Creativity in the Twenty First Century

Giovanni Emanuele Corazza
Sergio Agnoli *Editors*

Multidisciplinary Contributions to the Science of Creative Thinking

Springer

Creativity in the Twenty First Century

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Preface

This book arises from our perceived necessity to offer a broad view about the multidimensional world of creative thinking, which is a truly domain-general research topic, although full of domain-specific implications. Indeed, creativity and creative thinking cannot be imprisoned into a single scientific discipline, as they are central topics in a number of cultural areas, wherein their study takes on distinct scientific approaches and sometimes different terminologies. In a search for a unifying fil rouge, we are fascinated by the extraction of the common principles for idea generation which underpin all domains of application in a transversal manner. Giving an in-depth view about some of the most recent theoretical and methodological approaches used in different disciplines for the study and analysis of creative thinking, this book is intended as a contribution to the foundation of the science of creative thinking.

The book contains an introductory chapter, proposing a unifying theoretical framework for the science of creative thinking, and four parts: "Theoretical Aspects of Creativity," "Social Aspects of Creativity," "Creativity in Design and Engineering," and "Creativity in the Arts." Each part offers a vision about both state-of-the-art and future trends, in the diversified forms of theoretical chapters, research contributions, reflection chapters, and educational approaches written by eminent international specialists. As we make no claim for exhaustiveness, this edited book should not be taken as a handbook, but as a well-harmonized ensemble of scientific contributions showing the intrinsic multidisciplinarity that characterizes the science of creative thinking.

Multidisciplinarity is in fact a fundamental element in the spirit of the Marconi Institute for Creativity (MIC), founded in 2011 at the joint initiative of Fondazione Guglielmo Marconi and University of Bologna, with the specific aim of contributing to the establishment of the science of creative thinking and its divulgation in educational and research milieus. Working on this book with the support of the CREAM European Project, funded by the European Commission FP7 Programme, we selected the chapters to be the expanded forms of the best papers presented at the MIC Conference 2013. The conference was attended by eminent scientists in the field of creativity and by the Fellows of the Marconi Society, who in their lives have produced inventions in the field of information and communication technologies, from the Internet to mobile telephony. In particular, the 2013 Marconi Award was presented to Martin Cooper, who is accredited to have led the team of engineers that produced the first cellular telephone in the world. The MIC Conference 2013 was therefore a unique event in which theory, practice, and entrepreneurial success have met together and dwelled upon the state-of-the-art and the future developments of a field which is destined to become central to the culture of our society.

The chapters in the book have all undergone rigorous review. The editors would like to thank the anonymous reviewers selected by Springer as well as the experts who helped us in the revision work: Felicity Anne Andreasen, Roger Beaty, Valentin Bucik, Mercedes Ferrando, Andrea Gaggioli, Martina Hartner-Tiefenthaler, Maciej Karwowski, Mariann Martsin, Ingunn Johanne Ness, Jelena Pavlovic, Roland Persson, Ugur Sak, Eric Shiu, Lisa Min Tang, Luca Tateo, Susana Tavares, and Taisir Subhi Yamin. In addition, our sincere appreciation goes to the editorial board of Springer, who believed in this project and worked with passion to turn it into reality. Finally, our warmest thanks go to our spouses and life companions, Susy and Titty, for their patience, support, affection, and love.

We hope you will truly enjoy this book, as we have enjoyed editing it.

Giovanni Emanuele Corazza
Sergio Agnoli

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Introduction

If we were asked to identify the main discriminant between the human species and all other living species, we could expect a nearly unanimous response in terms of our capacity of generating new ideas. Albeit rudimentary forms of generative behaviour have been identified in a few species (Kaufman et al. 2011), this is incomparable to the abilities possessed by humans. In other words, creative thinking can be argued to be the most peculiar activity of the human brain, and as such it has been an eternal source of fascination in the history of human progress. But for centuries, this ability to produce novelty has been interpreted as a mysterious gift, resisting any possible rational explanation. Indeed, the mere act of trying to explain creativity was seen as endangering inspiration and stifling the possibility for a flow towards the distant lands of fantasy. It was only around the start of the XX century that this veil of mystery begun to be raised, not surprisingly in concomitance with the great progress by the Viennese school of psychoanalysis, as testified by the publication by Freud of his paper on *Creative Writers and Daydreaming* (1908/1962). Wallas (1926), in his landmark manuscript devoted to the *Art of Thought*, was the first to attempt a description through a simple model

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of the creative thinking process, there subdivided into four stages: preparation, incubation, illumination, verification. In writing this book, Wallas was certainly inspired by many famous thinkers of the past, of which at least one deserves explicit mention here: Poincaré (1914/1952), who wrote with accurate detail about his dreamful experiences in idea generation for chemistry and mathematics. Indeed, the famous model by Wallas, still cited today in works on insight phenomena (e.g., Kounios et al. 2006), was only an intermediate step in the raising of the curtain, as it attributes the main mechanism for idea generation to unconscious thought, culminating into the illumination moment. But it was a fundamental first step, which opened the path towards the foundation of a new science: the science of creative thinking. Literature on the subject has been abundant since then; let it suffice to cite here the *Encyclopaedia of Creativity* by Runco and Pritzker (2011), where exhaustive reference lists can be extracted. We are on our way, but the final objective is yet to be reached, as testified by the difficulty that the subject of creativity encounters in becoming a full part of educational programmes at all levels of schooling.

The first element in the foundation of any science is a clear definition of all terms of reference. As a minimum, we need a clear definition of creativity and of creative thinking. This is actually still an open issue for debate, but we can state that the following definition embraces most of the fundamental elements: *creative thinking is the multi-dimensional set of components that lead an individual or a group to the generation of new ideas that have value*. If we simply define *creativity* as *the use of creative thinking*, we see that the two terms essentially coincide, and we can use them interchangeably. A few comments on this definition are in order. First of all, it is clear that such a definition leaves out that form of generation of novelty that we can attribute to the evolution of nature. In other words, we confine our attention to beings that think, and as such can exert a form of control (either aware or unaware) on their outputs. This includes both human beings and cybernetic machines endowed with artificial creativity (and possibly pseudo-emotions). Second, this definition makes it clear that creative thinking involves a complex process, where multi-dimensionality stems from cognitive, dispositional, emotional, social, and cultural elements, all playing an important role in driving the individual or group towards the wanted end result. Finally, for the process to be successful we require the generated ideas to be both novel and valuable. These two elements cannot be separated, for value without novelty is pure continuation, whereas novelty without value is pure craziness. We can define originality as the single attribute of an idea that includes these two fundamental properties, and propose the shortest form of definition: *creativity is the generation of original ideas*.

It is interesting to note that there exists an optimal level of originality. In fact, both novelty and value are historic quantities that derive from the projection of the new idea onto existing knowledge (either of the individual or of society). If the intersection with the past is very large, there is very little surprise, although probably significant utility. On the other hand, if the intersection is very, very small, the new idea will be radical and will face harsh resistance to its implementation in practice. Therefore, between these two extreme situations there must exist an optimal level of originality that balances surprise, novelty, value, applicability, and acceptance by society. The quantification of this optimal level of originality is still an open issue, which of course depends heavily on the domain in which creative thinking is applied.

Indeed, one of the difficulties, and at the same time of the beauties, of the subject of creativity is the fact that many elements are domain dependent, and it is a serious challenge to identify common principles, which we can identify as domain-general. But certainly, these common principles have fundamental relevance and will sit at the core of the science of creative thinking. Obviously, creativity is a transversal subject, which matters for any and all disciplines in the realm of human knowledge. This is exactly the reason why the literature is abundant in contributions from a wide set of domains, including the history of science and art, philosophy, psychology, science and art, sociology, design, engineering, management, artificial intelligence, and the list could go on. Confronted with such a formidable but somewhat scattered panorama, it becomes natural to select but a small subset of it, and be captivated into what can be considered as a narrow vision on a multisided subject. This is the problem of fragmentation in the field of creativity, which is well analysed by Hennessey and Watson (2015), where they call for a cautious de-fragmentation action, avoiding that the extraction of commonalities annihilates the domain-specific richness, especially with regards to education and to profiling persons in fields that are as separate as art and science (Botella and Lubart 2015). Therefore, as mentioned in Dorniak-Wall (2015), the question arises: what can be said at a general theoretical level about creative thinking, its process, the outcoming products, the creative persons and the environments in which they operate?

Theoretical Approaches to the Study of Creative Thinking

It is undeniable that, for a science to be considered as such, there is a need for a theoretical foundation, which must be able to account for at least the basic mechanisms that allow the generation of ideas in the human mind. The theoretical approach needs confirmation from experimental evidence, but it provides the guiding light for the design of the experimental campaigns themselves. If we were to simplify the process of creative thinking to the maximum possible level, we would find it difficult to describe less than three states: (a) gathering and structuring of information elements; (b) ideation; (c) verification of the effects. We argue that without either (a), (b), or (c), the creative thinking process cannot be considered to exist. The most obvious necessity is that of state (b): no ideation is tantamount to absence of creativity. On the other hand, without the verification given by (c), it is impossible to assess the originality of the idea. In other words, the process is always incomplete without a projection of the idea onto the real world. A slightly more intricate explanation is required to justify the necessity for (a), the gathering of information. This descends from the interpretation of creativity as a process of transformation of existing knowledge through the possible introduction of new information elements, recombination, association, etc. But without existing knowledge in a domain, ideation is virtually impossible in that very domain. This leaves out the concept of creativity ex-nihilo, i.e. the pure generation of new concepts without any predecessors, a divine style of creativity. Of course, the contrast between these two meta-interpretations of the idea-generation process has been the subject of a long debate for centuries, which we do not intend to re-open here. May it suffice to say that, as a minimum, in order to generate an original idea we have to be able to represent it in an understandable form (e.g., through language or images), and this requires knowledge of the description of previous ideas in the domain, without which communication becomes impossible. Now, it may be argued that in this minimal description we are missing one initial state, corresponding to the identification of the area where thinking takes place. This has been identified in various forms in the past, e.g. problem definition, focus definition, or problem construction. Now, while we definitely agree on the importance of this state in order to achieve results with acceptable efficiency, we maintain that this is not as fundamental as the other three. In other words, even if the mind is not set on any problem, and the attention is not focused on any specific area, the mere fact that a human being exists in a certain environment at a certain time instant allows his/her mind to use the available information to generate an idea that impacts and transforms the environment. Let's say that this is a much more casual (or inspired) instance of creative thinking, which includes the important case whereby *there is no time to focus*, as for example happens in improvised music, or in a creative immediate response to an unforeseen event. At any rate, to close the issue we can consider the focus definition to be subsumed by state (a), whereby the gathering of relevant information only makes sense when we have defined the criterion for relevance, i.e., the focus area.

Given these three fundamental parts of the process, different theoretical models can be generated by specifying to different levels of detail the components and strategies that the mind can use to move from state to state, or the improve the efficiency of the entire procedure. The states can therefore be subdivided into two or more sub-states, as necessary, also depending on the domain of application and the context (Botella and Lubart 2015). Let's see how this was translated in some of the most recognized models. The famous four-stages model by Wallas (1926) essentially splits the state (a) into parts: preparation and incubation. Both the preparation and incubation parts are concerned with a restructuring of the information gathered to resolve the problem at hand, with a difference which is marked by the level of awareness: while the preparation is performed at conscious level, incubation happens without any conscious control. Therefore, according to Wallas, ideation corresponds to a sudden illumination, and insight, a eureka moment. These are all real phenomena, which most persons faced with an ill-defined problem can experience, but they don't exhaust the list of possible mechanisms for ideation, as we will see in the following. Coming now to a much more recent model by Mumford et al. (1991), then revised in Mumford et al. (2012), we can observe a much finer subdivision into eight stages: problem definition, information gathering, information organization, conceptual combination, idea generation, idea evaluation, implementation planning, solution monitoring. Using our classification into three macro states, we can say that problem definition, information gathering, and information organization belong to (a), conceptual combination and idea generation belong to (b), and idea evaluation, implementation planning and solution monitoring all belong to (c). However, this more refined subdivision is useful for at least two reasons: it allows for detailed monitoring of the different parts of the process and the consequent definition and set-up of experiments; it can serve as a guide to train specific abilities and apply methods, with the overall aim to improve the performance of individuals and groups.

On the other hand, it should be clear that a complex eight-stages model can be well fit for instances of creative thinking in domains where the process entails a rather long interval of time (from days to several months or years), but it hardly fits the necessities of rapid response situations. This is indeed the domain of application of the geneplore model (Finke et al. 1992), which is actually an iteration between two states, subject to constraints: the generation of pre-inventive structures and the exploration and interpretation of these very structures. When this iteration happens in real-time, we have a very good representation of the inventive process taking place during musical improvisation or composition (in a flow state), creative writing, or painting. In short, it is a model that fits well with artistic production. Apparently, the geneplore model only maps on the fundamental states (b) and (c), respectively for the generation and the interpretation of the pre-inventive structures. However, if we were to admit the possibility to generate pre-inventive structures without previous knowledge, we would fall again into the case of divine creativity, which is definitely fascinating and possibly meaningful in a spiritual sense, but it escapes the boundaries of scientific exploration. Since the latter is indeed our scope, we must conclude that the geneplore model is incomplete, in the sense that it understates a phase of acquisition of expertise a competence in a domain, in order to enable the generation of pre-inventive structures and their attribution of value. In short, the fundamental state (a) underlies the geneplore model and it could take a lifetime of study and practice, while the geneplore model represents in a very effective way the real-time performance of a creative artist.

We conclude this review of theoretical models for the creative thinking process by analysing the so-called DIMAI model (Corazza and Agnoli 2013), which is a five states model identified by the acronym that serves at its name: Drive, Information, Movement, Assessment, Implementation. Essentially, the drive and information states can be grouped into the fundamental state (a), assessment and implementation both belong to fundamental state (c), while movement maps one to one on (b). It is useful to see why we felt it necessary to distinguish drive from information, as well as assessment from implementation. The drive state contains not only the focus definition, but also the emotional-motivational-cognitive spark that must be present in the thinker in order for the process to have good chances for success. In this sense, the DIMAI model is confluent, as it includes in the process the influence of personality traits, emotional states, as well as intelligence (Batey and Furnham 2006; Eisenck 1993; Feist 1998; Hennessey and Amabile 2010;

Kirsch et al. 2015; Sternberg and Lubart 1991, 1996). It should be clear that these elements are extremely important and quite different from the mere collection and organization of facts, information, and knowledge in general terms. Thus, this distinction within the fundamental state (a) between *drive* and *information* is very useful to help separate elements which are pseudo-objective as the pieces of information should be, from elements which are strongly subjective and yet essential for the success of the process. Coming now to the distinction between *assessment* and *implementation*, the border demarcation is given by the frontier that separates intra-personal processes from inter-personal relationships: in the *assessment* state we collect everything that happens within the individual, to convince him-/herself of the validity of the idea and to make the decision to take the risk and let the idea be exposed to the outside world; in the *implementation* state we account for all interactions that subsequently have to occur with other persons, be them from a small environment (e.g., academia or work), or intended as society at large, representing a complex cultural environment. Therefore, the separation of the fundamental state (c) into *assessment* and *implementation* is useful to include in an explicit way both intra-personal and inter-personal determinants for the creative thinking process.

As well discussed in Hennessey and Watson (2015) and Dorniak-Wall (2015), the discussion on theoretical models is far from being concluded, and several questions are still open in terms of generality vs. specificity to the domain, or correspondence to empirical evidence collected in either in vitro experiences or natural environments, as advocated by Botella and Lubart (2015). A clear path towards the further development of theoretical models is towards the inclusion of social aspects of creativity. In fact, the generation of idea, even when modelled as the activity of a single individual, is always an instance of a relationship. How to introduce these relational elements in a theoretical model is certainly an open issue today, and one worth pursuing further. Let's go deeper into the discussion of the effects of the environment.

From the Isolated Individual to the Social Environment

Certainly, the analysis of the effects of the environment on human behaviour is not a new topic in human and social sciences. Cultural psychology for example is concerned with how human behaviour and attitudes are rooted and embodied in culture. According to this approach, the human mind and culture are therefore inseparable and mutually constitutive. Creativity is no exception, as well presented by Glaveanu (2015), who sees it as an interactive process emerging out of the interaction between an individual and his/her cultural environment. As explained by the author, this interaction plays a fundamental role in the assessment of a new idea, which is an interactive referential process of comparison of the idea itself against the criteria for usefulness/aesthetics deriving from the relevant cultural domain. And the interaction develops both in the time and space domains, implying that creativity is actually a distributed relationship. This concept emerges also in the domain of socio-cultural analysis, see for example Sawyer (2006), Sternberg (2006), and Silvia (2008), where we find that developing an idea is always related to its acceptability by the domain's experts and audience. This socioocultural perspective acquires central importance in the systems model of creativity by Csikszentmihalyi (1988), who presents creativity as the process emerging from the interaction of a person (i.e., genetic elements, experience, talents, etc.), a field (i.e., community of practice, network of stakeholders, gatekeepers, experts, etc.), and domain (i.e., accepted knowledge, methodologies, values, etc.). The systems model suggests that creative thinking interactions with the environment can be described according to different levels of analysis, from the most comprehensive to the most focused: social level, cultural level, field network level, and team level. The most interesting consequence of this multi-layer analysis is that, according to the level of interaction, the conditions that favour or stifle the creative process may vary. For example, we may organize a very creative team in a company (Walton 2015), which, depending on their specific position in the network field, may then turn out to be successful or unsuccessful in their efforts (Cattani et al. 2015).

Let's observe that the balance between the importance attributed to the social aspects of creativity and the role of any single individual within the network is very delicate. On the one hand, considering creative thinking as a process that happens within a single individual totally isolated from the rest of the world is a false myth that has been contradicted by extensive research (see for example Amabile 1983, 1996). On the other hand, the investigation of the interaction between the environment and the individual should not be arrested at the network level, but should return onto the individual to understand the modalities, the role, and the effects that these social interactions have on the creative thinking process taking place within one's mind. In other words, in the science of creative thinking it is necessary to find a balanced fusion of the approaches based on the individual and on the social aspects, avoiding a contrast which would be indeed artificial. The analysis of past eminent personalities and of the environments they lived in can be an exceptional source of insights, as pursued in the historiometric research by Simonton and Ting (2010). In the same way, the case studies proposed by Sgourev (2015) are effective exemplifications of a system approach to the study of creative thinking which joins micro (individual) and macro (socio-cultural field) levels and their dynamic interdependence, which turns out to be essential for the emergence of exceptional creative products.

Needless to say, the social and cultural aspects are always strongly related to the geographic displacement of the network. Nowadays, the connectivity can easily bring together international groups, but we have important cases in which language and borders are very effective walls. The most important instance is undoubtedly that of school education in general, and training for creativity in particular. As described by Zhou and Valero (2015), by comparing the cases of China and Denmark, it is clear that diversified culture indeed generates different drivers and barriers to the introduction of creativity in education. It is an interesting question to verify whether the understanding of cultural influences on the education of creative thinking can be exploited for the selection of the most efficient strategies to improve the educational curricula in different countries.

Let's now turn our attention to domain-specific aspects.

Idea Generation in Science and Engineering

The first question to be addressed when speaking of creativity in a scientific or technological domain relates to whether this corresponds to a discussion on problem solving. In fact, this kind of terminology is so widespread that in many theoretical models the process starts with a *problem definition* stage. This has critical importance not only to direct the thinker's attention towards a specific area of knowledge, but also to put into evidence all of the constraints, boundaries, and requirements which define that specific area. This could then be transformed into a discussion about the broadness of the term *problem*, i.e. on the relative weight that we place on those constraints. Honouring the importance of the etymological point of view, since medieval times the word *problem* stands for *a difficult question proposed for solution*. We could say that science, in its most general understanding, tries to answer the difficult question: *Which are the laws of nature*? Therefore, new ideas in science could in general be seen as the result of a problem-solving exercise. On the other hand, engineering, and the development of new technology in general, aims at progressing beyond the state of the art. In some cases, it is evident that the present status can and should be improved, due to *problems* which are visible to everyone, or at least to the experts in the field. But we cannot rule out the instances of idea generation in fields that were not at all perceived as *problems* nor necessities. If we can accept this as a fact, then we open the possibility to go beyond mere problem solving: even in technical fields, idea generation can be exerted in any focus area of interest, irrespective of the immediate perception of urgency or necessity, i.e., with very loose constraints and requirements. Years after, we could find that people cannot do anymore without the innovation introduced at the time of its generation: technology has been pushed over an area that was not perceived as a problem, and only a posteriori has it become a necessity. In passing, freeing up creative technical thinking from the narrow boundary of a problem brings it closer to the artistic approach, and also gives room for serendipitous findings, i.e. those instances whereby we find something that we were not looking for: it is clear that we have not *solved a problem*, and yet we have generated a concept which may turn out to be extremely useful.

A second distinction which merits consideration is between the terms *discovery* and *invention*. If science is only devoted to the understanding of nature, new ideas should be intended as discoveries. Yet, understanding can take on different approaches and methodologies, and these can be considered to be abstract products of human minds. We consider it to be entirely possible for a scientist to *invent* a new method of analysis. Furthermore, when one starts to play with nature, setting aside any and all considerations of the consequences in terms of ethics or sustainability of the world as we know it, then it becomes easy and natural to accept inventions in terms of, e.g., synthetic biology, genetically modified molecules, new hybrid species for flora and/or fauna. In the field of engineering, on the other hand, the primary goal is to create artificial systems, machines, algorithms, protocols, that perform functions of utility to human beings. Are these concepts always *inventions*? The immediate answer would be positive. Still, we can dwell on a distinction between those artificial systems that simply mimic nature, trying to reproduce artificially what would be a natural element of the world, and those more challenging products of our mind that actually extend the capabilities of humans and/or of nature. For example an artificial limb, which certainly requires wonderful technology, in-depth understanding through discovery, and possibly a number of patents on materials and algorithms, belongs to the first category. No human being can advocate to have invented an arm or a leg. In the absence of a single term, we propose to identify these ideas as *creative reproductions of nature*. Here, creativity does not lie in the subject itself, but rather in the way it has been artificially reproduced, in the number of functions it can perform, in the way it can be manufactured. On the other hand, we can invent devices and systems that can extend our capacities without any significant resemblance in nature. A fitting example is that of a car, intended as a vehicle moving on wheels connected by axes. The function that it delivers, however, is that of transportation over the earth surface, which is clearly pre-existing the concept of the car. Since this kind of moving platform has no equivalent in nature, but the function does, we can identify it as a *creative extension of capabilities*. A third category exists, including those inventions that allow human beings to live in conditions which are impossible in nature, and as such introduce unprecedented possibilities. Examples include: the submarine for life under the ocean; the airplane for life in the stratosphere; the space shuttle for exploration beyond the earth atmosphere. Each of these is actually an example of a meta-invention containing a number of smaller ideas, i.e. they are systems. We define this third category of inventions as *creative extensions of the conditions for life*. What about the Internet? Should we simply say that it is an extension of the capacity to communicate for human beings? Actually, it is much more. It is an extension of connectivity, of computation capability, of storage, of presence in remote place, of knowledge management, of socialization, of idea generation, of reality in virtual and augmented forms. Therefore, we can preliminarily conclude that the Internet contains all three elements: it is a reproduction of nature, when for example it mimics the interaction with a person represented by an Avatar; it extends human capabilities, allowing to retrieve information on any topic, anywhere and anytime; it extends the conditions for life, by introducing a number of virtual worlds which require multiple personalities for a single human being.

