (Figure 1.1B). Those two case studies will provide us with “data” of a sort we will have occasion to refer to many times as we consider theorizing concerning creative thinking. At various points in this book, we will discuss the Beatles, Edison, Darwin, the Wright brothers, and Mozart, among other creative thinkers, and the case studies presented in this chapter will provide an introduction to this method. The data from case studies such as those presented here, in conjunction with other results, such as those from laboratory studies of creativity, will allow us to bring an educated perspective to the sometimes conflicting claims made by theories of creativity.

The two case studies to be discussed—one from science and one from the arts—are relevant to the question of what differences may exist between the creative processes in those two domains. At first glance, it seems that we are talking about two different things when we talk about creative thinking in the arts versus the sciences. We use different terms to describe the process in the two domains: We talk about artists creating their works (Picasso created Guernica), but we talk about discoveries in science (Watson and Crick discovered the double-helix structure of DNA). There seem to be basic differences in our beliefs concerning the relation between the person and the product in the arts versus the sciences. It is obvious that, if there had never been Picasso, there would be no Guernica. Similarly, no Beethoven, no Beethoven’s Fifth Symphony. Artistic creativity seems to be an inherently subjective process, as the artist produces something that would not have existed save for the effort of that person. DNA, on the other hand, exists independently of Watson and Crick. If there had been no Watson and Crick, DNA would still have been there, waiting to be discovered, and at some point it would have been discovered. Scientific discovery, in this interpretation, is an objective process: Objects, events, and facts available to all of us are what scientists discover. As we work through the two case studies, I will try to make note of aspects of each that point to similarities, rather than cut-and-dried differences, between creative thinking in science and the arts. Artistic creativity is not as subjective, nor is scientific creativity as objective, as one might think.

Creativity in Science: Discovery of the Double Helix

In 1953, Watson and Crick published the double-helix model of the structure of DNA, which has had revolutionary effects on our understanding
and control over genetic processes. As one example of the impact of Watson and Crick's work, there has in recent years been much controversy over the possibility that scientists have succeeded or will soon succeed in cloning human beings. This possibility is but one of the remarkable developments that can be traced directly back to the discovery of the double helix. Geneticists, biologists, and other scientists, including Watson and Crick's teachers, had for more than 50 years been pursuing the question of the composition and structure of the genetic material (Olby, 1994). Watson and Crick succeeded in formulating a model of the structure of DNA after approximately one and a half years of work, and several misdirected attempts. Other research groups were at that time also working on the structure of DNA, and Watson and Crick were not the first to publish a possible structure, but theirs was ultimately judged to be correct (Judson, 1979; Olby, 1994).

DNA was a discovery of wide sweep, which involved a large number of contributors. Examining this discovery will provide information concerning how scientists become focused on the questions that they study. What, if anything, does the creative individual know that leads him or her to the important questions, the answers of which will change our world? Studying the discovery of DNA also will allow us to address the critically important question of how different scientists, while studying the same phenomenon, wind up taking different approaches, so that one is successful while the other is not. That is, we will begin to gather information on what, if anything, separates the individual who produces the important scientific discovery from the one who does not.

**Historical Background**

DNA was discovered in the middle of the nineteenth century, and by the early twentieth century it had been shown to be present in all cells (Stent, 1980, p. xiii). DNA is made up of a number of different components: a phosphate group, constructed around phosphorus; a sugar; and four different nitrogen-rich bases, adenine, cytosine, guanine, and thymine, abbreviated as A, C, G, and T. (See Figure 1.2.) One phosphate, one sugar, and one base form what is called a nucleotide, the basic unit out of which DNA is constructed. There are four different nucleotides, differing only in their bases. Thousands of nucleotides, strung together, form the complete DNA molecule. So the basic structure of DNA could be described as a polynucleotide, built out of a set of building blocks that repeat again and again.