Creativity in the field of science and engineering has therefore its own peculiarities. The interesting fact is that advancements in different scientific and technological fields can be associated with specific inventive principles; the extraction of fundamental rules can even allow to think that the principles of a determined field can be transferred to other fields, in a powerful interdisciplinary approach. This can be certainly possible through a brilliant use of analogical thinking, which is well described by Helms et al. (2015), who present a new methodology to solve technical problems by creating biologically inspired solutions. In this case, the *creative reproduction of nature* offers the inventive principles that guide the creative thinking process in mechanical engineering problem solving. Interdisciplinarity in the scientific domain can be interpreted as the fluid transfer of knowledge (theories, methodologies, techniques, etc.) from one area to another, to acquire multiple points of view through which one can understand, reproduce, or extend the laws of nature. Analogical thinking is evidently the fundamental enabler of this transferring of concepts (Dunbar 1995), as exemplified also by von Thienen and Meinel (2015), who use the principles of design thinking to create a new form of collaborative problem solving during psychotherapy, and demonstrate the effectiveness of this method. Other principles guiding the inventive process have been identified and extensively described in the literature, in particular by Altshuller (1984) in his theory of inventive problem solving (abbreviated from the Russian translation with TRIZ). Starting from the impressive analysis and classification of over 200,000 technological patents, he found that only a very small percentage of these were consistently new, and therefore he passed on to extract regularities and patterns at the basis of the problem solving process. His theory is today applied in a number of companies and mechanical engineering schools (Beccattini and Cascini 2015) to improve and systematise the inventive process. Improvement of the creative process can of course also be tackled by addressing the individual characteristics that foster and enable problem solving capabilities. Multidimensional approaches, for example, try to find latent models predicting problem solving and creative abilities (Kirsch et al. 2015). Thanks to the systematic analysis of the creative thinking process within scientific and technical domains, the identification of clearly defined stages and abilities subsuming the process is now possible, as Cropley (2015) shows for the engineering domain. This approach allows not only to describe the conditions and abilities favouring creativity and the inventive process, but also to introduce pertinent interventions inside technical curricula in the education system. A future challenge would be to design innovative strategies for using the different abilities in the various stages of the process, to optimise the creative product.

An Artistic Home for Creativity

Undoubtedly, one of the most widely accepted notions is that creativity is intrinsically connected with art and artistic behaviour. Since the earliest times of human civilization, artists were considered to be the repositories of the holy fire of inspiration that leads to creativity. Other forms of idea generation could therefore be seen as inferior forms of reproduction of the artistic creative approach. These and other similar myths have survived and still populate the literature on creativity, creating an apparent gap between the worlds of artistic composition/performance versus scientific/technologic production. However, if we are on the path towards a unified science of creative thinking, it is necessary to first highlight the basic commonalities and then discriminate on the specificities. Let's start by introducing a scientific definition for inspiration: *inspiration is the mental process that starts from the aware or unaware input of an unforeseen, unexpected, unplanned, irrelevant conceptual entity and terminates with the generation of a pattern that is afterwards seen to be relevant to one's focus*. We then say that the final product was inspired by the apparently irrelevant conceptual entity. Thus inspiration is actually a fundamental process, that in the previously mentioned DIMAI model for the creative thinking process corresponds to the *movement* mental state. In essence, no matter what the application area, the generation of original ideas always entails the processing of irrelevant information. From this point of view, artistic inspiration can be elected as the paradigmatic form of generative process, and at the same time it can be freed from long-standing myths of semi-divinity and peculiarity of the creator. In particular, the strange, psychotic, and unconventional behaviour often exhibited by artists would seem to suggest that rules are harmful to creativity, which is on the contrary nurtured by living at the margin of society. This is indeed a myth: while it is true that eccentricity may be useful to the introduction of irrelevant elements in one's thinking, as well as to lowering the barriers that are erected by placing reputation at a prime, we cay say that it may be a sufficient condition, but by no means necessary. In other words, once we realize that open-mindedness is the essential skill to allow the co-existence of relevance and irrelevance in the same thinking process, and that the ability to move from there is the key to generate ideas which are both novel and valuable, then these skills and these processes can be nurtured and applied without affecting one's external behaviour. Artistic inspiration can live side-by-side with social acceptance.

A confirmation of the scientific foundation of creative performance in artists is certainly given by neuroscience. Through the analysis of the neural structures subsuming creative behaviour, neuroscience reveals that creative thinking is sustained by basic cerebral interconnections between areas associated with specific cognitive functions. Neuroscience allows to associate bodily evidence to musical creativity, showing the activation of neural networks during music composition (Rahman and Bhattacharya 2015). Moreover, monitoring the brain activity gives a corporeal image to real-time musical phenomena, such as improvisation, showing how this behaviour is intrinsically linked with expertise. A broad network of brain regions is associated with musical improvisation, which is highly influenced by the performer expertise: the longer the experience in improvisation by a performer, the stronger the neural associations (Rahman and Bhattacharya 2015). However, the neuroscientific study of creativity is a relatively new field, that has yet to stabilize some important methodological issues. First of all, there is a large variety of methods to monitor the brain's activity (e.g., EEG, fMRI, PET), leading to variable agreement about the brain areas involved with creativity (Dietrich 2004; Dietrich and Kanso 2010). Secondly, and perhaps more importantly, creative thinking is a very complex mental process involving a multitude of skills and traits, as well as a number of cognitive, social, and motivational abilities. This complexity is clearly hard to appreciate with a neuroscientific approach based on the monitoring of a single task, such as for example the RAT (Remote Associates Test) by Mednick (1962). Notwithstanding these issues, the value of neuroscience in giving concrete evidence to the functioning of the human mind cannot be overestimated: it gives confidence and solid grounds to higher level theoretical approaches.

The systematic study of creative thinking in the artistic domain gives higher awareness on the generative process and, at the same time, offers insights on possible strategies and approaches to evolve artistic education. The key appears to be the search for an optimal balance between three opposing elements: talent and skill, freedom and discipline, inspiration and theory. In fact, exceeding in any of these extremes holds the risk either of stifling creativity with an over-disciplined approach, which does not allow to deviate from accepted theory and styles, or of becoming an inefficient and ineffective observation of talent and unfocused search for inspiration. This delicate balance must serve to activate the necessary attentive and motivational resources, and to this purpose *teaching by projects* appears to be one of the most effective educational methodologies. Similarly to the *problem* in the scientific field, the *project* assumes in the artistic field the key role of activating field knowledge, the necessary skills, and the required thinking strategies (Journeaux and Mottram, 2015): it represents the focusing method to concentrate the attentive, cognitive and attitudinal abilities of an artist. The main point is that, even though we are looking for some form of inspiration in order to use our talent, through the disciplined use of the skills that we have developed, the definition of clear objectives and the setting of boundaries in terms of both quantity and time are not only helpful but essential in order to educate a young artist. It is both a matter of management of spontaneity, ingenuousness, or disengagement, and a disciplined process towards the development of skills and the flexibility in their use (Sintoni 2015).

The increasing understanding of the fundamental rules regulating the creative process in the artistic domain is reflected also in the results obtained in artificial intelligence, and in particular in computational creativity. Even though we are at great distances with respect to the levels attained by human creativity, interesting results have been obtained by reproducing creative artistic behavior through simulation by *intelligent* machines. In his review of *artificial* creators, Sawyer (2006) analyzed software-enabled machines that generate paintings, poetries, chemical products, etcetera. Interestingly, the tools of mathematical-statistics have been used to simulate highly sophisticated artistic performance in accordance to the style of a specific artist (Ghedini et al. 2015). Every artist indeed is recognised by his/her own style, i.e., a personal and reproducible (even if subject to a constant process of refinement) generative schema. Thanks to the analysis of the corpus of sequences the creator has composed, computational techniques can derive and reproduce the creator's style in different domains, such as music composition, music harmonization, and text writing. Of course, one can question the effective level of creativity that these machines can produce, if any. The main criticism stems from the fact that these techniques do not include in their generative process emotional elements, which are however central driving elements in the human creative process. Only when artificial intelligence will be able to endow a machine with emotions, we will be able to start the assessment of the outcomes of computational creativity. Nevertheless, computational creativity is a valuable element in the study of the creative thinking process, which can offer additional insights to the understanding of the dynamics defining the process. A minimal lesson to be learnt is that if a machine can produce results that are in some form surprising, then there are vast possibilities to define, explain, teach and apply creative thinking methodologies to the much more powerful human beings.

Conclusions and Future Directions

We believe the science of creative thinking is based on solid principles and consistent facts, but the path towards maturity is still long and the open challenges are many. The first diachronic challenge is to reinforce the roots, based on a factual and methodological investigation of the creative thinking process characterizing geniuses of the past. There is a need to go beyond an anthological narration of the lives and personalities of eminent persons (artists, scientists, inventors, etc.), and move significant steps towards the understanding of their particular life conditions, as individuals immersed into a specific environment that favored their rise to excellence. The extraction of generative, evaluative, and motivational principles guiding past geniuses is now recognized as a fundamental matter of study, as testified by recent editorial ventures (Runco 2014). The study of past eminent persons can be interconnected by following a historiometric approach (Simonton and Ting 2010) which, in conjunction with psychometric analysis, can open the scene to the opportunity of looking at history from a new perspective: not a mere collection of facts, but a complex and dynamic ensemble of ideas. Revisiting our history on the shoulders of past personalities can provide a new interpretation of our cultural heritage, and a new sense of identity as being part of a well identifiable flow of ideas. The science of creativity would then become intertwined with the evolution of our societies, and as such it should be expanded to all knowledge domains. Only in this way a map of domain-general and domain-specific elements characterizing creative thinking through the ages can be drawn.

Focusing the attention on the synchronic study of creativity, we feel it is urgent and necessary to bring together the scope, theories, and methods of cognitive and neuroscientific investigations of creativity. The joint use of a behavioural and functional interpretative models with the evidence provided by neuroscience, holds the potential to offer new significant avenues to the study of creative thinking. In this context, artificial intelligence could be used to obtain a reference to compare human creativity and computational creativity. Another area that requires large investment in the future is the study of the influence exerted by emotions on the creative thinking process. Even if emotions, and in particular surprise, are a part of the definition of creativity (e.g. Simonton 2012), the study of their role in the creative process has been concentrated mainly on motivation (Amabile et al. 2005) and mood states (Dawis 2009). Much more can be said about the effect produced by distinct emotions (happiness, sadness, anger, fear, etc.) on the creative thinking process. Moreover, the interaction between creative abilities and emotional intelligence (Ivcevic et al. 2007; Sanchez-Ruiz et al. 2011) must be further explored, and we can expect that not only the ability to regulate and manage emotions will translate into higher effectiveness of the entire process, but also the capacity to induce emotional states into others will turn out to be the real enabler for creative environments.

While the science of creative thinking expands its application fields, further measurement approaches must be developed to catch the complexity of the creative thinking process. Not only the quantification of single cognitive abilities is required, but new measurement systems able to take into consideration cognitive, emotional and personalities components in an interactive relationship with the social and cultural environment. The identification of creative profiles within different *natural* environments, as indicated by Bottella and Lubart (2015), points to the fact that profiling shall not be limited to the individual but expanded to the environment where the individual performs.

We must also not forget that a field of investigation does not become a science unless it has visible influence on educational programs. Creativity in schools is typically equaled to teaching of arts. Although this is certainly valuable, we are far away from the systematic introduction of the science of creative thinking into national and international educational systems. Theories and methods for idea generation should become a self-standing discipline, with possible applications to many domains at the choice of the student. An interesting avenue, largely unexplored, is to consider the teaching of creativity as a life-long process that includes elderly people in the audience. History has shown that most of the important creative products are generated at a young age, but is this due to simple aging of the brain? Or, perhaps, is there a fixation of certain attitudes that impede creative activity, such as the immediate rejection of irrelevant information, rapid assessment of ideas, unwillingness to put one's reputation at risk? And are there ways to overcome and actually turn around these attitudes? All of these questions are yet waiting for answers.

A final challenge concerns all researchers and practitioners who are involved with the science of creative thinking. In the information society, where facts, data, and knowledge in general are in principle available to everyone, creativity becomes the essential activity that distinguishes human beings, and as such it is a necessity to their own dignity. Therefore, the development and dissemination of the science of creative thinking becomes a mission for benefit of every individual and of society in general, and everyone involved in this field should feel invested by such a mission.

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The Defragmentation of Creativity: Future Directions with an Emphasis on Educational Applications

Beth A. Hennessey and Malcolm W. Watson

Introduction

In 2010, Beth Hennessey and Teresa Amabile published a comprehensive review of the creativity research literature in the *Annual Review of Psychology*. In selecting which articles to review, rather than fall prey to their own potential biases, Hennessey and Amabile decided to rely on the consensus of experts. They started out by polling 21 eminent colleagues—all prolific researchers and theorists in the field of creativity research—asking that they nominate up to 10 articles or books, published since about 2000, that they considered to be "must have" references. Surprisingly, consensus was not to be had. In fact, this call for nominations did nothing more than add to their confusion. The poll yielded 110 suggestions of specific journal articles, book chapters, books, or entire volumes of a journal devoted to a particular topic. Of the 110 nominated references, only seven were suggested by two colleagues, and only one was suggested by three colleagues. Rather than make the reviewing process easier, this exercise only served to underscore the marked diversity of opinion and overall fragmentation of the creativity field.

Over the past few decades, there has been a virtual explosion in the creativity literature of topics, perspectives and methodologies. Yet careful scrutiny of the literature shows that few, if any, "big" questions are being pursued by a critical mass of investigators. In many respects, the scholarly understanding of the psychology of creativity has grown amazingly sophisticated, and contemporary researchers

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now bring to the table an ever-expanding variety of analytic methodologies, disciplinary training and backgrounds. The problem, however, is that investigators in one subfield often seem entirely unaware of advances in another. Many creativity researchers (ourselves included) were trained as experimentalists—systematically manipulating one or two variables at a time and making every effort to keep all other factors constant and controlled. This is the tried and true scientific method after all. Yet some experimentalists have become so focused on the minute details of a specific creative situation or participant cohort that they fail to seek the bigger picture. As a result, research is often carried out at only one level of analysis (e.g., the individual or the group) and within only one discipline or subfield at a time. Of course, this problem of isolation of sub-domains of research is not unique to the creativity field. It tends to pervade many disciplines of inquiry (Ambrose 2005; Persson 2012, 2014).

In its final form, the message of Hennessey and Amabile's *Annual Review* was that researchers and theorists must now work to develop a systems view of creativity. "The 'whole' of the creative process must be seen as much more than a simple sum of its parts" (Hennessey and Amabile 2010, p. 571). Creativity must be operationalized as a result of a system of interrelated forces operating at multiple levels and requiring interdisciplinary investigation. This call for reform seemed to be sound, but it is easier said than done. Might there be some hazardous consequences involved when researchers attempt to develop a unified systems model of creativity?

Since the publication of the 2010 review, the call for a de-fragmentation of the field has, in fact, been referenced by a variety of investigators and theorists. Many appear to agree that an integration of the creativity literature is long overdue. For example, some of the important work that was shared at the 2013 conference at the Marconi Institute for Creativity in Bologna was directed toward that goal. We believe that it would indeed be a big step forward, a significant accomplishment, if we could actually construct what appear to be useful systems approaches or, dare we envision, one single, all-encompassing systems model. The construction of such an all-encompassing model would serve as an impetus for future research and would be of great use in synthesizing the literature and coordinating research efforts. In our view, it makes good sense to continue working in this direction.

After all, this is the course of action that is generally taken in any scientific domain. Preliminary research sets out to test one or more hypotheses. Soon, scientific models are constructed to depict or describe the phenomena in a way that makes them easier to understand, visualize and quantify. Over time, these initial models lead to the generation and systematic testing of new, more nuanced, hypotheses and models. Yet models run the hazard of sometimes oversimplifying reality because they cannot include all aspects. If they then end up complicating researchers' views of reality or taking them down wrong paths, they cease to be useful models.

Importantly, as the scientific inquiry of a phenomenon grows and becomes more and more multi-faceted, there sometimes comes a sort of tipping point, a juncture at which it is no longer possible to synthesize the scholarship, no longer possible to extract commonalities across the many sub-areas of inquiry appearing in the literature. At such a point, creating a useful scientific model may not be possible because there would be too many phenomena left out or left unexplained. The empirical investigation of creativity seems to have reached this point.

Although we believe that researchers and theorists must now work to develop a systems framework of creativity that would support scientific model construction, the primary goal of this chapter is to voice our concern that this work does *not* end up leading to a sort of wholesale reduction of the field and to the creation of models that do not clarify our understanding of reality. In addition, we engage in the empirical study of creativity not ultimately for the sake of research but in order to better understand how to promote and "grow" creativity, and when we remind ourselves of that real-world focus, we come away questioning whether a so-called systems model or "grand theory" will do much to guide us in applied settings.

Integrative Models of Creativity

What would a truly integrative systems model consist of? How can we construct an integrated model that captures the highly complex system of interrelated forces operating at multiple levels to produce creative outcomes? Does it at all make sense to ask researchers and theorists to work to construct a systems model that simultaneously accounts for so-called "Big-C" (Einstein level creativity), "Pro-C" (the creativity of R&D developers working on the next "big thing"), "Little-C" and "Mini-C" (everyday level) creativity (see Kaufman and Beghetto 2009)? Perhaps this is not a realistic goal. Perhaps it is not even an important goal. Here are some related questions. Should both trait (personality and intelligence) and state (situation-specific) measures of creativity be included in our overarching model? Could one model adequately capture the creativity of children as well as the creativity of adults, both novices and experts in their fields? And would it make sense to incorporate into our model data collected worldwide, or would multiple models be necessary to account for demographic, ethnic and cultural distinctions? Moreover, if we are to subscribe to some recent research showing creative performance to be primarily domain-specific (as opposed to cutting across domains), should not even the most integrative model of creative behavior also focus on only one area of expertise at a time?

In 2011, John Baer published an especially thoughtful paper entitled *Why Grand Theories of Creativity Distort, Distract and Disappoint*. It is Baer's contention that we will never succeed in constructing an all-inclusive "grand", or systems, theory. Baer well understands the appeal of such an approach and reminds readers about how the study of particle physics was rejuvenated by just such an all-encompassing model. Yet he cautions that it is unlikely that any one theory or model will ever adequately describe, as he puts it, "the many very different kinds of cognitive [/behavioral] processes that underlie creativity in diverse domains" (p. 73). As Baer argued, trying to force such a theory is bound to impede both theory and practice and lead to more misunderstandings than worthwhile breakthroughs.

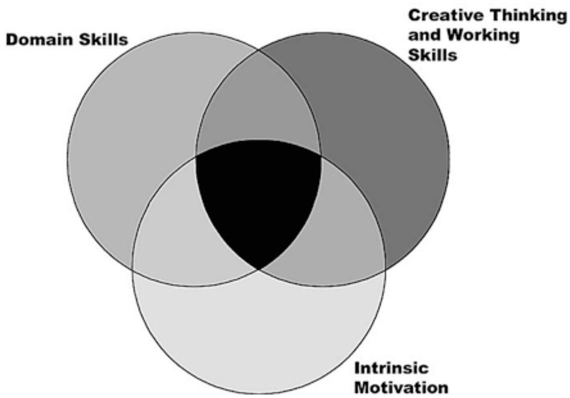

Fig. 1 The creative intersection (Reprinted with the permission of The National Research Center on the Gifted and Talented.)

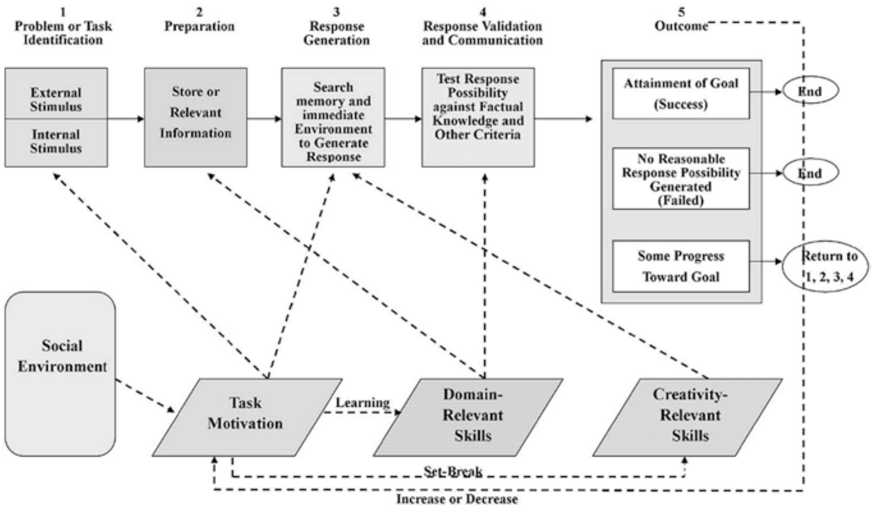

Fig. 2 Amabile's componential model (Reprinted with permission from: Amabile 1996, p. 113)

In an effort to make the problems inherent in model building more concrete, it might be helpful to consider some specific examples. For many years, a three-part rubric, the "creative intersection", first proposed by Amabile in the early 1980s (see Amabile 1996), guided much of Hennessey's own empirical work on creativity (see Hennessey 2004; Fig. 1).

This model was effective in simplifying the antecedents in the creative process and in providing a clear visualization, but the model functioned more as a metaphor than an accurate portrayal of causal pathways. Then, over time, Amabile and others began to build upon this conceptualization with the incorporation of additional constructs. In this next model offered by Amabile in the mid 1990s, cognitive components and feedback loops involved in the creative process were added (Fig. 2).

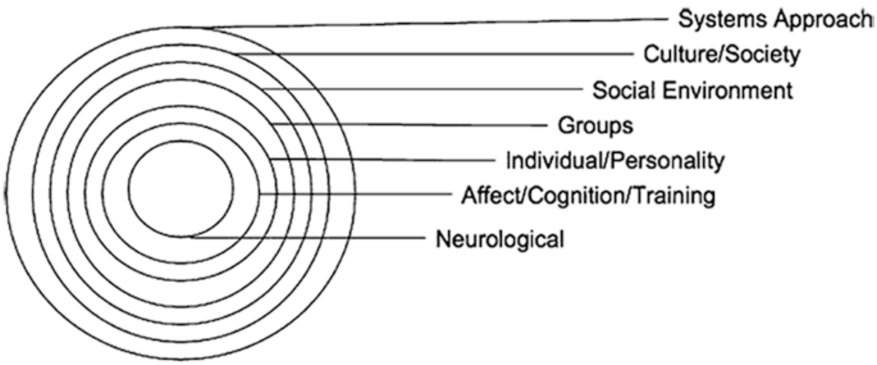

Fig. 3 Amabile and Hennessey annual review model (Reprinted with permission from: Hennessey and Amabile 2010, p. 571)

As would be expected, the complexity of models like this one is considerably greater than that of Amabile's original three-part rubric. Any theoretical framework or working model will likely increase in complexity as more is learned about the phenomena under study and as researchers' and theorists' understanding becomes increasingly nuanced.

But what about a consideration of individual differences and personality variables, cognitive developmental stages, the role of society and historical time and place, cultural and cross-cultural considerations, and the list goes on? In their *Annual Review* article, Hennessey and Amabile (2010) argued that researchers must realize that creativity arises through a system of interrelated forces operating at multiple levels and often requiring interdisciplinary investigation. They offered a simplified schematic of the major levels at which these forces operate. We say "simplified" because, of course, even the existing research does cross levels (Fig. 3).

Because any good theory or model will provide a better understanding of human behavior, it would serve as an impetus for future research and assist investigators in forming hypotheses to be tested. In fact, there are already a handful of systems models available that have done much to help creativity researchers and theorists organize their thinking and move forward in their research. For example, Csikszentmihalyi's (2006) framework suggests that a consideration of culture should be placed at the top of the hierarchy that explores how creative endeavor emerges within a social field.

And Glăveanu's (2010) work on creativity as cultural participation incorporates a three-way focus on creator, audience and existing artifacts (Fig. 4).

The Challenge of Applying Theory to Practice

Models such as those presented above have the potential to generate new research questions and directions, but will a systems view bring us closer to the successful application of research findings and theories in real-world contexts? What

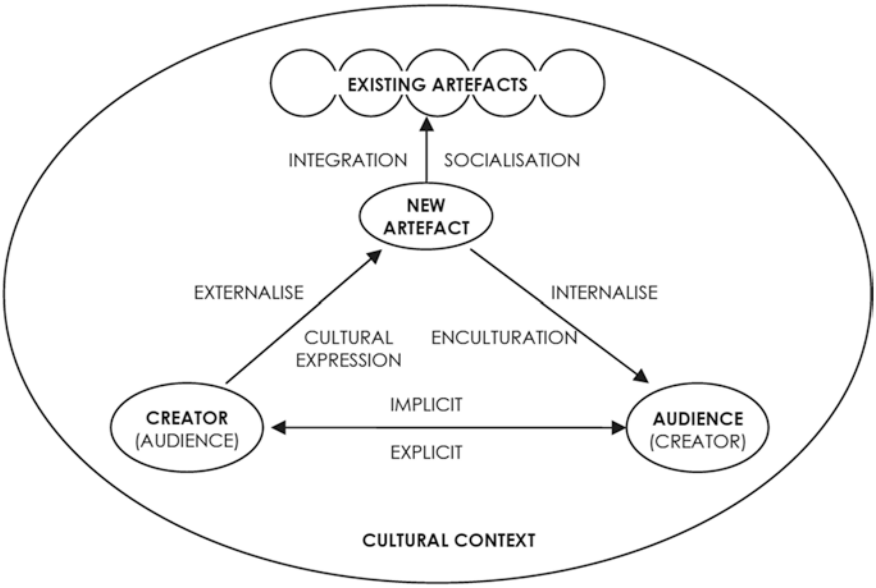

Fig. 4 Glăveanu's creativity as a socio-cultural-psychological process (Reprinted with permission from: Glăveanu 2010, p. 210)

real benefits will such systems models bring to the teachers of New York City or Bologna or Shanghai? Or what could they offer the so-called "managers for innovation" in Los Angeles, Rio or Warsaw? Will systems models make it any easier to promote the creativity of children in classrooms or help adults to make groundbreaking discoveries in the workplace? Will efforts to construct an all-encompassing systems model really make our own lives or the lives of others any better? Our own intuition is that attempts to apply multi-faceted systems perspectives to real-world problems and settings will only move us further away from the consideration of real people and their real needs. Because systems perspectives often complicate, rather than simplify, already highly complex situations, chances are good that practitioners—managers, teachers, trainers and product developers—will become paralyzed, unable to decide which pathways to explore, what to "fix" first. This distancing of theory and models from real-world applications will occur if our theorizing does not also remain mindful of the applied outcomes.

In our own work, we are both theoretical and applied. For example, we have theorized about how intrinsic and extrinsic motivation affect creativity, and we have used this theory to assess how motivation impacts actual creativity in classrooms in several different cultures. Others, of course, have focused on the promotion of creativity in the business world—in multi-national corporate settings or small entrepreneurial start-ups. Any consolidation of the scholarship on creativity must be driven in large part by the question of how best to serve real-world constituencies.

Those seeking to de-fragment the field have already encountered a number of inevitable forks in the road. Over time, they may conclude that it is impossible to construct a single systems model that applies across cultures and situations and serves equally well to inform school administrators and curriculum developers, scientists and engineers in the laboratory, and R&D team members and their managers in the workplace. They may discover that they need to construct multiple complementary models rather than a single, unified systems model of creativity. And perhaps that would be the direction to go.

We find it both somewhat surprising and at the same time hopeful that this same sentiment was recently expressed in an on-line blog appearing on the website of the *Harvard Business Review.* As part of this blog, Pallotta (2013) asks "What's the point of creativity?": "Increasingly, creativity—and the study of it—is divorced from the real needs of real people. Adding ever more gimmicks to a smartphone in the interest of increasing market share, rather than giving people something revolutionary that will make their lives better, reeks of something other than love and has no power to stir people's enthusiasm. So the question we have to ask ourselves in business is this: Why create? Are we doing it for the gratuitous sake of creativity itself, without any larger purpose? Are we doing it because *Harvard Business Review* writes about it all the time? Are we doing it out of fear? To make more money? To get on the cover of *Wired*? Or are we doing it out of a desire to improve people's lives and transform their sense of what possibilities life itself has to offer?" (retrieved from http://blogs.hbr.org/2013/09/does-your-innovation-come-from/).

What Pallotta is referring to here is a glaring disconnect between creativity theory, creative education/management training and actual creative problem solving. By definition, applied work must involve a step back from the level of abstraction adopted in a core theory. Only in this way can theory and the research findings it has generated throw light on specific creative challenges and situations.

Early explorations in the area of applied creativity were frequently directed at K-12 classrooms. Pioneers in this area included Torrance and deBono, as well as researchers and theorists associated with the Creative Education Foundation (CEF) in Buffalo, NY. In fact, Parnes, Osborn and others at the CEF actually used the term "applied creativity" to describe their work. Creativity mainstays such as brainstorming and Creative Problem Solving's (CPS) deliberate creativity techniques emerged from these efforts, and the CEF, now relocated to Scituate, Massachusetts, continues to make significant contributions to our understanding of real-world creativity and its promotion. But in the grand scheme of things, it must be observed that over the past few decades relatively little effort has been devoted to the application of research findings to classroom learning or other real-world settings where creativity might be helped to flourish.

One exception to this rule, of course, has been in the area of corporate creativity and innovation. Dozens of best-selling books and hundreds of empirical papers have been written with the intention of specifying what business leaders and their managerial forces can do to boost the creativity of their workers. Yet as Pallotta (2013) and others point out, the essential goal of these publications is to help companies boost profits, which may or may not involve real problem solving. Moreover, an essential distinction must be made between the carrying out of research in real-world settings and the actual application of those research findings. At present, many creativity/innovation consultancies implement change models that lack strong empirical support or theoretical backing. Consultants are frequently hired on the basis of reputation or educational pedigree, and price is too often taken as an indicator of quality (von Nordenflycht 2010). In fact, consultants rarely return to assess whether their efforts have had a positive impact; and if they were to return, they would find that an assessment of their success (or lack thereof) was especially problematic. As Christensen et al. (2013) point out, it is exceedingly difficult to judge consultants' performance because a variety of external factors, including fidelity of execution, management practices, and the passing of time, greatly influence the outcome of the consultants' recommendations. Yet they argue that this situation is about to change. They identify what they term a "disruption" in the field of consulting for innovation. Christensen and colleagues also foresee on the horizon a similar disruption for education (Christensen et al. 2008).

American Schools: A Case in Point

We discuss the problems of fostering creativity in the American Education system as an example of the problems of tying theoretical research and scientific evidence to the solution of real-world problems. We suspect that the example of American education probably reflects similar cases and issues in other countries as well.

Across the past few decades, opportunities for the development and exercise of creativity in U.S. schools have been continually eroded. In this age of accountability and nationally mandated *No Child Left Behind (NCLB)/Common Core* regulations, the current U.S. educational climate is fraught with more killers of student (and teacher) intrinsic motivation and creativity than at any other time in the recent past. Teachers now face all sorts of possibilities for scrutiny as they "teach to the test" and worry that their salaries, and maybe even their ability to keep their jobs, may be dictated by their students' scores. Children attend pep rallies and chant slogans reminding them to "do their best" on upcoming high-stakes examinations. Entire schools branded by labels like "failing" or "underperforming" push on against incredible odds to boost student performance. Test scores mean everything, and thus there is no room for creativity in the classroom.

What are the signs of a disruption of this educational system in the U.S.? Slowly but surely, parents, teachers and even entire legislatures are rising up. Since 2011, at least 42 states and the District of Columbia have applied for and have been granted waivers allowing them to bypass one or more of the NCLB mandates. Most recently, the Iowa legislature voted to altogether opt out of the national educational standards, and many believe that this move will embolden other states to follow. Multiple reputable national polls also show that large segments of the population are deeply disturbed by what they see as an overemphasis on standardized testing and a "one-size-fits-all" nationalized curriculum. In 2012, a Gallup poll revealed that the majority of U.S. citizens supported the idea that teachers should be evaluated on the basis of their students' test scores, but by 2013, another poll showed a marked reversal of opinion (Watanabe and Villeneuve 2013).

Coupled with this dissatisfaction with the educational status quo have been movements to infuse opportunities for creativity back into the classroom. Educational observers increasingly worry about the need to educate for the 21st century. Students, they argue, need to gain not only basic reading and writing skills and knowledge across the disciplines but also core competencies in critical thinking, creativity and innovation, problem solving, communication and collaboration. The global workforce needs to be schooled in both ways of thinking and ways of working (e.g., Saavedra and Opfer 2012). In response to this call for reform, a few states in the U.S have recently passed legislation mandating that schools provide frequent, high quality opportunities for students to engage in creative work. The details are still being worked out, but it appears that our own home state of Massachusetts, as well as Oklahoma, California and a few others, are moving toward the implementation of a so-called "creativity index" (Robelen 2012) designed to rate public schools on how well they "teach", "encourage" and "foster" creativity in students. One of the primary measures underlying this initiative is a tally of the number of opportunities each school provides for students to engage in creative activities. Our own concern here is that politicians and their educational advisors must be helped to understand that student *and teacher* creativity does not come easily. Given the pressures of NCLB/Common Core regulations and testing, it is already the rare teacher who can find the time, much less the motivation, to build opportunities for student creativity into the school day. The last thing teachers need is another punitive checklist against which their own performance and the performance of their students will be judged. And even if teachers were given the resources, the license and the time to organize science fairs, theatre productions and other open-ended activities, there is no guarantee that students' creativity would be increased. Creativity must not be trivialized by being reified by simplistic tallies of creative activities available.

Final Remarks on Theory and Practice

As argued previously, complex systems models are not likely to bring us closer to the successful application of research findings and theories in real-world contexts. Lawmakers, teachers, consultants and mangers need far more concrete and directed tools upon which to base their efforts to effect change. Creativity researchers and theorists wishing to contribute their expertise to educational or consultancy reform could learn a great deal from their colleagues in the area of "applied economics".

In the opinion of many economists, theory building and application must be treated as entirely separate enterprises. It appears that in this field there is an accepted “theoretical core” that has been applied to a wide range of domains. But this theory, this core, was developed independently of individual applications; and within the economics profession, there are differing views as to exactly what belongs in the core (e.g., Backhouse and Biddle 2000).

As early as 1917, Keynes introduced a sharp conceptual distinction in the economics literature between political economy as a science (whereby laws governing the production and distribution of wealth are formulated) and political economy as an art (using those laws to solve practical problems). A similar view is also gaining momentum in the fields of architecture, engineering and business. Termed “Design Thinking”, this movement advocates a sort of bifurcation of research and practice. Design Thinking is a methodology for generating practical, creative solutions to actual concrete problems. Rather than follow the scientific method, which would start with a precise definition of all the parameters of the problem, design thinkers begin with a focus on the goal that is to be achieved. Starting with the solution, design thinkers work to form an empathetic understanding of what it is that people really need or want and what they like or dislike about the current products, solutions or pathways available to them. Simply stated, Design Thinking matches real-world needs with what is practically feasible (see Brown 2008; Martin 2009).

We believe that these examples from economics and engineering may provide a useful roadmap. Nevertheless, the scientific method of empirical research and the quest to construct unified systems models are still important parts of the process. In a discussion of the differences between basic and applied research, Watson (1982) noted that we often talk as if one is theoretical and the other is not; we define basic and applied research in large part on a theoretical-atheoretical dimension. Atheoretical research comes about as researchers attempt to answer immediate, applied problems. That sounds efficient, but such research usually leads to a dead end because it supplies facts regarding a specific situation but no framework for making the facts generalizable to many situations. In truth, our systems models and unified theories are not really unifying if they cannot help to relate their theories to the goals and outcomes of teachers in the classroom or managers in the workplace, but, likewise, our applied research is not generalizable if it is not based on theory and model building. The difference between basic and applied research should not be thought of as whether the research is atheoretical or theoretical; it should all be theoretical. Rather, what makes both basic and applied research valuable is a focus on the applied problems in the real world as we develop our theories and models. Just like design thinkers who start with a solution, it is time for creativity researchers to set out to construct new, more situation-specific models—models that start with the needs of the constituencies in question. What do educators need to promote the creativity of their students? What do managers need to grow the creativity and innovation of their designers, their R&D scientists? Research directed at these questions should be used to build our theory and models in order to advance our understanding of the interrelated antecedents leading to creativity at the same time that researchers consider how their empirical findings can best be applied to real-life needs.

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A Review of Integrated Approaches to the Study of Creativity: A Proposal for a Systems Framework for Creativity

Kristina Dorniak-Wall

The study of creativity within the field of psychology became popular after being introduced in Guilford's 1949 address at the American Psychological Association annual convention. Over the subsequent 50 years, dramatic progress in the studies of creativity has been made (Mumford 2003). As a consequence, we now have a sophisticated understanding of focused studies and variables, perspectives and methodologies in the creativity literature. However, although there is a vast amount of information on many areas relating to creativity, there is a growing fragmentation of the field (Hennessey and Amabile 2010). Often researchers in one subfield seem entirely unaware of advances in another (Hennessey and Amabile 2010). Each approach taken by a researcher concentrates on the issue of creativity differently; devising their own theories, methods, and investigative paradigms (Batey and Furnham 2006). Through examining correlates of personality or motivation in isolation, researchers may be producing misleading results that are also un-replicable as the interaction between components relating to person, process and the environment necessary for creativity in different domains is complex and not fully understood (Batey and Furnham 2006). Therefore, this chapter has three main aims: to review the current models that look at the interactions between components, assess them for their strengths and weaknesses, and to propose guidelines for the development of a new model of creativity and Innovation.

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Defining Creativity and Innovation

A chapter looking at constructing a model of creativity and Innovation should begin with a definition of the two terms. The most agreed upon definition of creativity is something that is original but also accepted as tenable or useful (Guilford 1950; Runco and Jaeger 2012; Stein 1953). Therefore creativity does not exist without practical restraints, and these ideas must be appropriate and significant to the problem or opportunity presented (Amabile 1988; McIntyre 2012; Oldham and Cummings 1996; Shalley 1991). In addition, effectiveness is necessary so that ideas are not useless and have some adaptability to reality (Barron 1955; Runco and Jaeger 2012).

Innovation encompasses creativity but also extends to the implementation of creative ideas; it is "a process of developing and implanting a new idea… the process of bringing any new problem solving idea in use… it is the generation, acceptance, and implementation of new ideas, processes, products or services" (Van de Ven and Angle 1989, p. 5). The focus of Innovation is to take on a creative idea and bringing it to fruition; it is the applicability of new ideas to address particular problems (Kanter 1983).

Conceptualising Creativity: The 4Ps

Since the inception of creativity research, creativity has been thought of and described in terms of the 4Ps (Barron 1955; Rhodes 1961): *Person, Product, Process* and *Press*. Person refers to personality, intellect, temperament, physique, traits, habits, attitudes, self-concept, value systems, defence mechanisms, and behaviour (Rhodes 1961). Process refers to motivation, perception, learning, thinking and communication—factors that contribute to a person to strive for original answers to questions. Press refers to the relationship between human beings and their environment. The last of the 4Ps, Product, refers to an idea in a tangible form. A product can refer to a physical object, an idea, a system, service or process.

Each component of the 4Ps has been favoured during different decades of the twentieth century and has settled into different sub-disciplines of psychology as well as other areas such as human resources, management and entrepreneurial studies (Hennessey and Amabile 2010). This monolithic approach is useful in understanding a certain factor of creativity such as personality, however, the 4Ps do not happen in a vacuum or in isolation. Progress within the field of creativity has been slow, as many students and researchers of creativity have taken as Mumford (2003) describes, a "magic bullet approach, proposing one simple, all-encompassing mechanism to account for creative thought…blind variation, divergent thinking, motivation and so forth" (p. 109). The 4Ps framework provides researchers within the field a solid basis for investigations into creativity, whereby although "each strand has unique identity academically… only in unity do the four strands operate functionally" (Rhodes 1961, p. 307).

Although Rhodes' model initially suggested that all four 'Ps' should be looked at in conjunction with one another, little contemporary research has looked at a more integrated approach (Montuori and Purser 1995). The 4Ps framework acts as both the cause for fragmentation in the field as well as the solution. In a review of the creativity literature, Hennessey and Amabile (2010) comment on the expansion of research and literature within the field, however, they call for more research to be conducted looking at a more integrated approach: "deeper understanding requires more interdisciplinary research, based on a systems view of creativity that recognises a variety of interrelated forces operating at multiple levels" (Hennessey and Amabile 2010, p. 569).

The diversity of views relating to creativity has led to the expansion of the literature and interest within the field of creativity, however, by only looking at one element of a phenomenon researchers are providing misleading results (Batey and Furnham 2006). In addition, by only concentrating on one factor of creativity, there is a growing fragmentation of the field (Hennessey and Amabile 2010). It appears to be the case that researchers in one subfield seem entirely unaware of advances in another (Batey and Furnham 2006; Hennessey and Amabile 2010). Through examining correlates of personality or motivation in isolation, researchers may be producing misleading results that are also un-replicable as the interaction between components relating to person, process and the environment necessary for creativity in different domains is complex and not fully understood (Batey and Furnham 2006).

Fragmentation

Although there is a vast amount of information on many areas relating to creativity and Innovation, there is a growing fragmentation of the field (Bledow et al. 2009; Hennessey and Amabile 2010). Often researchers in one subfield seem entirely unaware of advances in another (Hennessey and Amabile 2010). There is a tendency for researchers to concentrate on the issue of creativity differently, devising their own theories, methods, and investigative paradigms (Batey and Furnham 2006). The literature suggests that the demands of Innovation differ from those of routine performance (Bledow et al. 2009). However, it also suggests that "routine performance is based on the exploitation of knowledge, skills and abilities that emphasise quality and efficiency criteria" (Bledow et al. 2009, p. 308). Thus, there are some behaviours and ways of approaching problems that are good for Innovation at one stage but may prove detrimental at another. Indeed, Csikszentmihalyi (2006) indicated that the personal and environmental conditions involved in creativity are not always universally favourable or unfavourable to creativity. By maximizing the factors that facilitate the development of new ideas, it is likely to simultaneously cause conditions that may inhibit idea implementation and, therefore, Innovation overall (Bledow et al. 2009).