It was not until the late 1940s that researchers began to agree that DNA was the genetic material. Although DNA is found almost exclusively in the chromosomes, which are the sites of the genetic material, there is more protein than DNA in chromosomes, which led to the belief that protein
might be the critical material. In addition, it was also thought originally that DNA was a relatively simple molecule, too simple to carry out the tasks required of genetic material (Olby, 1994). It was initially believed that the DNA molecule was simply a tetranucleotide, that is, that the complete molecule consisted of one of each of the four nucleotides, and nothing else. It was soon shown that the molecular weight of DNA was much larger than only four nucleotides, but researchers then assumed that the large molecule simply consisted of the four nucleotides repeating monotonously in the same sequence. In both those analyses, DNA was relatively simple in structure. The function of the genes is to direct synthesis of proteins, which are complex molecules. It seemed to follow from this that the genes would have to be complex as well. Therefore, DNA with its simple tetranucleotide
structure could not serve that purpose. It was assumed by some that DNA was present in the nucleus only to serve as a “stretcher,” so that the protein genes could be straightened out to carry out their functions.

In the 1940s, several different sorts of evidence pointed to DNA as the genetic material. In 1928, Griffith had shown that injection of purified material from virulent pneumococcus bacteria (that is, bacteria that caused illness—in this case, pneumonia) into heat-killed bacteria that were benign (i.e., that no longer produced pneumonia) could transform those benign bacteria into virulent ones (Olby, 1994). Most important, this transformation could also be passed down to subsequent generations, which indicated that the genetic material of those benign bacteria had been altered. The critical question then centered on the chemical composition of the extracted material, or “transforming substance,” and in 1944, Avery and colleagues identified it as DNA. Furthermore, since the transformation could be passed down genetically, identifying DNA as the transforming substance indicated that DNA might be the genetic material as well.

Also during this decade, a study by Hershey and Chase examined the
mechanisms whereby viruses attacked and killed bacteria, in order to gather information about the composition of the genetic material (Olby, 1994). When a virus attacks any organism, including a bacterium, it takes over the reproductive mechanism of the host organism’s cells and uses them to reproduce itself. A virus is essentially genetic material encased in a shell. Hershey and Chase used radioactive phosphorus (which is incorporated into DNA) and radioactive sulfur (which becomes part of protein) in order to produce strains of viruses with different radioactive “signatures.” They then traced the fate of those radioactive chemicals after the marked viruses had infected bacteria. In a methodological innovation that became legendary, the researchers used a kitchen blender to separate the infected host bacteria from the shells of the viruses that were attached to them. The results indicated that when viruses attack bacteria, the viral DNA is introduced into the host bacteria, while the shell of the virus, which is made up of protein, stays outside the host. The protein shell seemed to serve as a kind of hypodermic that injected the viral DNA into the host. This result provided strong support for the idea that DNA was the material carrying the genetic information from the virus to the bacteria.

Finally, in a series of chemical studies of DNA, Chargaff showed that the tetranucleotide hypothesis of the structure of DNA was incorrect (Olby, 1994). He analyzed the relative proportions of the various bases in DNA from different organisms. The results, shown in Table 1.1, contradicted the tetranucleotide hypothesis in two ways. First, within each species, the proportions of the various bases were not equal, and second, the ratios of the various bases differed in different species. So there was much more variability in DNA than researchers had believed, perhaps enough variability for the DNA molecule to function as the carrier of the genetic code. Another interesting finding reported by Chargaff was that, even though the proportions of the bases differed from species to species, in each species there seemed to be equal proportions of A and T, as well as equal proportions of G and C.

Table 1.1 Chargaff’s data on the chemical composition of DNA from different species (Chargaff’s ratios)

<table>
<thead>
<tr>
<th>Species</th>
<th>Base composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Human (liver)</td>
<td>30.3</td>
</tr>
<tr>
<td>Bacterium (tuberculosis)</td>
<td>15.1</td>
</tr>
<tr>
<td>Sea urchin</td>
<td>32.8</td>
</tr>
</tbody>
</table>