Systems Theory

The literature suggests that there is a need for a systems approach to the study of creativity (Hennessey and Amabile 2010). The notion of 'systems approaches' to the study of any field have existed since the time of European philosophy (Von Bertalanffy 1972). One such formulation was that of Aristotle, "the whole is more than the sum of its parts" (Von Bertalanffy 1972, p. 407). It was philosophised that "since the fundamental character of the living thing is its organisation, the customary investigation of the single parts and processes cannot provide a complete explanation of the vital phenomena" (Von Bertalanffy 1972, p. 41). The characteristics of systems thinking was pioneered by biologists who emphasised the view of living organisms as integrated wholes in the 1920s, and these ideas emerged simultaneously within several fields such as Gestalt psychology, ecology and quantum physics in the early half of this century (Capra 1996). Thus, the terms 'systemic', 'systems thinking' and 'ecological' are used synonymously (Capra 1996). To understand things systemically means to put them into a context, to establish the nature of their relationships. Thus, a systems view emphasises the importance of an organism or living system are properties of the whole, which arise from the interactions and relationships among the parts (Capra 1996). These properties are said to be destroyed when the system is dissected into isolated elements (Capra 1996). Within this holistic zeitgeist, key characteristics or criteria for systems thinking have emerged. Systems thinking involves shifting from the parts to the whole; "living systems are integrated wholes whose properties cannot be reduced to those of smaller parts" (Capra 1996, p. 36). Furthermore, systems arise from the configuration of ordered relationships and are contextual—that is they can only be explained in terms of their environment. Thus, all factors must be looked at together taking into account any contextual factors.

Von Bertalanffy (1972) suggested that a general systems theory would offer an ideal conceptual framework for unifying various scientific disciplines that had become isolated and fragmented (Capra 1996). He believed that "the customary investigation of single parts and processes cannot provide a complete explanation of the vital phenomenon…and gives us no information about the coordination of parts and processes" (Von Bertalanffy 1972, p. 64). Therefore, taking a systems approach to the study of creativity may help alleviate the fragmentation within the field and help provide a more complete explanation of the interactions amongst aspects of creativity.

Extant Models

Although the research within the field tends to gravitate towards more fragmented approaches, a number of integrated approaches to the study of creativity can be found in the literature. Table 1 presents a chronological summary of models that take integrated approaches and whether they include all aspects of the 4Ps.

Table 1 Summary of extant systems models

Model	Person	Press	Product	Process	Research evidence	Interactional
Stein (1953)	✓	✓		✓	✓	
Barron (1969)	✓	✓		✓	✓	
Arieti (1976)	✓	✓		✓		
Gruber (1981)	✓	✓		✓	✓	
Amabile (1983a, b)	✓	✓	✓	✓	✓	
Harrington (1990)	✓	✓		✓		
Sternberg and Lubart (1991)	✓	✓		✓	✓	✓
Woodman et al. (1993)	✓	✓		✓		✓
Csikszentmihalyi (1996a, b)	✓	✓		✓		
Taggar (2002)	✓			✓	✓	
Pirola-Merlo and Mann (2004)	✓	✓		✓	✓	

In addition, the table indicates if the models look at the interactions of the 4Ps and whether they have been supported by research evidence.

Stein (1953)

One of the first documented instances of creativity being discussed as an interaction of Person and Press was by Stein, who proposed that approaches from the two dichotomous fields of psychology and sociology need to be utilised for a greater understanding of the phenomenon that is creativity. Within his seminal research, Stein (1953) proposed a transactional approach to creativity which stresses the importance of social milieu in which the individual creates. This approach has three underlying assumptions:

1. Creativity consists of processes that occur within the individual (a process of hypothesis formation, testing, and the communication of results).
2. Creativity is the resultant of processes of social transaction (individuals affect and are affected by the environments in which they live).
3. Creativity is that process which results in a novel work that is accepted as tenable or useful or satisfying by a group at some point in time.

Stein investigated creative individuals in case studies of industrial research chemists. Within his research he explored the different roles these individuals had to adopt at work including an investigation into the social role they need to play (Stein 1963). He argues we need to understand the different roles individuals need to take on at work in order to understand and predict creativity, however acknowledges his research is not supported with quantified data. The role an individual has to play at work (environment) dictates the type of psychological characteristics an individual should possess to manifest creativity. When observing the psychological characteristics of individuals, Stein used psychological tests as well as biographical data to determine attributes of more or less creative individuals.

Although Stein's approach to the problem of creativity has been supported through the use of case studies, this research does not provide a comprehensive view of how different aspects of a person and social environment may interact to inhibit or allow creativity and it also does not include all aspects of the 4Ps.

Barron (1969)

A pioneer of research on contextual/systemic approaches to the study of creativity, Barron suggested that creativity is the product of a conjunction of social and psychological processes whereby the creative individual is engaged in a relationship with the environment and the environment is a source of information that creates periods of disequilibrium within the creative person (Barron 1969; Montuori and Purser 1995). Creative thoughts need to be not only new to the person that thinks them, but to everyone; they need to create new conditions of human existence (Barron 1969). Creativity may be motivated by a desire for integration and communication with others (Montuori and Purser 1995). In his studies, Barron identified that some aspects of a person's personality plays an important role in their capacity to think and act creativity. However, no empirical research investigated the integrated effect of all 4Ps.

Arieti (1976)

Likewise, Arieti (1976) proposed a systems model of the interaction between culture and the individual whereby the individual offers or exposes his biological potentialities to the culture, and the acquisition of things already present in culture by the person (Montuori and Purser 1995). Arieti adopts the philosophical view of Von Bertalanffy who stresses that all fields are systems or complexes of interacting elements, and he also follows the view of Maslow (1972) that the creative person needs to be considered holistically not atomistically (1976). He views the creative process as being part of an open system, and suggests that man without culture would be a purely biological entity, not a sociobiological entity. Within his research, Arieti has proposed 9 sociocultural factors which foster creativity: availability of cultural means, openness to cultural stimuli, stress on becoming and not just being, free access to cultural media for all citizens, exposure to different and contrasting cultural stimuli, tolerance for diverging views, interaction of significant persons and promotion of incentives and awards. Although Arieti's research has been described "as one of the most systematic contributions to the delineation of factors that allow for creative development" (Montuori and Purser 1995), his research has not been supported by any evidence and is purely theoretical.

Gruber (1981)

Gruber (1981) has also recommended an evolving systems approach of creativity. This approach concentrates on case studies of famous people and has three guiding ideas: the creative person is unique, developmental change is multidirectional and the creative person is an evolving system (Gruber and Wallace 1999). He suggests that it may not be possible to make many generalizations about the ways in which all creative people are alike as their uniqueness cannot be reduced to a description of a fixed set of dimensions (Gruber and Wallace 1999). Therefore, this model focuses less on understanding the particulars of a specific creative act than on how those particulars fit into the context of an individual creator's goals, knowledge, and reasoning, as well as larger social forces and creative paradigms (Kozbelt et al. 2010). This model presents an account of what creators do instead of attempting to search for the origins of creativity or try to propose a single model of the creative personality (Kozbelt et al. 2010). It looks at how creativity works, what people do when they are being creative and how they use their resources to be creative. This model has not been empirically tested and has mainly concentrated on case studies of eminent individuals.

Amabile (1983a, b, 1996)

Amabile (1983a, b, 1996) has proposed a componential theory of creativity that incorporates three individual components that influence creativity and the social environment. This theory posits that domain-relevant skills, creativity-relevant skills and intrinsic task motivation combine and lead to creativity. When these three components share their greatest overlap, creativity will be the highest (Collins and Amabile 1999). Research suggests that the most immediate and prevalent influence of the social environment is exerted on the motivational component (Amabile and Pillemer 2012). Furthermore, Amabile's model suggests that different components are likely to influence different stages of the creativity process. In the first stage in which tasks or problems are identified, motivation plays a prominent role and determines whether and how a person may choose to engage with the problem (Amabile and Pillemer 2012). In the stage of preparation, domain-relevant skills assist as they play an important role as the person gathers information (Amabile and Pillemer 2012). In the third stage, response generation, candidate solutions or response possibilities are produced, both creativity-relevant and task motivation determine the outcome (Amabile and Pillemer 2012). The fourth stage, response validation, domain-relevant skills are useful in determining the novelty and usefulness of the candidate responses (Amabile and Pillemer 2012).

Amabile's Componential Theory of Creativity was tested in her T.E.A.M study, where in conjunction with a number of researchers and professionals, she looked at cross-professional teams and identified three categories that appear to predict collaborative success: (1) project-relevant skills and knowledge (diversity and complementarity in skills, perspectives, knowledge of team members, paired with a common core understanding of the problem domain, (2) collaboration skill (which stems from experience with collaborative relationships), (3) attitudes and motivation. The results of this study allowed for Amabile to elaborate on her Componential Theory of Creativity (Amabile and Mueller 2008). The theory now includes affect and the events in a daily work environment that can induce affect. In addition it proposed how the work environment can influence creativity-relevant processes which in turn influence creative responses, as well as proposed a feedback loop from creativity back to affect.

Further research undertaken to find support for this model has been completed by Conti et al. (1996). Through correlating multiple measures of creativity undertaken within the same domain and context, Conti and colleagues (1996) suggested support for the Componential Model of Creativity. This suggests that creativity measures taken within the same context and domain should be strongly and positively related. Research conducted by Sternberg and Lubart (1995) found that high levels of domain-relevant skills, motivation and creativity-relevant skills must co-occur in an appropriate environment to yield high levels of creative performance.

Although research supports the inclusion of each of these components in the model (Amabile 1996), and all elements have been shown to be correlated, there is no evidence to suggest different strengths of these variables. It also does not propose whether having a strength in two of the components in the model can make up for a weakness in another component. Furthermore, this model does not take into account the idea of paradoxes—that at some stages of the Innovation process, variables that are seen as harmful for the Innovation process may actually be helpful. This research has not taken into account interactional effects between the components. By looking at the interactions between components in the model a more accurate examination of Innovation may be conducted as it is unlikely in a real-life setting that all individuals, teams or organisations would possess variables that are perfectly aligned to Innovation. This theory specifies that all components are necessary for creativity and that generally, the higher the level of each of the components the higher the ultimate level of creativity (Amabile and Mueller 2008). Indeed Amabile herself suggests that "it will also be important to expand (her) methods to allow simultaneous exploration of the various elements of creativity specified in the componential theory, and how they might interact dynamically to form a creativity system" (Amabile and Mueller 2008, p. 59).

Harrington (1990)

Harrington (1990) defined creativity as part of an ecological system whereby "creativity does not reside in any single cognitive or personality process…does not happen at any particular place, and is not the product of any single individual" (p. 150). His theory suggests that the creative process, person and environment are linked in an ecology of creativity. This ecological approach elevates the importance of the habitat and conditions necessary for fostering the growth and maintenance of creative social systems. In his research Harrington had discovered that "many and perhaps most creative accomplishments in this world are neither the products of single individuals working in isolation nor the products of historical geniuses but are instead the products of several people working in intended or unintended collaboration" (Harrington 1990, p. 144). The main goal of his theory is to bring together the three lines of investigation: characteristics of creative processes, creative people and creative environments. He aims to connect the intrapsychic, interpersonal and social facets of human creativity in a coherent conceptual scheme. In addition, Harrington has included a development dimension to his ecological model of creativity as personal attitudes, strengths and skills are often developed over time (Harrington 1990). Creative people may be in situations or ecosystems that do not foster their creativity or they may be surrounded by people who do not encourage creative behaviour. Therefore, the impact of environmental factors is pertinent.

Harrington views people who make creative products as functioning within an ecosystem that allows and provides the essential ingredients for their creative activity. Creative processes place psychosocial demands on creatively active individuals and their ecosystems. Almost all forms of social creativity place demands on creative agents and ecosystems by requiring certain levels of knowledge, imagination, skills, physical resources, time, communication channels, and access to appropriate audiences. In order for the creative processes to flourish these psychosocial demands must be met. Harrington suggests that people may be in charge of selecting their environment, which he terms 'niche-picking'. In the case of Silicon Valley, engineers and entrepreneurs alike chose to re-locate or locate themselves in this area as it surrounded them with other creative individuals and also was an environment that encouraged and supported Innovations (Harrington, D, personal communication, 19 April 2013). As well as niche-picking, the ecosystem itself may place demands on a person. For example, organisations that require targets to be met may not give individuals the opportunity to be innovative. While Harrington's ecological view of creativity enhances the idea of interactions amongst the environment, processes and individuals, at this stage his research is theoretical. There has been no empirical evidence to support his model.

Sternberg and Lubart (1991)

As a means of understanding the nature of creativity, Sternberg and Lubart (1991) propose that six resources: intellectual processes, knowledge, intellectual styles, personality, motivation and the environmental context contribute to creativity. Sternberg and Lubart acknowledge that creativity is not about one singular thing, but a system of things (Sternberg 2012). Their investment theory of creativity suggests that creative people are ones who are willing and able to pursue ideas that are unknown but have growth potential. Once the idea has grown to its potential, the creative individual sells it while it is still high and moves on to the next new idea (Sternberg 2012). Although some dimensions of this model have been assessed, they do not sample all domains and have been on limited populations. Furthermore, these have only been studied on individuals and not groups. Results have indicated that high levels of creative-related skills, domain-relevant skills and motivation need to co-exist in the right environment to yield high levels of creative performance (Sternberg and Lubart 1995). In addition, it was found that there is some support for the benefits of buying low. Although there has been some evidence to support this model, it does not indicate what environment may hinder or assist creativity and what combination and interactions of creative-relevant skills, domain-relevant skills, motivation and environment can be conducive to creativity.

Woodman and Colleagues (1993)

Woodman and colleagues proposed an internationalist model of creativity which, at the individual level, asserts that creativity is the complex product of a person's knowledge, antecedent conditions, cognitive style and ability, personality factors, motivation, social influences and contextual influences (Woodman et al. 1993). Thus, a combination of Person, Process and Press leads to the birth of a product. This suggests that although a single facet of creativity may be measured, no single facet exists without relation to other facets of creativity (Batey 2012). Woodman's interactionalist model of creativity allows the cognitive, personality, and social psychology explanations of creativity to be combined into a single, unifying perspective. When used to look at organisational creativity, this model provided a theoretical framework that not only included process, product, person and situation, but allowed these to be addressed at both the individual, group and organisational levels. This model has been applied to both individual creativity (Woodman and Schoenfeldt 1989, 1990) as well as organisational creativity (Woodman et al. 1993). Although this model provides a solid theoretical underpinning of creativity, it has not been validated through research and it also does not provide any information pertaining to mediating variables.

Csikszentmihalyi (1996, 1999)

More recently, Csikszentmihalyi has proposed a systems theory that involves multiple factors and takes a broad view of the phenomenon of creativity. His view emphasises the ubiquitous role of Press (environment) among the Ps, and elaborates the nature of the creative person by detailing how individuals other than the creator contribute to the emergence of creativity (Kozbelt et al. 2010). He regarded creativity judgments as emerging from three interacting components: the domain, or body of knowledge that exists in a particular discipline at a particular time; the individual, who acquires the domain knowledge and produces variations on the existing knowledge; and the field, comprised of other experts and members of the discipline who decide which novelties produced by all of the individuals working in that discipline are worth preserving for the next generation (Csikszentmihalyi 1996). Csikszentmihalyi's (1988, p. 336) view de-emphasises intrapsychic processes and individual contributions, concentrating on collaborative creativity and societal conditions that can best foster creativity and Innovation: "we need to abandon the Ptolemaic view of creativity, in which the person is at the centre of everything, for a more Copernican model in which the person is part of a system of mutual influences and information". His view stresses that creativity is just as much a cultural and social event as it is psychological event (Csikszentmihalyi 1999). Csikszentmihalyi presents a sophisticated theoretical model for understanding creativity; however, it has not been supported by any empirical evidence.

Taggar (2002)

Taggar (2002) has adapted Amabile's model to incorporate a group's ability to utilize individual creative resources effectively in order to produce team creative output. This model is composed of four components that must converge for creativity to occur: domain-relevant skills, task motivation, creativity-relevant processes and team creativity-relevant processes. In his study of undergraduate business students, Taggar found that groups with creative members and high levels of creativity-relevant behaviours yield high group creativity (2002). In addition, in creative groups, team members engage in creativity-supporting behaviour establishing the right social environment (Taggar 2002). These results demonstrate the importance of individual aspects of creativity as well as a supportive environment for group creativity. Although these are promising results, Taggar highlights some concerns regarding priming of participants through the explicit use of the term creativity when measuring creativity. It would be useful to look at teams in a real life organisation that have worked together on tasks for an extended period of time. Thus, there is a need for more research investigating different factors that contribute to a real working team's creativity.

Pirola-Merlo and Mann (2004)

Pirola-Merlo and Mann (2004) propose a multilevel theoretical model which views team creativity as the simple aggregate of individual creativity. They acknowledge this model is meant as only one possible explanation of how creativity unfolds in teams over time and how this is influenced by the climate for creativity. The climate for creativity is seen as a team-level factor that emerges from shared perceptions of team members (Pirola-Merlo and Mann 2004). Pirola-Merlo and Mann completed research on real working Research and Development teams and found that creativity unfolds in teams over time and this is influenced by the climate for creativity. In addition, team creativity was related to organisational encouragement and support for Innovation was a significant predictor of team creativity. This study had mixed results with regards to whether averaged individual team member responses were a good predictor of team creativity. This study utilised self-ratings of creativity and Innovation as well as team leader ratings of creativity, Innovation and performance. However, this model did not look at the interactions amongst all possible aspects of climate and did not take into account other factors such as personality variables, social factors or processes.

Proposal for a New Model

The consequence of fragmentation in the study of creativity is an abundance of knowledge on single aspects of creativity, but a lack of understanding on how all aspects of creativity (Person, Process, Press and Product) interact in a real-life setting. While some models that take a more 'systems view' approach do exist, there is no predominant model that is used by researchers. In addition, while some models do take into account the 4Ps, they all place a different emphasis on each element, depending on the relevant level of creative magnitude (Kozbelt et al. 2010). The extant models presented provide a good starting point for investigating creativity and Innovation as well as constructing a systems framework. They provide some information with regards to which aspects of Person, Process, Press and Product should be included in a systems model of Innovation. However, more research needs to be conducted to determine how these aspects interact in real life settings, as without empirical evidence it is impossible to determine the strength, reliability and validity of such models.

The author of this paper proposes the following four criteria must be met to produce a realistic framework of Innovation. These criteria have been chosen as they ensure scientific rigour without being too constraining therefore resulting in a misrepresentative model of creativity in real life.

1. *Cumulative Science*

An integral part of cumulative science is ensuring that it contains significant samples, theory development and good thinking (Makel and Plucker 2014). Beghetto (2014) urges that researchers within the field of creativity need to spend sufficient time constructing and strengthening their theoretical work. Once a theory has been through ideational trial and error (Campbell 1960; Gibson and McGarvey 1937) and thought about in multiple ways and from multiple perspectives can a theory be empirically tested.

In addition, we need to replicate and test other existing theories rather than just making new ones (Makel 2014; Vartanian 2014). While replication, the duplication of research procedures, is generally thought of as a direct replication, conceptual replications may also be useful to substantiate whether the original findings are generalizable to other contexts (Makel 2014). Conceptual replication involves varying some part of the original procedure but following or testing the same concept or hypothesis. Replication studies within the field of creativity are a "paradigm-preserving contribution" (Makel 2014, p. 2) that do not alter the field, but rather helps to strengthen the knowledge that currently exists and so that the field is actually where it believes itself to be. In addition, by fine-tuning theories through replication, it may be possible to increase the explanatory power of a theory so that it can account for more phenomena than the original theory was intended to address (Vartanian 2014).

Empirical evidence is also essential for cumulative science as it provides both internal and external validity as well as reliability, and both are needed to determine if the results of an experiment and the conclusions drawn from the results are justified (Wilkinson 1999). Reliability refers to the likelihood that a study's finding will be replicated by different research with different participants, and the ability of observations to be repeated and verified by others is said to be the essence of the scientific method (American Psychological Association 2010). This is important as it suggests the results can be generalized and the information obtained can be used to understand many different situations. Internal validity is important as it allows us to determine whether the relationships among variables are genuine or due to other undetected factors. External validity shows the extent that findings apply to new settings.

This framework will also need to include all the necessary statistics to provide reliable evidence for its existence. The APA Task Force proposes that more extensive descriptions of data be provided to readers including means, standard deviations, sample sizes and effect sizes (both direction and size of effect): reporting and interpreting effect sizes in the context of previously reported effects is essential to good research. It enables readers to evaluate the stability of results across samples, designs and analyses (Wilkinson 1999). Therefore this research needs to aim to provide more information rather than just the results of a significance test and also convey information about the practical importance of the difference (effect size), quality of the research, reliability and validity of the measures, fidelity of the treatment and whether the results are replicable (Tabachnick and Fidell 2007).

Therefore, future research needs to collect, report and analyse data appropriately. Detailed information on the data collected, the sample and methodology need to be provided. In addition, all statistical analyses must be thoroughly reported.

2. *Domain-specific and domain-general*

Future research would need to combine both domain-specific and domain general aspects of creativity. When referring to creativity, the term 'domain-general' suggests that people creative in one area are creative in all areas, whereas 'domain-specific' implies people are only creative in specific areas (Silvia et al. 2009).

Baer and Kaufman (2005) propose an Amusement Park Theoretical (APT) Model of Creativity. They suggest there are initial requirements that must be present at some level for all creative work (domain general). Following this, there are general thematic areas in which someone could be creative (e.g. arts, science) and then specific domains (i.e. Biology, Chemistry). Lastly, there are micro-domains that represent specific tasks associated with each domain. Initially, a systems framework of creativity will need to begin domain specific, but with more research may eventually contain some domain general aspects. As Baer and Kaufman (2005) suggest, there is a "need for a theory that encompasses both the domain-general and domain-specific aspects of creativity". In order to accomplish this, a model must not make claims about domain-general aspects of the model until further evidence has been collected to support the claim. Therefore, it will need to be domain-specific, only apply in the context the data is collected from and results should not be generalised until enough data has been collected to be able to make generalisations.

3. *Importance of looking at interactions—not just aggregating scores*

Hennessey and Amabile call for a systems approach to the study of creativity. A new approach must consider the interactions of all aspects of creativity and how this affects the creative outcome (Hennessey and Amabile 2010; Montuori and Purser 1995). In addition, this suggests that simply aggregating scores may not be useful in understanding creativity; "creativity may be more than the simple sum of a person's attained level of functioning on each component. Partial compensation may occur, in which a strength on one component counteracts a weakness on another component, and interactions may also occur between components" (Sternberg and Lubart, in Taggar 2002, p. 327).

Therefore, research must endeavour to look at the interactions amongst aspects of creativity.

4. *Based on real-life functioning individuals, teams or organisations*

A majority of the research examining creativity has been conducted on students or groups formed for the purpose of the exercise. Data needs to be collected from real-life functioning individuals, teams or organisations. Peterson (2001) suggests that in order for results to be generalizable, replication of studies must be completed with nonstudent samples. Using real-life functioning samples, it is possible to gain a better understanding of how creativity comes about naturally rather than in contrived situations. This may help eliminate any possible variables that may influence the results and allow a more accurate understanding of creativity.

Looking Ahead

The consequence of fragmentation in the study of creativity is an abundance of knowledge on single aspects of creativity, but a lack of understanding on how all aspects of creativity (Person, Process, Press and Product) interact in a real-life setting.

While some notable systems-like approaches to the study of creativity do exist, more research needs to be conducted looking at the interactions amongst aspects of creativity. Research needs to be empirical in nature and utilise real-life functioning teams rather than contrived teams or those composed of student samples.

A new systems model will benefit from adopting the aspects already suggested in previous research and using these in addition to previous research to formulate a new framework. This framework should then be rigorously tested with real-life working populations and the interactions amongst aspects should be examined. To begin with, frameworks should remain domain-specific, and only once enough data has been collected can the framework be extrapolated to greater populations.

Our knowledge of the phenomenon that is creativity could be improved by a framework respecting these four criteria. A framework based on evidence in real-life setting ensures that scientific rigour is maintained. By respecting the four criteria specified in this chapter, we may arrive at a more realistic representation of creativity and only then may we begin to investigate how to enhance and utilise creativity.

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Creative Processes: Art, Design and Science

Marion Botella and Todd Lubart

Introduction

Since Wallas (1926), many authors have tried to determine the stages describing the creative process (Busse and Mansfield 1980; Osborn 1963; Treffinger 1995). These conceptions concern creativity in general including art, science, design or music; other conceptions concern specific creativity only for one domain. But what is the status of process-related differences and similarities between creative fields of endeavor? In this chapter, all the models in these domains will not be presented but three specific models will be described as examples of the creative process in art, design and science, suggesting the differences between the creative fields of endeavor (for a review on the creative process, see Lubart 2001).

The Creative Artistic Process

Mace and Ward (2002) proposed a specific model of the artistic process based on interviews with professional art students; it is a dynamic model in four stages. The artistic process begins with the *conception* of the artistic work. The work is introduced by an idea or a more or less vague impression. The second stage corresponds to the *development* of the idea. Art students structure, complete and restructure the idea. Also, they identify the work development possibilities according to their ideas and feelings. Furthermore, art students multiply the implicit and explicit decisions

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by observing their work. This evaluation incites them to question the ideas, expressions, metaphors, analogies that they wish to use and those that they prefer to abandon or to put aside for future work. The third stage is the *realization* of the idea in which art students transform the idea into a physical entity. The fourth and last stage is the *finalization* and the resolution of the artistic work. The art students evaluate the production: they can choose to end the production, to pursue it, to abandon it, to postpone it, to store it or to destroy it. If the art students consider that the production is a success and satisfying, they can choose to expose it.

Whatever is the result of the artwork, art students enrich constantly their experience and their knowledge. Their knowledge is the result of a dynamic and perpetual interaction with artistic practice. The art students add and refine their skills, techniques and knowledge. Also, they sharpen their interests and their artistic personality. During a work, new ideas can appear and be reused later. Thus, Mace and Ward (2002) did not propose a linear but a dynamic and iterative model as far as the artistic process is under the constant influence of multiple factors, including the development of other productions.

The Creative Design Process

Based on the function (task analysis), behavior (conceptual design) and structure (embodiment design) work by Gero (2004), Howard et al. (2008) reviewed the literature on the design process and the creative process, and proposed a new description of the creative design process with eight stages. The first stage is *formulation* in which design students adapt constraints on expected behavior. Then, design students make a *synthesis* structuring the expected behavior into a potential solution. The third stage corresponds to the *analysis* of the solution during which a behavior is derived from the potential structure. Design students continue by *evaluating* the behavior that derives from the structure in terms of the expected behavior. Then, *documentation* allows describing the design. The last stages correspond to three different types of *reformulation*. If the behavior produced is unsatisfactory, design students change the structure of the design (stage 6), the behavior (stage 7) or the function (stage 8). The main interest of this model is that Howard and his colleagues proposed a dynamic model in which feedback is possible between stages.

The Creative Scientific-Inventive Process

Based on research with science-engineering students and engineers, Shaw (1989, 1994) proposed a cyclic and dynamic model in five stages. In this first phase, called *immersion*, the problem is posed. Then *incubation* follows with unconscious associations of ideas in which solutions begin to form. Shaw considers that these two phases are not independent but mixed. Next, *illumination* or *insight* occurs and ideas become conscious and accessible. The engineers *explain* their idea and realize a *creative synthesis* by producing it. These two stages are also mixed.

The model proposed here is dynamic; at each stage, it is possible to return to the previous stage. Furthermore, this model is circular. The *validation* of the production leads to a new creative process. According to Shaw, there are two kinds of validation: personal validation and collective validation. The personal validation consists of estimating the work and of using the experience acquired during the process to generate a new creative process whereas collective validation concerns the evaluation of the production by peers, public or critics. This validation can lead to a new process only if the creator accepts the evaluation; the comments of the public must be recognized to engage a new creative process.

Shaw describes also affects involved in mechanisms of thinking. The first two phases (immersion and incubation) involve a pole of positive affect and a pole of negative affect. The conception of affect is based on the notion of maximizing the creator's concentration, interest and pleasure ("*Flow*", a concept developed by Csikszentmihalyi 1990). The positive pole corresponds to a state of obsession, fussiness, strain and interest. The negative flow corresponds to a need "to unwind", a work overload, a stress or high blood pressure. These two orientations bring different illuminations. Negative illumination is based, among others, on frustration, fear, anger and aggressiveness whereas positive illumination corresponds to euphoria, a happy state, enchantment, good feelings and a strong level of pleasure. In the last stages (explanation and creative synthesis), both poles are again involved. The positive aspect is defined by a state of power, exuberance and frenzy whereas the negative pole presents a state of resignation, anxiety, fatigue and invasion. The effect of mood on creativity is too complex to be described in this chapter (for more detail see recent meta-analysis as Baas et al. 2008 or Davis 2009).

Overview and Aims

Considering the relative lack of consensus observed between these three models on the number of stages and the transition between stages, the objective of this chapter is to describe the creative processes in Art, Science and Design respecting an ecological approach by observing the process in its' natural context (in real-life settings of students who create work as part of their master program courses).

Method

Participants

The global sample consisted of three groups of students: 27 undergraduate art students in their third year at a French art university (21 females, 6 males, $m = 22.75$ years, $sd = 1.16$ years, age range: 21–25 years), 27 design students in their second year at a design school (18 females, 9 males, $m = 23.18$ years, $sd = 4.79$ years, age range: 20–45 years), and 27 engineering science students in their fifth year at an engineering school (4 females, 23 males). Within each group, all students attended the same university classes.

Material

Based on the work of Glaveanu et al. (2013), who interviewed different experts in these three domains and also in music and script writing, a booklet was constructed. This booklet consisted of a structured self-report focused on stages of the creative process in which participants indicated their weekly progress. Thirteen stages of the creative process were considered in the booklet: definition of the problem, reflection, documentation, consideration of constraints, insight, associative thinking, divergent thinking, convergent thinking, the benefit from chance, implementation, finalization, judgement, and taking a break. All these stages were presented with a short definition (see Table 1) based on the interviews of Glaveanu et al. (2013). At each evaluation episode, students checked whether they had engaged each stage during their project work.

Table 1 Description of the thirteen stages of the creative process used in the booklet material based on Glaveanu et al. (2013)

Stages	Description
Definition of the problem	To focus, to explore the theme, the aims, need to create, need to express, challenge
Reflection	To ask, to interact with the work, understand
Documentation	To capture and search for information, to be attentive, to always have the project in mind, to store information, to accumulate, to be impregnated, receptive, available, to observe, to show sensitivity and awareness
Consideration of constraints	To define constraints, to identify a customer's request, to set constraints for oneself and define one's rules and freedom
Insight	To have an idea, to experience the emergence, the sudden appearance of an idea
Associative thinking	Resonance, to play with forms, materials and significations, imagination, daydream, analogy
Divergent thinking	To try, modify, manipulate, and test
Convergent thinking	To crystallize, to make a prototype, to visualize and structure, to establish order, sequence, to control and organize
The benefit of chance	The luck of the environment, aleatory processes, to be open to chance, to take a walk, to accept accidents and chaos
Implementation	To transpose, make, illustrate, produce, compose, give shape, apply
Finalization	To edit, develop, complete, justify, explain one's work, exhibit
Judgement	To be self-critical, to stand back, to analyze, check the quality of a result
Taking a break	To rest, to digest an idea, to let time pass, to do something else

Procedure

Each group of students completed the booklet at different moments while creating a production for one of their university or school classes.

Art students had one semester—12 weeks—to create freely an art work. At the end of each week, students had to complete a page of the booklet on the stage(s) of the creative process they engaged during that session. Most students completed the booklet in class but some of them preferred to complete it at home.

Design students had 7 weeks to create individually a graphic poster on a given topic: answering a brief about an event called “Green-Box”, promoting an ecological approach to packaging. They completed the booklet at least on average 10 times. They used the booklet typically at the design school, during classes, but had also the option of completing it at home.

Science-engineering students had 10 sessions distributed over 8 weeks. They were asked to propose six different layouts for a functional kitchen located in a campervan. From these, two were short-term implementation projects (<1 year), two were medium-term and two were long-term projects (>10 years). The layouts had to respect a set of technical constraints, defined in advance. Students completed the booklet after each session.

Results

First, the frequency of each stage of the creative process was calculated for the three domains (see Table 2) and a correspondence analysis was conducted to describe and compare the frequently-cited stages in each domain. No important differences were observed between creative fields for the stages of definition of the problem, reflection, associative thinking and judgement. However, art students cited more frequently than science-engineering students the stages of implementation and breaks whereas the opposite was observed for the stages of insight and associative thinking. Design students cited more frequently than the two other groups the stages of documentation and finalization and design students cited more frequently divergent thinking than engineering students. Finally, science-engineering students reported the stages of consideration of constraints and benefit from chance than design students.

Second, analyses of the transitions between process stages, by domain, and across domains show specific patterns underlying creative work. This quantitative analysis was conducted on the 13 stages of the booklet. In each domain, a transition table was constructed summing the number of times that one stage was followed by another stage. The participants were not aware about their transitions because they were calculated after the completion of the booklet. For example, if at time1, a participant indicated the stage of definition and, at time2, he or she indicated the stages of reflection and documentation, we count 1 transition from

Table 2 Frequency of the stages and resume of the transitions between stages of the creative processes for art, design and scientific-invention

	Art		Design		Science-engineering	
	Frequency (%)	Transitions	Frequency (%)	Transitions	Frequency (%)	Transitions
Definition of the problem	32	**Documentation**, *insight*, chance	28	**Documentation**, *insight*, associative and divergent thinking	23	Reflection, **documentation**, constraints
Reflection	44	**Definition**, judgement	43	**Definition**, *documentation*, insight	34	**Definition**, *documentation*, constraints
Documentation	33	**Definition**, divergent thinking	52	**Definition**, *reflection*, insight, associative thinking	34	**Definition**, *reflection*, constraints
Consideration of constraints	34	Finalization	28	Associative and convergent thinking	49	Definition, reflection, documentation, insight
Insight	28	Definition, *documentation*, *chance*	36	Reflection, *documentation*, constraints, *chance*	44	Associative thinking, judgement
Associative thinking	42	Constraints, *finalization*	47	Definition, Documentation	49	Convergent thinking, implementation, *finalization*
Divergent thinking	38	Reflection	47		29	Implementation, judgement,
Convergent thinking	34	Constraints, **finalization**, *judgement*	40	Implementation, **finalization**, *judgement*	41	**Finalization**, break
Benefit from chance	17	Constraints	22	*Implementation*	36	Associative thinking, *implementation*, finalization
Implementation	23	*Finalization*, *break*	17	Definition, *finalization*, judgement, *break*	26	Associative, divergent and convergent thinking, chance
Finalization	55	*Judgement*, convergent thinking	47	Implementation, *judgement*	33	Associative thinking, chance
Judgement	18	Chance, *Finalization*	31	Convergent thinking, *finalization*, break	19	Implementation
Taking breaks	40	Implementation	35	Constraints	17	Chance

Note In **bold**, transitions similar in all domains; in *italics*, transitions similar in two domains; in normal text, transitions specific to each domain
For example, the stage of definition is cited globally 32 % of time by art students during the task, 28 % by design students and 23 % by science-engineering students. This stage of definition leads to the stage of **documentation** (in bold) across creative fields. It leads to *insight* (in italics) in Art and Design whereas it leads to chance (in normal text) only in Art. This transition is specific to art students

definition to reflection and 1 transition from definition to documentation. All the transitions between all the stages are possible but some of them are more frequent than others. Using this transition table, a correspondence analysis was conducted based on the frequency of transitions to retain only the main transitions in each domain. Graphic resumes of these analyses are presented in Fig. 1 (common transitions between the creative fields of endeavor) and Fig. 2 (specific transitions in art, design and scientific-invention).

Results reveal that the "*definition* of the problem" stage is always followed by documentation. Additionally, for art and design students, the definition is often followed by insight. More specifically, art students reported following chance after the definition stage, design students report following associative and divergent

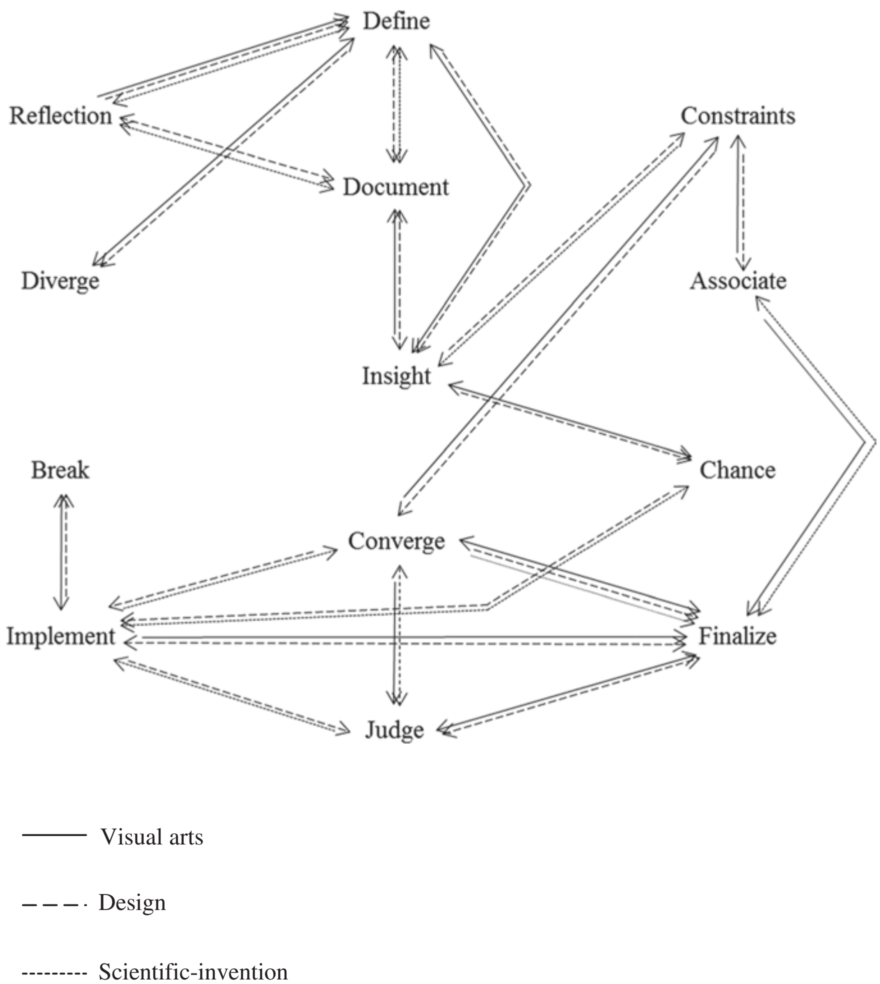

Fig. 1 Representation of common transitions between creative process in visual art, design and scientific-invention

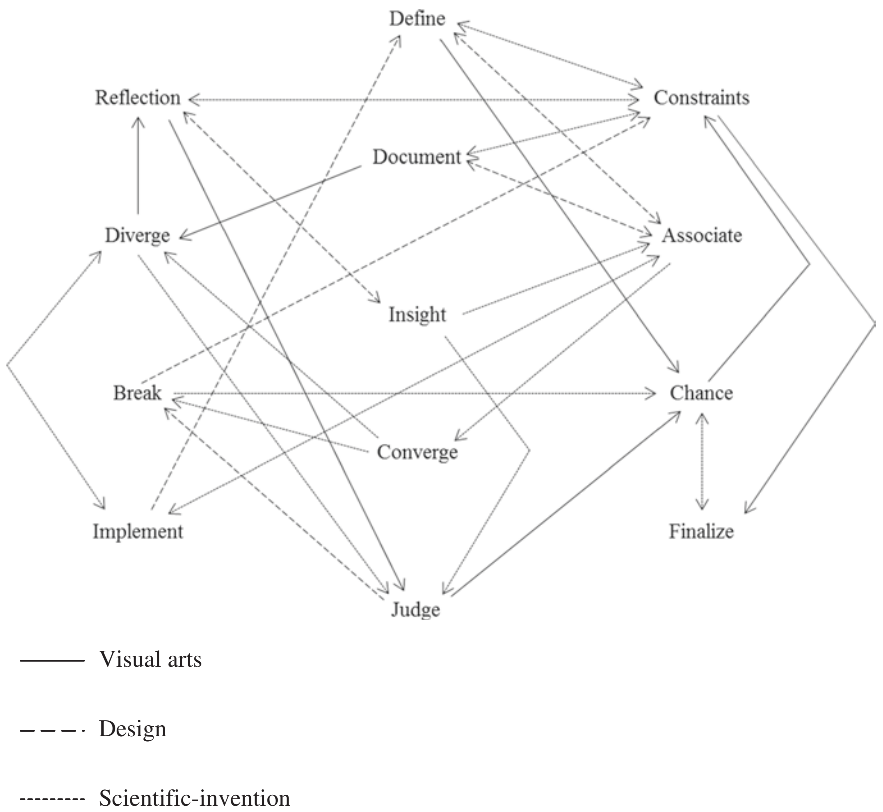

Fig. 2 Representation of specific transitions of creative process in visual art, design and scientific-invention

thinking whereas science-engineering students report following reflection and consideration of constraints. *Reflection* is followed by definition in all the domains whereas design and science-engineering students proceed to documentation. More specifically, art students continue with judgement, design students continue with insight, and science-engineering students continue with consideration of the constraints. In all domains, *documentation* leads back to definition. Another similarity is observed between Design and Science for documentation which leads to reflection. However, dissimilarities are observed between the fields when art students move from documentation to divergent thinking, design students move to insight and associative thinking, whereas science-engineering students are still considering constraints. The stage of *consideration of the constraints* is very specific for each domain: in Art, it tends to be followed by finalization; in Design, it tends to be followed by associative and convergent thinking; and in Science-engineering, it tends to be followed by definition, reflection, documentation, and insight. The stage of *insight* is followed, for art and design students, by documentation and chance.

Art students continue this stage by defining the problem, design students continue by the stages of reflection and consideration of constraints whereas science-engineering students continue by associative thinking and judgement. *Associative thinking* leads art and science-engineering students to finalize their production. Art students continue also by consideration of constraints, design students continue by definition and documentation, and science-engineering students continue in convergent thinking and implementation of their production. The *divergent thinking* stage is followed by different stages according to the domain: in Art, it tends to be followed by reflection; in Design, it is not followed by any specific stage; and in Science, it tends to be followed by judgement and implementation. The transition from *convergent thinking* to finalization is common to all creative domains. For art and design students, convergent thinking is often followed by judgement. Additionally, differences are observed for this stage in which art students continue to the consideration of constraints, design students continue to implementation, and science-engineering students go on to a break. The stage of *benefit from chance* leads design students and science-engineering students to implement their production whereas it takes art students back to the consideration of the constraints. Moreover, science-engineering students continue with associative thinking and finalization. The *implementation* stage leads to finalization and breaks in Art and Design. Only science-engineering students are different with implementation being followed by associative, divergent and convergent thinking, and benefit from chance. Moreover, design students continue by definition and judgement. *Finalization* is followed typically by judgement for art students and design students only. However, this stage is followed by various stages according to the creative domain: in Art, it leads to convergent thinking; in Design, it leads to implementation; and in Science, it leads to associative thinking and benefiting of chance. The transition from *judgement* is common only for art students and design students leading to finalization whereas art students go alone to benefit from chance and design students go alone to convergent thinking and taking a break. Science-engineering students continue from the judgement stage to implementation. Finally, *taking a break* tends to lead to different stages in each domain: break is followed by implementation in Art; by consideration of constraints in Design; and by benefiting from chance in Science.

In a last part of the results, differences were calculated on the transition tables from each domain. Observed differences indicate that more stages lead art students to *reflection* than science-engineering students. Especially, the transition from finalization to reflection is more frequent in Art than in other domains. Design students pass more frequently than science-engineering students from insight, associative thinking, benefiting from chance and judgement to *documentation*. In science, the stage of *consideration of constraints* follows less the stage of definition than in other domains. The transition from benefit from chance to consideration of constraints is more frequently cited by art students. Design students pass less from finalization to consideration of constraints than those in other creative domains. Also, they show less transition from implementation and finalization to *insight* than science-engineering students. Additionally, design students cited less *associative thinking* after finalization than other groups. However, various stages lead them to *divergent thinking* (definition, insight, associative thinking and judgement). Science-engineering students continue more by *convergent thinking* than others after divergent thinking and more than art students only after benefiting from chance, judgement and taking a break. Moreover, science-engineering students continue more often to *benefit from chance* than others after associative and divergent thinking, and finalization, and more than design students only after convergent thinking, implementation and judgement. In contrary, science-engineering students pursue less *implementation* than both art and design students after reflection, documentation and consideration of constraints and less than art students only after definition. Design students continue particularly in this stage of implementation following finalization. In Art, transitions to *finalization* are frequent from consideration of constraints, insight, associative, divergent and convergent thinking, benefit from chance and implementation. Finally, science-engineering students pursue less the *judgement* stage after divergent thinking compared to design students, and science-engineering students pursue less the *break* stage after definition, reflection and documentation compared to art and design students.

Discussion

This study revealed that the subprocesses involved in creative work are sequenced in somewhat specific ways based on the domain of endeavor. There are similarities and dissimilarities between art, design, and science-engineering and therefore partial overlaps between domains. For example, one dissimilarity is that design and science students begin by analyzing constraints whereas graphic art students are particularly influenced by chance events. This specificity of art students supports the creative artistic process model of Mace and Ward (2002) for whom artistic work begins by more or less vague impressions. According to our findings, the impression guiding the artistic process could be discovered by chance. During this stage, art students seem more surprised than in other domains. Then, as found by Mace and Ward, art students developed their idea, switching between divergent thinking, definition, documentation, reflection, insight, judgement and chance. Then, art students implement their art work and finalize it. At this point, it is important to note the cyclic characteristic of the artistic creative process. Finalization can lead back to the judgement stage.

Contrary to the artistic creative process, in which the consideration of constraints appears only when finalizing the work, in the Design field the constraints are central to the process emerging from the definition of the problem and leading to many stages (insight, reflection, judgement, implementation, chance, and convergent thinking). The first stage described by Howard et al. (2008) of formulation in which design students interpret the constraints in term of expected behavior is found in the present study in the transition between constraints and reflection stages.

The synthesis and analysis stages corresponding to the transformation of the expected behavior into potential structure appears in the chance and convergent thinking stages. The last stages formulated by Howard and colleagues involve different types of reformulation in which design students change the structure, the behavior or the function of the design because they evaluated that the behavior produced is unsatisfactory. These reformulations are viewed in the present study as the transition between implementation, convergent thinking, chance, breaks, judgement and finalization. Design students judged the production implemented unsatisfactory, took breaks and profited from chance, converged, returned to implementation, and, if the behavior produced was evaluated finally as satisfying, design students transited to finalization. Moreover, it is interesting to note that these stages are linked to chance and breaks as a way to think outside the box. Maybe design students used the breaks to discuss with their colleagues on their work. Nemiro's study (2002) with interviews of individuals in virtual teams highlights the social factors involved in design creative process: the wheel approach in which one individual serves as a key to communicate with other members of the group; the modular approaches in which the work is distributed among the group and, when the work is completed, the group works together to finalize and implement; and the iterative approach in which the group works a little together, and then a little alone, and then a little together and so on. In the present study, even if the creative process was individual, considering the constraints of the design task, we could suppose than a modular approach have been used by some design students.

Finally, the scientific-engineering creative process differs from the art and design process. The immersion and incubation stages described by Shaw (1994) correspond, in the present study, to the interaction between reflection, definition, documentation and constraints leading to insight. The explanation stage described by Shaw corresponds to the chain of associative thinking—convergent thinking—divergent thinking and judgement. The process ends with creative synthesis called implementation and finalization in the present study. As in the Design domain, chance and breaks tend to be reported at the end of the process whereas in Art, they are present in the beginning. Moreover, science-engineering students declared less social interactions during their process except for the break stage for which no differences are observed between groups for environmental factors.

Conclusion

This study was limited by the number of participants in each group and especially by the specificity of each task: the differences in the creative processes depend on the students' background (art, design and science) but could also depend on the nature of the problem and the timeline selected for each domain. The participants in each of the three domains were asked to solve a different kind of problem with different levels of constraints (less constrained for art students and more constrained for science students). The level of constraints is inseparable from the creative domain explaining the differences observed: design and science students begin by analyzing constraints whereas graphic art students are particularly influenced by chance events. Additionally, the time is different is each domain. Maybe an interaction exists between the nature of the task and the timeline. At the point, it is difficult to separate all the aspects. However, the originality of the present work was to investigate the creative processes in three different domains with the same process-tracing material using ecological observations. The generalization of such results is limited but this study is a starting point to compare quantitatively creative processes in various fields. It seems important to follow the research on creative processes in various fields simultaneously, with a common method, to improve the understanding on generalities and specificities of each creative process. For example, the Cognitive Processes Associated with Creativity scale (Miller 2009) could be used to assess brainstorming, metaphorical and analogical thinking, perspective-taking, imagery, incubation, and flow in many fields. If the processes are studies with different methods in each domain, it will be harder to see the general pattern across creative fields.

The originality of the material—the booklet—was based on interviews with experts from all domains. The material is easily adaptable to other creative fields and can be used to compare various domains. Additionally, this study proposes a graphic representation (as illustrate in Figs. 1 and 2) of a real process, observed in its natural context of emergence. Finally, a new vision of the creative processes, across creative fields, is offered by exploring the transitions between the stages and not only describing the stages of the creative process as well as a new methodology to investigate it.

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Distributing Creativity: Three Thought Experiments

Vlad Petre Glăveanu

The topic of creativity presents scientific inquiry with a paradox. On the one hand, the aim of a scientific investigation of this phenomenon is often to describe and explain it, ultimately trying to predict when and how it will be expressed. However, by its very nature, creativity relates to the unexpected, to the production of 'useful novelties' that often surprise creators themselves, as well as their audiences. Moreover, while creative action can, at first at least, generate unfamiliarity, even resistance, it is also part and parcel of our everyday life and all the small adjustments and transformations we initiate and undergo as we navigate our social and material environment. Adding to this the fact that we live in a day and age in which creativity is widely regarded as a value (Mason 2003), leading to positive personal and societal changes, legitimises efforts to understand and foster its dynamic. Under these circumstances, both lay people and scientists, particularly psychologists, are struggling to make sense of creativity and creative people, to explain their processes and products, and study their environment (see the 4 Ps typology; Rhodes 1961).

In order to demystify creative experience and construct models of the creative process we need first to 'locate' creativity, to be able to identify it and isolate its expression or outcomes in ways that facilitate analysis and measurement. If what we call creativity is in fact an 'objective' feature of a person or a product, than we have a better chance of scrutinising that individual or that product in order to understand what makes them different from others. Knowing what creativity is goes thus very often hand in hand with individualising it (for a critique of this tendency see Amabile 1996). Explaining why some persons are more creative than others requires further analytical reductions leading us to the study of personality structures, cognitive styles or brain functioning. And this process of essentialising

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creativity (i.e., considering it a stable, measurable quality or 'essence' of certain people or things) is not only reflected by scientific investigations but describes also much of everyday thinking about and societal discourses regarding what creativity is. It suffices to turn on the television or read the news and we will find at least a few examples of what can be called the *centric perspective*—the view that creative expression originates *inside* the individual and, in this sense, the *individual mind* is the 'centre' of creativity.

In opposition to this localised, centric way of considering creative work, I will develop in this chapter an alternative view—*the paradigm of distributed creativity* (see Glăveanu 2014a). This perspective challenges the notion of a 'centre' of creativity and considers creative action distributed within relationships between people, objects, and across time. As such, it builds on existing work within the field of distributed cognition (Hutchins 2000), on sociocultural scholarship (e.g., Vygotsky 1991), systemic models (Csikszentmihalyi 1998; Gruber 2005), and the social psychology of creativity (Amabile 1990; Hennessey 2003). While it might seem at first sight that advancing the notion of distributing creativity means dissolving creativity within ever-changing relations and interactions and losing our capacity to study this phenomenon scientifically, I will argue that, on the contrary, such a paradigm shift furthers our understanding of creative phenomena as psycho-socio-material processes (Glăveanu 2011). By paying attention to the multiple ways in which creativity connects persons with their environment and culture I am not denying a 'centre' (or agent) of creative action but conceptualise this centre as *multiple, dynamic, and relational in nature*. But, at the same time, it is important to acknowledge the fact that there are many obstacles to developing such a new understanding. The chapter opens with a brief discussion of why centric models have such a strong hold on creativity theory and then argues, using three thought experiments, why creativity is necessarily a distributed phenomenon that engages sociality, materiality and temporality in its unfolding. The chapter will conclude with a reflection on the meaning and role of distribution in the case of creativity and relate it to broader questions about individuals, society, and culture.

The Appeal of Centric Models of Creativity

There are many reasons why centric views of creativity dominate theory and everyday thinking and they can be grouped broadly under three main categories: psychological, societal, and scientific. In this section I will consider why it is hard to construct creativity models that don't focus on the individual mind as a privileged locus of creative production. The next section will show that a paradigmatic shift towards distributed or relational perspectives is not altogether impossible, even more, that it is a necessary step towards advancing our understanding of this phenomenon.

One way of explaining why we focus so much on the creativity of individuals—particularly highly visible creators or geniuses—is that it is literally hard to think otherwise. Previous literature on human mental functioning as driven by the need to save cognitive energy (hence the metaphor of the 'cognitive miser'; Fiske and Taylor 1991), suggests that people are inclined to use heuristics that help them adapt to their environment without necessarily becoming reflective about it, at least most of the time. This generates what cognitive science refers to as biases or tendencies to systematically favour one type of information over others. To take a concrete example, the fundamental attribution error (Ross 1977) reflects a general tendency, especially in Western contexts, to attribute the cause of events internally or dispositionally instead of formulating external or situational attributions. For instance, when someone bumps into us on the street we are most probably inclined to find the person rude or careless (internal attribution based on personality traits) instead of thinking what might have made the person be in a hurry in that particular moment (external attribution, for example rushing to the hospital). In other words, when learning about the world we live in, it is much more economical to assume that it is an orderly and predictable universe in which things have an 'essence' or set of stable characteristics. In this way, we are able to adapt to the environment more successfully because our reactions to it (people or events) are fast, particularly in familiar situations. But of course this energy-saving drive can also put the person in trouble in cases when the usual assumptions don't work anymore and, especially, when confronted with new circumstances.

Creative acts and outcomes are the ones that usually challenge our presuppositions and familiar ways of thinking and they do so by confronting us with the unexpected. More than this, it is common for creative processes to be unknown and unpredictable. As such, it becomes even harder to derive causal explanations that would require a lot of thinking and for which we would spend a lot of time and energy. It is indeed much easier to assume that the origin of creative action is 'inside' the individual and that it expresses who the person really 'is', rather than ponder on the various life circumstances that led to the creator being who he or she 'is' (for an extensive discussion of creativity and attribution theory see Kasof 1999). The tendency to simplify reality doesn't stop to human action but, as Heider (1944) showed from early on, marks the way we think about the natural world in general. An example of this centralised mindset is represented by the assumption that a flock of migrating birds has a leader and that is the bird flying first in the V formation (Saywer 2006). Scientific evidence contradicts this easy conclusion and yet this doesn't stop us from 'reading' the world around us in terms of organised structures and individuals who act within them based on inner drives, talents or dispositions.

This type of bias is supported also by societal practices for recognising creativity. From early on we get to learn the history of the world we live in as shaped by the actions and inventions of 'great men' (see the He-paradigm; Glăveanu 2010) and celebrate their genius and leadership. The singularity of creative people in history is emphasised by the fact that awards in domains such as science and art are usually given to individuals rather than teams (with a few more exceptions in recent decades). Copyright laws are also based on the assumption that there is an 'author' to any cultural product, this author can be identified and his or her rights need to be protected. Just as in the case of psychological tendencies, this form of organising societal recognition has its own socio-economic logic and it seemingly helps us be more efficient as a collective. For instance, it would be much harder to build statues or monuments for groups rather than individuals and thus engage with questions of who contributed to a certain creative outcome and how (which would require a model of distributed creativity we don't typically have or use). Finally, these societal arguments can also hide a much more problematic reality whenever the creativity of certain people or groups is not recognised for ideological or political reasons and systematically entire segments of the population are being marginalised or even excluded from creative or cultural production, despite their involvement and efforts (see, for example, the history of women's contributions to science and art).

Last but not least, there is something about the way in which science, particularly modern psychological science, is constructed that prevents us from abandoning a centric model of creativity. Although its early beginnings as a discipline were marked by a much stronger recognition of the socio-cultural making of the human mind (e.g., folk psychology; see Wundt 1927), particularly with the rise of behaviourism and cognitivism, the unit of analysis got restricted to the behaviour or mental processes of isolated individuals, respectively. This focus was not only very much in line with the individualism of Western societies (Farr 1996) but also served many 'scientific' purposes. On the one hand, it solved psychology's quarrels with neighbouring disciplines such as sociology or anthropology by giving it a clearly demarcated object of study: the person's psychological functions and processes. On the other, it made the discipline more 'scientific' by claiming that psychological functions and processes can be measured. This coincided with the emergence of psychometrics and its ethos of quantifying human behaviour, something that also contributed the development of the psychology of creativity (Plucker and Renzulli 1999). Both in the field of creativity studies and in psychology at large, quantification and measurement are much simpler when performed individually (studying social interaction is very difficult and often falls back on understanding individual action within a group context). The 'noise' of the social needed to be excluded from creativity research in order to create more parsimonious models (Runco 1999), frameworks that tell us something more 'objective' about creativity rather than leaving it at the mercy of changing social circumstances. Centric models thus flourished in this new field of study at the expense of more systemic and distributed perspectives (Amabile 1996; Hennessey 2003; Glăveanu 2010).

'Breaking' the Centre: Three Thought Experiments

Despite the psychological, societal and scientific considerations above, adopting centric views of creativity remains a choice and is by no means unavoidable. This is demonstrated by the growing literature in the psychology of creativity dealing with collaborative creative action (John-Steiner 1992), group creativity (Paulus and Nijstad 2003), historiometrical research (Simonton 1999), co-creation (Potts et al. 2008), and systemic models (Csikszentmihalyi 1998). Socio-cultural theoretical perspectives, initially applied to developmental issues (see Vygotkian-inspired scholarship; Moran and John-Steiner 2003), are gaining momentum and cultural psychology is currently used as a platform for rethinking creativity and the creative person (see Glăveanu et al. 2014). This paradigmatic shift, from centric to distributed frameworks of the phenomenon is more radical and influential than initially expected as it both builds on and contributes to a reconceptualisation of the human mind, of society, and the role and agency of individuals and groups within it.

What does a new, distributed perspective entail?

1. *The interdependence between self and other in creative action*. Centric models of creativity are not only based on an almost exclusive emphasis on the self (creator) as the locus of creative production, but they also implicitly promote a sharp distinction between self and other, between creators and their collaborators, critics, and audiences in general. The process of creativity is situated within the mind of one person and although its expression often requires the other, at least as someone who sees and evaluates the creative product, this social phase is not considered the essence of what it means to create. Creating, for centric models, is associated mainly with getting original and useful ideas and this defines creative people. On the contrary, cultural psychology starts from the premise of the interdependence between self and culture, between Ego and Alter (Shweder 1990; Marková 2003). Overcoming the Cartesian split located at the heart of mainstream theorising in psychology, this approach focuses on continuity, through interaction and communication, between people and their social and material world. The human mind is not contained by the brain or even the body, it extends into the world of others through action, including creative action. Creativity, in this paradigm, designates precisely a form of relationship between self and environment, a quality of the encounter between self and others leading to the transformation of both.
2. *Creativity is not a thing but a relationship*. What derives from the above is that, in a distributed model, we can no longer think about creativity as a stable, objective quality embedded within people or things. The psychometric drive of testing large numbers of people, individually, and offering them creativity scores that are considered to reflect something more or less 'stable' about their creative potential (at least within a short timespan) is not supported by this perspective. If we adopt relational ways of looking at creativity (see also Glăveanu 2012a) then we must consider it fundamentally context-dependent. To act creatively means to relate to the world in a new manner in ways that engage both self and world as co-participants to the creative act. Unlike the ethos of scientific measurement to reify phenomena and make them static, this perspective acknowledges the dynamic, transformative nature of creativity and, as such, brings to the fore collaboration and participative action rather than stable individual processes.

3. *People and culture as becoming rather than being*. Theories of creativity have a lot to do with how we conceptualise not only the individual or the mind but also society and culture. For a long time our view of creativity placed great creators in opposition to the society they lived in and the conformist tendencies of culture. Geniuses are typically defined by this struggle, by their defiance in the face of oppressive people and institutions. Such a perspective operates with the implicit assumption that human society is characterised by stability and resistance to change and it is the role of a few 'chosen' individuals to radically transform it. In a similar vein, cultural systems are represented by rules and scripts that regulate our expectations and make social life predictable. The normative, stable aspects of society and culture dominate many early models of creativity (see Arieti 1976). The distributed paradigm challenges this view by pointing to the fact that socio-cultural systems are by definition open and flexible. A static perspective on socio-cultural systems not only excludes the possibility of development but also underestimates the constant changes that make living together in human communities possible. Creativity is not situated outside of society and culture but right at its core (see Glăveanu 2014b), and this pushes us to rethink social reality not in terms of how it 'is' but how it 'becomes'.

The three premises above are fundamental for establishing and operating with a distributed model of creativity. They are also hard to accept or integrate within current centric frameworks because they question some fundamental assertions regarding the stability, boundedness and 'centrality' of the individual mind. And yet, what I will try to demonstrate below is that thinking of creativity in centric ways is not only problematic but unfeasible and ending in paradox. To do this, I will not conduct research in the classic sense but use a much older method: the thought experiment. With documented origins in Greek dialogues (see Plato's cave allegory in The Republic 1987), thought experiments propose imaginary scenarios which are often unlikely or even impossible in the real world but, due to their implications, reveal something essential about how the world 'works'. By formulating simple yet extreme situations, they push us to make explicit our assumptions (in this case about creativity as a centric process) and consider possible alternatives (i.e., the intrinsic distribution of creative action). As 'what-if' scenarios, they are also an interesting example of creativity (Craft 2005) since a thought experiment tends to break old ways of thinking and can lead to unexpected conclusions. In what follows, I will describe and discuss three such hypothetical situations, each conceived to 'test' (conceptually, not empirically) one of the three premises presented in this section. While my aim here is not to offer irrefutable proof regarding the distributed nature of creativity (this would require engaging as well with empirical evidence), I do hope these thought exercises are able to question easy assumptions about creativity and open the door to new understandings.

The Deserted Island

Imagine a person living alone on a deserted island. Since the conditions of living on this island are so harsh and the person is completely isolated from other people, he or she needs to constantly improvise in order to survive within this difficult environment. One of the only sources of meat on the island is fish but fishing in the waters around the island is very dangerous. One day this person discovers a new, less hazardous and more effective way of catching fish. This method doesn't use any of the conventional means for fishing. Moreover, there is nobody else on the island either to help the person by offering an example or to appreciate this new fishing method. Can we call the action of fishing in this new way creative?

This imaginary situation resonates widely with familiar stories about people who, by accident, become trapped on lands far away from civilisation (a classic example being Defoe's Robinson Crusoe). And yet the question of creativity perhaps rarely crosses our mind when thinking about such extreme circumstances. Similar to the famous interrogation of whether or not a falling branch in an uninhabited forest makes sound, this quasi-philosophical question calls for some interesting reflections about the nature of creativity. This is so because it actually raises the issue of the role of others for creative expression. Reformulated for our purposes in this chapter, this question reads: can we call something creative if produced by a person in complete isolation from other human beings?

At first sight this is quite simple to answer yes to; the person we imagine would be capable of creating even if his or her creative outcomes might generate novelty for the self but not necessarily for others. This difference between P-creativity, or creative for the person, and H-creativity, or creative at a historical level (see Boden 1994), seems to easily solve the dilemma. Adding to it the usual double criterion of novelty and utility of the product (Lubart 2003), we can say that if the action leads to outcomes that are new and useful for the person than it probably qualifies as creative. Perhaps this new method would also be considered creative (novel and useful) by other people, should they ever travel to the deserted island and see its isolated inhabitant. But, adopting a centric interpretation of creativity it is not necessary for others to actually come, see or evaluate what is being created. A single individual is enough and his or her creativity only requires being able to come up with new ideas and successfully apply them.

And yet, is this really the case? One thing to ask further is whether the person is able him or herself to recognise the creative nature of a new solution (or, extending this, if he/she has the capacity to develop the intention of acting creatively within a particular situation). In other words, if he or she is able to evaluate the creativity of a new fishing method in order to notice and conserve, as well as perfect, this 'novelty'. Otherwise perhaps what might seem from the outside as creative action might be a mere happy accident that has no consequences for the life of the person on either short or long term. And if the ability to evaluate one's creativity is important, then we have to wonder if our imagined individual has been socialised within human society before being stranded on the deserted island.

Just as in the case of feral children (McNeil et al. 1984), the capacity to develop a reflexive mind is rooted in early social interaction between self and other and any dysfunction in this regard has serious developmental consequences. In our case, if the person did not have any human contact before, then it is likely that he or she is not able to appreciate fully the value of creative action in ways that can take it forward and maximise its utility (which is not to say that such action and its outcomes would not be noticed at all or that creativity needs to be guided at all times by the intention of acting 'creatively'; see Glăveanu 2012b). In this situation, the creativity involved in a new form of fishing would mainly be attributed 'from the outside', by others who understand how different and useful it is. If, however, our isolated individual did benefit from socialisation early on, and can reflect on his or her action by using mediational tools (e.g., signs), then the new experience would be considered creative through the act of positioning oneself as a viewer of one's own action and looking at it as an 'other' would (the evaluative position). Moreover, in this latter case, previous social interaction within the world of culture would have given the person symbolic resources to understand his or her creative expression, including benchmarks to evaluate it against.

In sum, the creativity of an action or outcome produced by an individual is never 'complete' in the absence of social relations. The absolute absence of this network of sociality would make the creator unable to recognise and cultivate his or her creativity and, indeed, make him or her unable to perform other acts considered human precisely because of their cultural origin (see Vygotsky's discussion of higher mental functions; Vygotsky 1978). While social interaction might not be always required to generate novelty, the evaluation of this novelty—an essential part of the creative cycle—depends on on-going processes of socialisation. In the hypothetical situation of the person living alone on a deserted island, his or her creativity should be appreciated not in terms of isolated acts or outcomes but in relation to how these acts and outcomes are understood by the person in view of how others might understand them as well (see dialogical theories of the mind; Hermans 2002). In this sense, convergent with our first premise of interdependence between self and other in creative action, the social element is present even when creative acts are performed in complete solitude (Glăveanu 2011, 2014a).

The Creativity Oracle

Imagine that people would depend for their creativity on getting new ideas from an external source, an oracle taking the form of a gigantic head without body. The oracle receives, separately, visitors coming to learn a new and creative way of solving everyday problems. They formulate a single question in a concise manner and wait for a couple of minutes for the giant head to speak. Typically, a single answer is offered for each problem. In each case, the advice of the oracle takes the form of what seems to be a highly original and potentially useful idea. The visitors then return to their homes and try to implement this suggestion as best as *they can. They are allowed to visit the oracle again but with a different question. Considering the novelty of the solutions people receive, can we say that the giant head is creative?*

This thought experiment draws on other popular representations of oracles in Greek and Roman antiquity served by priests or priestesses such as Pythia in the Delphi temple. But there is a difference. If for the latter people came to find direction in their life and often received enigmatic replies that needed further interpretation, the creativity oracle imagined here is meant to offer very original and plausible—thus creative!—solutions. The question is whether the gigantic head formulating these solutions can be legitimately called 'creative'. In the end, this supposed creator does not participate at all in implementing any of its ideas. So the question becomes: can we label as creativity the generation of ideas before they get to be 'tested' in the real world and meet material and practical constraints?

At first sight we might be able to agree that ideas offered by the creativity oracle have the *potential* to be creative and whether or not they are indeed creative is decided later on, when put into practice. And yet, centric views of creativity also tell us that the mental processes leading to the generation of an idea (e.g., association, selective combination, divergent thinking, etc.) bear the mark of creativity. So in a sense perhaps the giant head is indeed very creative and the people taking part in this creativity afterwards are nothing more than mere followers who have very limited input. They are what Howard Becker (2008) calls 'support personnel' in the case of artistic work in order to expose the fact that all other people who contribute to a work of art but are not its actual 'creator' are rarely recognised for their inputs. The imaginary scenario proposed above is not really that far from reality if we think about the situation of apprentices working for the great artists of the Renaissance or, closer to our times, in the studio of creative geniuses like Picasso. And yet, there is here a fundamental difference: while Picasso generated many potentially creative ideas he was also closely monitoring their application; the oracle in our example stands completely disconnected from any form of 'doing' or practice, a mere head without body.

What this scenario makes a caricature of is the pervasive conception of the mind as the primary locus of creativity and of creativity as a 'thing', a stable quality of people or objects. Disembodied and generally disconnected from the environment, the cognitive processes of the mind can both generate 'candidate' ideas and evaluate them (see the Geneplore mode; Ward et al. 1999) in ways that complete the creativity cycle. The materiality of creative action tends to escapes centric models (but note that the Geneplore does take constraints into account). And yet the key question to be raised, similar to the first thought experiment, is whether the giant head really participates in the evaluation of its own ideas. In order to assess the quality of a solution one needs to express and/or implement it, give it a material form (Dewey 1934). Implementation is by no means a second or secondary phase of creative production as no idea stays the same from the beginning to the end of a creative process. It is only by acting on them that initial thoughts are reformulated and, oftentimes, radically transformed. Imagining otherwise would mean that any process of 'making' is mechanical and reproductive which is clearly not the case for creative activity in any domain, including everyday life (Glăveanu et al. 2013; Willis 1990).

In conclusion, our imagined oracle can be considered part of a larger process of creativity that brings together the idea generation and idea evaluation phases and recognises the creativity of both those who propose *and* apply creative solutions. Of course, in our scenario, this dynamic between generation and evaluation is interrupted by the fact that the giant head is actually outside the socio-material world in which ideas play out and solutions are implemented. In fact, we can even question whether it would be possible for the oracle to propose any creative ideas in the first place due to this disconnection from actual practice since 'great' insight builds on previous, 'smaller' insights emerging out of a continuous engagement with the problem at hand (Sternberg and Davidson 1999). The centre of creativity is therefore necessarily distributed both in time (interrelating preparation, idea generation, evaluation and implementation) and in space (where making something requires interaction with a social and material environment), bringing further support to the initial claim that 'creativity is not a thing but a relatonship'.

The 'Preservation Law'

Imagine a world in which all creations are protected by a preservation law equally enforced in every country around the world. This law was considered a necessity by the international community given the rate at which culture change was taking place and the need to create stability and help people understand the correct way of using cultural artefacts. The law was thus meant not only to protect new artefacts from further transformation but also specify their intended use, established by their identified author. As such, people are left either with the option of using the artefact in ways inscribed within the law or generate something completely new. This novelty would then be evaluated by a commission of experts and, if sufficient, placed under the protection of the law. Alteration or change of registered artefacts is forbidden. How does creativity take place in this world?

The imaginary scenario above seems to take to the extreme current copyright law arrangements meant to protect the rights of the author over his or her creations. In this alternative reality the preservation law would be much more radical and try to effectively prevent any new uses of an existing cultural resource beyond those clearly specified from before. As such, its aim would be to make human culture much more stable and predictable at the price of eliminating diversity and, ultimately, reducing creative expression. However, one might argue that not all creativity is eradicated from society but only 'minor' or everyday creations that make small changes to what already exists. Revolutionary or Big-C creativity (for a full typology of creative acts see Sternberg's (1999), propulsion model), associated with radical novelty, is not prevented by the preservation law. The question is: would this type of creativity even be possible?

Our first, romantic conceptions of the genius were largely based on his (it is male eminence typically recognised by history) special qualities. These special qualities set the genius apart from others and make ‘real’ creativity exclusive and elitist (Glăveanu 2010). A radical form of centrism promotes the view that creativity is associated, in the person of the great creator, with unique hereditary or neurological features (e.g., Galton’s influential work on Hereditary Genius, Galton 1874) or, in less essentialist descriptions, with a high level of intelligence or special set of personality traits (Barron & Harrington 1981). Part of the fascination with great creators comes in fact from the misconception that they create in a Godlike manner, *ex nihilo* or out of nothing (Negus and Pickering 2004). Although most creativity researchers would agree nowadays that creative work exploits what already exists in the world and reshapes it in new and useful ways (a process that also requires a period of practice and the development of mastery or expertise; Glăveanu 2012b), the question remains of how different are creative products from what already exists in order to call them really ‘new’. In our imaginary scenario, when would novelty be accepted by the preservation law?

It is clear that such an alternative universe would not only encourage radical novelty but also undermine its own development at a cultural level. By regulating how people can interpret and use a certain artefact, this society would experience almost no historical evolution of its cultural system. The gradual accumulation of changes is known to be the basis for the transformation of both biological and cultural systems and, in fact, legally constraining this change would be virtually impossible. This is because a finished product is never completed by the author him or herself and then sent off into a static world that receives and preserves it. A famous painting like Mona Lisa is not creative (only) because Leonardo da Vinci masterfully depicted its enigmatic smile, but because generations after generations of viewers continue to be inspired by it and (re)interpret its meaning and value. Perception and use are thus creative processes, at the same level as making, since they too result in useful novelty (Dewey 1934; Eco 1989). In this sense, creative action continues well beyond the moment a creator considers a product finished. Creative artefacts are creative precisely because they invite others to participate in their symbolic (sometimes material) re-creation with each view and use.

In conclusion, the imaginary preservation law discussed here is based on the centric assumption that creativity is a rather stable attribute and that culture and its artefacts ‘are’ rather than ‘become’ (see the third premise of a distributed theory of creativity outlined here). In essence, such models are non-developmental both in terms of their understanding of the individual and of society (i.e., with reference to ontogenetic and sociogenetic change). But, most of all, they tend to deny, similar to the preservation law, microgenetic changes, the minute transformations of objects and ideas that are associated with our everyday contact with them. Integrating such changes into the theory of creativity would necessarily expand our focus from the person of the creator or the nature of the object to their dynamic evolution in time. Distribution integrates temporality by theorising creativity in terms of evolving systems of relationships.

Distributing Creativity: From Centre to Periphery

The three thought experiments presented above were meant to illustrate the difficulty of operating with a centric and static view of creativity. Each one of the hypothetical situations they described brought new arguments for why, in fact, creative action is distributed (at once) socially, materially, and temporally (for a broader discussion of this see Glăveanu 2014a).

The deserted island scenario questioned the strict separation between self and others in creative work and supported the view that others are an integral part of creative production even when working in solitude, ultimately because they 'populate' the (socialised) self. The human mind is social in nature and bears the mark of interactions between people and engagement with cultural scripts. Being able to evaluate one's on-going creative activity requires this background of sociality as it both draws on cultural conventions about what creativity is and it depends on the gaze of the other (in our case the creator him/herself takes the position of a viewer would take in relation to his/her own creation). The creativity oracle pushes this relational logic further by challenging the centric assumption that creativity takes place in the mind. Creative expression builds not only on contact with other people but also on the creator's engagement with the material world in which new ideas are tested, refined, and ultimately transformed. The false gap between idea generation, and idea evaluation and implementation (alimenting much of today's distinction between creativity and innovation; see West 2002) separates the two coordinated and alternating phases of any creative process. The giant head in our thought experiment has no bodily means of putting ideas into practice and this makes their creative value uncertain. Once more, the evaluative aspect of creativity comes to the fore, this time adding materiality to the social aspects highlighted before. Finally, the 'preservation law' was a hypothetical scenario meant to make us sensitive to the dynamic aspects of culture and the impossibility of eliminating its creative appropriation and use. If creative action always reshapes what already exists than the continuity between past and present needs to be added to that between self and other, self and objects. Taken together, these inter-relations construct an image of creativity that questions centric notions of the isolated creator or the creativity of individual minds.

It is important to add here that distributed views of creativity don't deny the existence of 'centres' of creative production but consider them relationally and place them within extensive socio-material networks. In fact, individuals are recognised as agents of their own creativity and as actors who can transform their culture but who also share this agency with others precisely in the process of enacting it. The human mind is the locus of idea generation but creative ideas themselves are not contained 'inside' the mind. They connect minds through acts of communication and make the person adapt to and master his or her environment. Recent debates about situated, extended or distributed cognition (Lave 1988; Hutchins 1995; Rowlands 2010) point precisely to this paradigmatic change from centre to periphery towards an expanded view of what the mind is. The study of creativity is instrumental for this debate since it talks precisely about people's relationship to their world and their capacity to change as well as be changed by it. Distributing creativity doesn't therefore only inform us about the creative process itself but constitutes a theoretical lens through which people, society and culture can be understood in their interconnection. Moreover, it can be the foundational paradigm for practical interventions not only in the sphere of education but society as well, supporting our efforts of collectively dealing with complex social, economic, and environmental problems that threaten the existence and well-being of communities around the globe (the 'wicked problems'; see Conklin 2005).

Finally, I would like to restate the fact that the three thought experiments included in this chapter were not meant to offer a final proof of distribution but open up important questions that can be used to guide further research. While some of these interrogations might seem philosophical rather than psychological it is important to realise that the theory of creativity needs to recognise its own epistemology and therefore should always question its implicit assumptions. In the end, we can think about the consequences of adopting a distributed view of creativity also in terms of a thought experiment. What would it mean for us as people, as researchers, as a society, to abandon centric perspectives for a focus on relationships, to give up considering creativity a more or less static quality and observe its transformation in time, to stop looking for a single creative 'author' and recognise the creativity of entire communities? This mental exercise does require a bit of imagination because, at the moment, the theory and, most importantly, the methodology of studying distributed processes are still underdeveloped (despite notable achievements in this area coming from decades of research within the social psychology of creativity). For the latter, process-oriented methods, comparative case studies and longitudinal research designs are much better equipped to capture distribution then our usual psychometric methods. The consequences of adopting these theoretical and methodological lenses are enormous, ranging from how we recognise creativity to how we foster it, including in education and in society at large. My hope is that such a perspective would also make us more reflexive and responsible towards ourselves, others, and the world we live in.

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Part II
Social Aspects of Creativity

Creativity and a Human Dichotomy: Individual or Part of a Team?

André P. Walton

Discovery consists of seeing what everybody has seen and thinking what nobody has thought.

Albert von Szent-Györgyi
[Irving Good (Ed.), *The Scientist Speculates*]

Defining Creativity

Since the focus of this book is *creative thinking* it behooves us to define what it means to think and act creatively. Although there has by no means been consensus regards the definition and assessment of creativity (Amabile 1996), a common definition used in organizational and social science settings is that something is creative if it is both novel and useful or appropriate, i.e., has utility in a particular context (c.f. Barron 1955; Bruner 1962; Newell et al. 1967; Stein 1974). Although this definition has face validity and has garnered considerable support over the last few decades, it is, I believe, problematic in several ways. First, both novelty and usefulness have highly subjective and dynamic components to them (Aarves-Yorno et al. 2006). While at first glance the meaning of *novel* may seem

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self-evident, on close inspection this may not be the case on two grounds. Some acts of creativity are, as it were, quantum leaps, and some are more evolutionary. The revolutionary acts of creativity can often be readily identified and it may be self-evident that they fulfill the requirement of novelty. Cubism, for example, represented a radical departure from previous visual art forms. There was no obvious predecessor to the internal combustion or jet engines, or to the atom bomb.

Most other examples of creativity, however, have clearly evolved from some previous version of the idea or product. There is a clear conceptual path from the refrigerator to air conditioning, for example, or from the inline internal combustion engine to the V8. In this latter category there are many occasions when it may be difficult to decide whether an evolved idea fulfills the criterion of novelty or not. Ultimately the decision may be highly subjective, and it is not obvious that the creative processes responsible for developing an evolutionary idea are the same as those responsible for a radical innovation. Piling lots of televisions on top of and beside each other in order to create a display for a very large image may require some degree of inventiveness in order to segment the picture onto each of the screens appropriately, but is the end result inherently creative? In other words, given that the television had already been invented, does this primitive 'big-screen' pass the test of novelty?

A second problem with *novelty* is that of simultaneous invention. If two people, half a world apart, come up with similar ideas at roughly the same time, it will be the person who shouts loudest or makes public her or his idea first who is likely to be credited with being the creator. The other poor sap may well get labeled the 'also ran'. In the case of the invention of a vaccine for polio, for example, Jonas Salk was a natural leader who loved to be in the public eye, even to the point of using himself and his family as guinea pigs (Anti-polio vaccine 1953) and was the first to announce the invention of a polio vaccine to the world. However, most of the vaccine used in the developed world since that time relies on a different process and was developed simultaneously by the very thorough and somewhat more recluse Albert Sabin. Although the, now more popular, vaccine can be taken orally and is cheaper to produce, Salk will be forever labeled the inventor of the polio vaccine.

Turning now to the *useful* aspect of the traditional definition, this also presents problems. Although history books differ regards details of the story, it seems clear that the group of scientists that decided to explore coherent light did so out of scientific curiosity, not with a view to solving a specific problem (Chu and Townes 2003). The laser, then, would probably not have passed the test of usefulness when originally invented. Those scientists were not to know that by the turn of the century many families in the developed world would owe much to the laser—in the form of the CD and DVD players in their homes and cars, for example. They were not to know that lasers would be used for surgery, cutting steel and cloth, and be the subject of children's comic books in the form of intergalactic warfare! In the words of Robert Sternberg, "…what a field judges to be creative at one time might differ from what it judges to be creative at another. The work of composers such as Bach or artists such as Van Gogh now appears to be viewed as more creative by the members of these fields than the work was at the time it was done." (Sternberg 1999, p. 84). Is it appropriate, then, to 'reclassify' a product or idea retrospectively if it is suddenly discovered to have practical use?

Once again, though, there are also subjective aspects of *useful* that are problematic. Who is to say if the invention of cubism or the whole-tone musical scale was useful? They were clearly judged as highly innovative at some point in history, if not when they were first developed, but, particularly in the case of less extreme examples (of many evolutionary innovations, for instance), 'use' and 'appropriateness' are highly subjective concepts.

Finally, the traditional definition of 'novel and useful', as typically adopted by social scientists, implies creativity to be a unitary construct (Unsworth 2001). A more 'global' examination of the multiple views of creativity in the literature, including that from Freud (1908), or from perspectives such as the interactionist one (e.g., Woodman et al. 1993), a cognitive one (e.g. Mendick 1962), a personality one (e.g., Barron and Harrington 1981), an organizational one (e.g., Shalley and Zhou 2008), or a social psychological one (e.g., Amabile 1996), would suggest that such a singular view of creativity might be inappropriate. That is not to suggest, however, that the fundamental motivation to be creative essentially differs between these different domains. It does suggest, though, that a study of creative thought might usefully be conducted at a more fundamental level in order to try and explore factors that influence creativity regardless of the domain in which it becomes evident.

Since ideas are originally generated by individuals, it makes sense to have a definition of creativity that reflects this individuality and uniqueness independent of the way in which it ultimately shows itself. Reflecting on my granddaughter, I propose, then, that creativity can be defined as 'having an idea or performing an action that the individual has not thought or done before'. Although this is somewhat subjective regards whether someone had a particular idea previously, or whether the idea is simply stimulated by a desire to react against or conform to social norms, for instance, (which may not necessarily be motivated by the desire to be creative), this definition reflects a *process*. This process—the process of creative thinking, is based within the individual and requires a departure from the well-trodden path, which also requires a departure, as we shall see later, from thought patterns that have gone before. The individual nature of this process is, I believe, reflected in this definition.

Innovation

Since, at least within an organizational context, creativity and innovation are intimately linked, it is relevant to define innovation and the ways in which it is differentiated from creativity. According to van der Meer (1996), innovation is 'the total set of activities leading to the introduction of something new, resulting in strengthening the defendable competitive advantage of a company.' In principle, this author agrees with that definition except to differentiate between the initial stage in the ‘set of activities’ that involves idea generation. Anderson et al. (2014) appear to be in accord with this approach and state: “The creativity stage of this process [creativity and innovation] refers to idea generation, and innovation refers to the subsequent stage of implementing ideas toward better procedures, practices, or products”. In other words the generation of the creative ‘germ’ (the ideation phase) is conceptually different from the stages involved in evolving that idea into a novel product or process, i.e., innovation. That is not to say that this evolution that is the innovation is devoid of further creativity; on the contrary, creativity may be involved in all stages of the creativity/innovative process, which may be iterative in nature (Paulus 2002). However, the ultimate product or process will owe its evolution to the original generation of a unique thought or idea (Oldham and Cummings 1996; Rank et al. 2004) by an individual.

Creativity: A Universal or an Individual Phenomenon?

Until around the early 1970s (Amabile and Pillemer 2012), many researchers seem to have made the assumption that creativity is an unusual attribute of ‘special’ people (Oldham and Cummings 1996; Paulus and Nijstad 2003; Woodman et al. 1993). The research approach derived from this premise is one of ‘dissecting’ the lives and actions of eminent, creative people and has produced remarkably little in the way of useful guidance regards the basic processes involved in how creativity occurs and what motivates it (Kabanoff and Rossiter 1993). Certain common factors have been identified, such as ‘the need to be motivated’, and ‘generally had a mentor’, but, in general, other factors that correlated with creative eminence were domain specific and, thus, of little help in understanding fundamental creativity processes. In other words, from this creativity research perspective, eminent authors seemed to have little in common with eminent architects, painters, mathematicians or engineers. A more recent approach to creativity research, still based on the level of the individual, focused specifically on psychological factors that contribute to creative behavior such as personality attributes, intelligence and motivation (see, for instance, Haslam et al. 2013). This approach shares a common attribute with earlier work in that it largely ignores the influence of the social environment on individuals’ motivation to be creative and has not lead to any more generally applicable fundamental theory regards creative processes.

Other more recent approaches to creativity research include the social identity approach. This approach examines the motivation to be creative as a function of the creator’s expectations regards how the ultimate product will be perceived (i.e. judged). In particular, the social identity approach is centred around the social processes of judgement and evaluation of creative products (Adarves-Yorno et al. 2006), and, by implication, the influence that this has on creative people. While expectations regarding the judgements of others has considerable potential to influence creativity, there are other social influences that also share this potential, including the focus of this chapter: The influence of individuals' relationships with their groups versus their desire to display individuality.

Where Does the Drive to Be Creative Come from?

Humans are a bundle of contradictions. We often set ourselves specific goals and then take actions which appear to lead in a direction counter to their achievement (Brandstätter et al. 2013). There is a very real possibility that some of these contradictions derive from opposing drives inherent within the human psyche. One pair of such opposing drives is of particular relevance here and critical to our understanding of creative processes.

First, we all have a need to demonstrate our individuality and to have it recognized by others. The psychoanalyst, Rank (1932/1989) saw this need to demonstrate individuality as having its roots in a desire for immortality (Becker 1973). This desire, Rank posited, could be satisfied by distinguishing oneself from others during life in a way that would be remembered even after one's death. In other words, through creative action individuals anticipate that others will respect their uniqueness and afford them some degree of (at least, symbolic) immortality. Whether one chooses to accept Rank's, perhaps rather extreme, views on the display of individuality, the fact remains that we all need to feel, and be seen to have, some degree of uniqueness. This has been known by those in power throughout history. Prisoners are often stripped of their identities and referred to simply as numbers. They may also be deprived of their individuality in other ways and made to wear generic clothing, eat an identical diet and perform the same day-to-day activities as other prisoners. Still the case in many schools today, in the past it was the norm that students wore a school uniform, identical to their colleagues in every possible way. The urge for individuality is so strong, however, that students often use every conceivable way to individualize their generic dress, in order to establish their uniqueness.

The other drive that we all have is the need for connectedness with others; for an affiliation with a group or groups. Psychologist Abraham Maslow suggested that this need is second only to the need for food and drink (Maslow 1968), and Baumeister and Leary (1995) also considered group affiliation truly a need, comparable to basic physiological needs, rather than being just a desire. Military leaders throughout history have also been aware of the strength of this drive and have recognized that depriving people of interaction with others provides a potent punishment in the form of solitary confinement. Most of us cannot tolerate being deprived of the company of others for long without suffering negative psychological and sometimes physical consequences (Grassian 1983).

Our Need for Groups

The groups with which we feel a need to be associated may come in all shapes and sizes. In principle a group can be simply a couple (dyad), but more commonly we think of groups as several or many people. Our groups might comprise our family, our work colleagues, other members of clubs and societies that we belong to, other church goers, fellow students at school or college, even others of our nationality; in other words, those who share similar characteristics and collectively have a sense of unity. As Forsyth (2006) puts it: "Hundreds of fish swimming together are called a school. A pack of foraging baboons is a troupe. A half-dozen crows on a telephone line is a murder. A gam is a group of whales. But what is a collection of human beings called? A group. …Thus, a group is defined as two or more individuals who are connected to one another by social relationships."

Individual or Group Member?

When we are identifying with one or more of our groups, i.e. we are sharing a particular experience with other family members, or enjoying some recreational activity involving others, or at work coordinating with other team members, it is our *similarity* with those others that is foremost in our minds. On the other hand when we are focused on our uniqueness it is our *difference* from others that is salient. One of the times, of course, when we are focused on our uniqueness, is when we are being creative. That is, we are deliberately generating ideas and then acting in such a way that we are differentiating ourselves from others—walking a path down which others (or we) have not previously travelled (Fig. 1).

This contradiction, from which all humans suffer to some extent, has an important feature: these two drives cannot occur simultaneously. In other words, when we are focused on group membership and our similarity to other ingroup members, we cannot also be focused on our difference from others, or our uniqueness. The critical point here is that any force that induces us towards group membership also undermines our creativity (Fig. 2).

In other words, our need for affiliation with others is contradictory to the demonstration of our personal distinctiveness, for instance, through creative acts. Both Snyder and Fromkin (1980) and Brewer (1991) posit a fundamental tension between the need for connectedness with others, and the need to demonstrate one's individual uniqueness. Creativity was not the explicit focus of either Brewer or Snyder and Fromkin, but having novel ideas and performing creative actions is intimately related to the process of establishing distinctiveness, which was central to their theories.

In order to generate the kind of unique and creative idea that may lead to an innovation, then, we may have to depart from the comfort of the group. This departure from the group may also isolate us from the kind of social influences

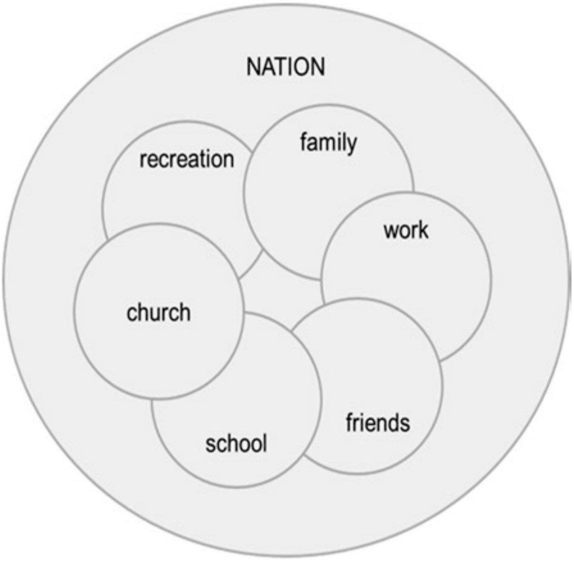

Fig. 1 Groups can come in all shapes and sizes

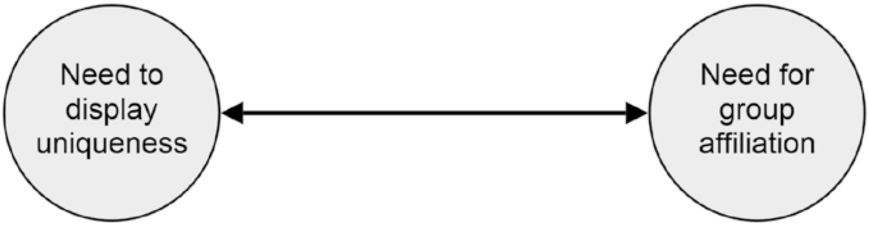

Fig. 2 Our need for connectedness opposes our need to display uniqueness

that can be negative to our motivation to be creative, such as those that generate fear of failure or rejection. To what extent this means that we physically need to isolate ourselves from others depends on many constraints, personality factors, the degree to which what we are doing is unique and different, and in what way we are displaying our creativity. Historically, many writers, painters and other creators have chosen to travel or become isolated from their friends (and sometimes family) during those times when they were being creative. Once that 'creative phase' was complete they reunited with other group members to discuss their work, perhaps. Maybe for others it might be sufficient to put on some headphones and shut the office door in order to achieve the 'departure from the group'; but, either way, this self-versus-group model suggests that some separation from social interaction is necessary to maximize our creative potential.

It is important to note that I am not suggesting that under the self-versus-group model there is no room for group level creativity; indeed, there is considerable support for the value of teams in creative work. Hirst et al. (2009) researched creativity as a team-level construct within a social context and found that a team context can enhance creativity through individual learning. In the study researchers even predicted employee creativity from their learning orientation. In other words creativity still occurred at the individual level, although it was influenced by others in the team. In a technological context particularly, the diverse skill set required to achieve innovation may dictate group level creativity to optimize the final outcome. In the self-versus-group model of creativity I am simply suggesting that the generation of the original creative 'germ' of a unique idea (whether an innovation is developed from it or not) occurs at the individual level.

Groups, Fear and Threat

In the current, highly competitive world in which organizations find themselves, it behooves us to examine how the stress of competition might influence our motivation to think and act creatively. One of the things that happens when people are threatened, or placed in a situation of fear, is that their groups become more important to them (Elder and Clipp 1988; Rofe 1984). In other words, they feel the need for closer connectedness with others. Back in 1959, Schachter reported a series of studies in which participants were told they would undergo an electric shock as part of a learning experiment. Some were told that the shock was innocuous, and the others were lead to believe that it was going to be quite painful. Participants were then told that they had to wait while the equipment was being prepared, and that they could either wait on their own or with others (whom they did not know). Those participants in whom fear had been induced by the expectation of pain were significantly more likely to want the company of others than those in the low fear group.

Also, research by Greenberg et al. (1997), suggests that when people's mortality is made salient they have a tendency to conform more to culturally shared worldviews, in other words, social norms. After the terrorist attacks of 2001 the U.S. flag started appearing on American front porches and car antennas, showing a clear desire for connectedness with the group 'The Nation'. Americans reported going to church more often, planning more family-oriented vacations, and relating more closely to their school or college; all clear signs of greater ingroup attachment (see, for instance, Penner et al. 2005). In the absence of factors that might lead to threat being a motivator (De Dreu and Nijstad 2008; Smith et al. 1994), we would expect that this increased ingroup attachment would lead to a reduction in the motivation to be creative. In other words, since creativity is inherently a departure from established ways of thinking and doing things, in the face of threat, the motivation to be connected with others outweighs our need for uniqueness and our motivation to create decreases. Putting it another way, threat can stimulate a need to minimize ambiguity which can hinder individuals' ability to deal with complexity and to solve creative problems. This is even the case even when conflict is merely observed (Friedman and Forster 2001, 2002, 2005; Miron-Spektor et al. 2011).

The Influence of Social Norms

As well as fear and threat, creativity has the potential to be influenced by other social contexts, including culture. Culture, whether organizational or societal, comprises a system of values and norms (Newcomb 1958; Walton 1980; Whyte 1943). Values represent generalized goals that define what is considered important and worthy of pursuit. Norms are socially shared standards against which individuals make comparisons regarding their behavior, or intended behavior (Abrams and Hogg 1990; Birenbaum and Sagarin 1976; Sherif 1936). The appropriateness of these attitudes and behaviors is defined by norms, in the sense that they influence how individuals interact with one another, approach problems, and make decisions (Bettenhausen and Murnighan 1991). In other words, norms and values form the basis of social controls. Thus, although the generation of unique ideas maybe an individual act (that may, or may not, occur in relative isolation), the overall context for the creative process is a social one. From another perspective, a playwright, actor, composer or painter needs other people. This 'social context' may comprise an audience, or it may be a need for the ideas of like others as a source of stimulation and to build on. Either way, this context will include a feedback component regards whether 'it is O.K. to be creative'. As an example of the importance of this last point, the social norms relating to musical structure in the late nineteenth century were not conducive to the creative extremes to which Rachmananov went in his first major composition. The reception to his composition was so poor and influenced the composer sufficiently that he ceased composing for many years after and became a virtual recluse (Culshaw 1950). At a different time, or, possibly, in a different social context, norms and values might have been more conducive to, and tolerant of, Rachmananov's expression of uniqueness.

Through support or chastisement, then, norms can act as positive or negative means of ensuring conformity, and can form the basis of sanctions to deviant behavior (O'Reilly and Chatman 1996). Creative behavior is inherently deviant, since it requires a departure from established patterns of thinking and acting. However, people still need affiliation with, and validation from, the group, even when they are acting creatively. Therefore, people are susceptible to the influence of group norms even when they are expressing distinctiveness through the performance of individual actions such as creativity.

In an organizational context it is critical, then, to incorporate the importance and acceptability of creativity as a core organizational value if the overall goal is to generate an environment that stimulates creativity and innovation.

Creativity, Groups and Brainstorming

Over the past several decades work groups have been the focus of much attention in an organizational context. While this has many positive implications for innovation and for individual feelings of wellbeing, it may not be very conducive to the generation of unique and novel ideas (Mullen et al. 1991; Simonton 1988). Similar conclusions have been reached regards brainstorming (Brown and Paulus 2002; Diehl and Stroebe 1987; Lamm and Trommsdorff 1973).

Alex Osborn was a partner in B.B.D.O., an advertising agency that was widely regarded as the most innovative firm on Madison Avenue. When Osborn (1948, 1957) popularized brainstorming he predicted that it would double the number of ideas that a group of people would generate in response to a problem or challenge. Osborn believed that brainstorming was central to B.B.D.O.'s success, and he described the process in military terms: "When a group works together, the members should engage in a 'brainstorm,' which means using the brain to storm a creative problem—and doing so in commando fashion, with each stormer attacking the same objective." Although brainstorming was Osborn's key to turning a group of employees into idea machines, it proved not to live up to his expectations. In fact, research later showed that it actually *reduces* the number of ideas a group produces when compared with the number of ideas that can be generated by those same individuals on their own (Diehl and Stroebe 1987; Lamm and Trommsdorff 1973). This was a source of frustration to Osborn for the rest of his life.

There are several explanations regards why brainstorming underperforms individual contemplation in terms of generating ideas. These include the phenomenon by which team members strive for consensus (thus, not fully evaluating all possible options), known as Groupthink (Janis and Mann 1977). Diehl and Stroebe (1987) showed that much of the low efficiency in interacting brainstorming groups could be attributed to 'production blocking', which occurs when factors such as waiting for their turn to speak keeps individuals from contributing some of their ideas. Diehl and Stroebe (1987) also demonstrated that even when individuals worked alone, they produced fewer ideas if told that their output would be judged in a group with others rather than being judged individually. This lead to another explanation regards the shortcomings of brainstorming, the notion of individuals undervaluing their ideas because they feel they are less significant when combined with the ideas of the group at large. However, further experimentation suggested this as only a minor contributor to productivity loss compared with whether the brainstorming is in group or individual format (Diehl and Stroebe 1991).

Social loafing offers another explanation for poor brainstorming performance in group format compared to that in 'nominal groups'. It is the phenomenon whereby people exert less effort to achieve a goal when they work in a group compared with when they work alone (Karau and Williams 1993). Social loafing comprises two separate ideas, that of the "free-rider" theory and the "sucker effect". Free-riding describes the situation when an individual reduces effort compared with their potential in order to avoid the possibility of their working harder than fellow group members (Gilovich et al. 2006). The sucker effect describes when people think other group members claim credit for the outcome but leave them to do all the work. To avoid feeling like the “sucker” they wait and see how much effort others put into a task before they invest theirs. Obviously if all group members indulge in the sucker effect then group performance will fall significantly short of its potential (Thompson 2003).

In an organizational context, if a culture of absence becomes established as the norm then the pervading attitude becomes one where employees feel they deserve to have a certain number of days of paid absence, regardless of whether or not they are actually sick. Others that have not used the maximum number of absence days, may demonstrate the sucker effect because they feel that they are “… carrying an unfair share of the workload” (Krumm 2000). While social loafing and free-riding are thought by some to be two of the main reasons that groups are sometimes less productive in ideation than the combined performance of their members working as individuals, there are other contributing factors, such as coordination problems, that account for or contribute to this reduction. Also, brainstorming groups may suffer motivational losses (Paulus and Dzindolet 1993), whereby group members lower their performance goals because of social comparisons with other less-productive members.

Even after precautions are taken to minimize the effects of the above shortcomings on group brainstorming performance, the evidence seems to show that groups of people cannot outperform the ideation ability of those individuals working alone (Connolly et al. 1993; Mullen et al. 1991). The individual-versus-the-group model of creativity provides one other possible explanation. As long as we gather people together to perform a task (such as generating ideas in order to solve a problem) we create an environment in which the group becomes salient, along, of course, with group membership. If, however, we generate ideas on an individual basis, by sending group members off in different directions so that they are not even in the proximity of each other, we might reasonably expect to generate a more effective environment for the ideation stage of the problem solving process. In other words, the very act of making people members of the brainstorming ‘group’ or ‘team’, may cause them to think in a less individualistic (and creative) way. We can bring those individuals together as a group later to share their ideas and, subsequently, build on each other’s. Individuals can diverge and converge again as necessary, before the idea list is finalized and one idea chosen to pursue to the next stage.

Creative problem solving (CPS) and innovation are both multi-stage processes, one of the earliest stages of each is idea generation. As discussed above, there is evidence that teams may not be appropriate at this stage of CPS (Paulus and Yang 2000). If this early (and critical) step in innovation is flawed then it follows that the whole innovation process will be sub-optimal.

Teams and Innovation

The subsequent steps in CPS, or innovation, including implementation, can, and generally should, be conducted by the group as a whole or by selected members from it, depending on the specific skills required, the critical ideation stage having been completed at the individual level.

"[And] the ideas that allow an organization to achieve, grow, and prosper as opposed to merely survive will be created only when teams leverage their combined skills and hold themselves mutually accountable. No individual, no matter how brilliant, is likely to have the skill set to take projects from start to finish in this fast-paced and complex environment." So writes Piasecki (2013) regarding the importance of teams to innovation at the organizational level. Piasecki focuses on the skills involved in innovation, however, not just on generating unique ideas. Many contemporary products are complex, perhaps in terms of the materials used and the firmware and software involved, with many different skills needed to combine technologies effectively. Also, innovation requires communication skills in order to convince stakeholders, gatekeepers, and other parties critical to successful product development and launch. Generally, this divergent list of skills requires several people to combine their assets in order to fulfill all requirements.

Team building within organizations, then, may not be the silver bullet for all situations or all stages in a problem solving process (i.e. in idea generation), but when the goal is innovation, a team will probably be critical in taking an idea to market. However, the generation of the initial idea to develop may be best done by individuals working independently. In other words, clearly separating the creative idea generation stage(s) from the rest of the innovation process may be strategically important.

Social Culture

As discussed above, normative influences have considerable power to guide individual action. Here I focus on the norms of collectivism and individualism since they are intimately linked to how individuals perceive and relate to themselves within their groups. In fact, the tension between the establishment of distinctiveness and connectedness to others is analogous, in some ways, to the tension between individualism and collectivism.

Individualism and collectivism describe the ways in which individuals feel socially connected to others (Earley and Gibson 1998). The terms have also been defined as: "describing the relationship between an individual and members of a common group membership" (Oyserman et al. 2002; Triandis 1995). In environments that are highly collectivist, ingroup members share a sense of solidarity and mutual obligation. In an organizational context, corporations emphasizing collectivist norms, place priority on group (e.g., work group or organizational) goals, and individuals are rewarded for working with others to achieve those goals. In environments where individualism is valued, on the other hand, independence and personal needs take priority. Organizations structured along individualist lines give priority to individuals' goals, and reward members based on individual achievements (Ho 1993; Voronov and Singer 2002). Note that personal reward is achieved in both individualist and collectivist environments, it simply results from the fulfillment of goals in different ways. It is an error to confuse collectivism with altruism at societal or organizational levels (Voronov and Singer 2002).

Although this simplistic description might suggest that individualism and collectivism are mutually exclusive and in opposition, this is not necessarily the case. Both individualism and collectivism can operate in all societies in varying degrees (Ho and Chiu 1994; Triandis 1995). Each society has different domains and contexts within which different norms apply. Although the United States is said to be the bastion of individualistic principles (cf. Oyserman et al. 2002), one might not guess this from watching a football match with the audience all wearing one or the other team's colors. It has been suggested, then, that individualism and collectivism be viewed as separate dimensions in order to better accommodate such anomalous behavior (or someone within a collective displaying "individualistic", for instance, creative behavior) (Earley and Gibson 1998; Oyserman 1993; Triandis 1995). It is possible, then, to have both individualist and collectivist sub-groups coexisting within the same environment, whatever the prevailing social norms (Earley and Gibson 1998), level of analysis (Schwartz 1990), or situation (Triandis 1995). For instance, an American multinational may maintain its individualist corporate culture throughout its branches, even in collectivist countries. Employees may, thus, be obliged to adopt an individualist outlook during their working lives while maintaining the collectivist culture of friends and family. Also, an individualist organization may have collectivist groups working within it, or vice versa.

Deaux and Reid (2000) defined collectivism as a way of identifying with a particular group or category. Using this approach, variations in degrees of collectivism can be considered down to the individual level. In other words, not all group members will share the same sense of individualism or collectivism regarding the group, and individuals do not relate to all groups with the same collectivistic or individualistic orientation.

Although collectivism and individualism have their origins in the categorization of societal differences (Hofstede 1980), they have been extensively studied in many contexts and levels of analysis, including in organizations (e.g., Earley 1993; Van Maanen 1991). At both societal and organizational levels a defining characteristic of collectivism is that individuals share a sense of connectedness and identification with their ingroups. Collectivists tend to draw more clearly defined ingroup-outgroup boundaries than individualists and are also primarily supportive of ingroup members. This might be one reason why there has been an emphasis on hiring employees who display 'collectivist' characteristics (Blackburn and Rosen 1994). Note though that this may be counterproductive to the goal of innovation.

Individualists, on the other hand, have looser ties between themselves and others, and are characterized by the expectation that everyone should primarily look after themselves and their immediate families (Hofstede 1991). According to my self-versus-group theory of creativity, the looser nature of these ties implies that creativity should be greater for individualists than for collectivists, since the forces binding the individual to the group are weaker and present less of a hindrance to establishing distinctiveness (Walton and Kemmelmeier 2012).

There is little in the way of conclusive evidence from prior research regarding the absolute levels of creativity between collectivists and individualists, although it does appear that different types of creative products emerge from collectivist and individualist communities (Bhawuk 2003). Where the expression of individuality is emphasized, creative products are diverse and of a form that differentiates the individual creator from others. In collectivist cultures, however, creativity tends to be supported only when its products are sanctioned by the group and, therefore, tend to be more evolutionary than revolutionary (Bhawuk 2003). Cultures which differ with regard to their individualism-collectivism orientation do, then, appear to differ with regard to the types of creative products that they produce, and there is no reason to believe that this distinction should not apply to organizations also.

Conclusions

When seeking to improve the innovative performance of an organization it is a strong temptation to look for an individual, or a team of individuals, who have developed a historical reputation for innovation. There is clearly sound reasoning behind this philosophy, since you know, at least, that the individual or team have the *potential* to be creative. However, this approach is far from guaranteed regards success. A significant player in the gaming industry, for which I was consulting, purchased, at great cost, an individual with an excellent track record of creativity in a parallel industry. After a year it became apparent that no ground-breaking new product ideas were likely to emerge from him in the near future, and he was moved sideways. Inevitably blame was apportioned to the individual with some lesser amount shared by upper management. The alternative explanation, finally accepted by the company, was that no matter how potentially creative the individuals within a team or an organization are, if the organizational structure and norms are not conducive to creativity then it will probably not emerge. However unpopular the unstructured and, sometimes, unpredictable, environment generated by Steve Jobs when he ran Apple Inc., that loose structure and emphasis on individual performance contributed in no small way to Apple's innovative abilities.

The lesson here is that creativity and innovation are not best generated by 'bolting on' a creative department to an existing, highly structured, organization. To some extent this may have worked in the past, but now that competition has increased the stakes and innovation is critical to the survival of many more organizations than before, creativity has to be incorporated as a core value within the structure of an organization if innovation is one of its goals. This implies a leadership of greater risk-taking at the individual level, generation of an environment within which it is O.K. to make mistakes, and where new ideas are welcomed, how absurd some of them may initially seem to be. I suggest that when these notions are incorporated within the very core of an organization then brainstorming, a poor proxy for the processes that really occur when people are being creative, may be a thing of the past.

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Dangerous Liaisons: Bridging Micro and Macro Levels in Creativity Research

Stoyan V. Sgourev

Introduction

Most research on creativity is at the individual level. This is hardly surprising given that creativity is overwhelmingly approached—in scholarship as much as in everyday life—as an individual attribute. An attribute, moreover, that is increasingly recognized and revered. Ironically, the tendency to glorify outstandingly creative persons, such as Mozart, Einstein or Steve Jobs, goes hand in hand with the conviction that creativity is something that can be taught and developed, and which is more widely distributed than typically believed. A quick glance at the riches of readings and talks on the subject conveys the sentiment that creativity is not exclusive and that it is capable of enriching not only our personal lives, but society as a whole.

However, the reason why we put figures like Mozart on a pedestal is precisely because of the understanding that their achievements are exceptional, lying far beyond what could be expected of an everyday practitioner. It is the combination of exasperation and delight with which Salieri peruses the astounding elegance of Mozart's scores in Milos Forman's film "Amadeus" that remains as one of the most vivid representations of the emotional ambivalence that creativity provokes—true creativity is a deviation, it is never the norm, and as such, it can be celebrated and disparaged at the same time.

The growing use of the concept of creativity in popular and scholarly literature is based on an intrinsically "positive" definition, where creativity is the process of generation of something "new and valuable". Emphasizing the positive function of creativity—the generation of novelty, inevitably draws attention away

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from the fact that any act of creativity is in its essence a deviation: from the established ways of doing things, from the routines, norms or expectations that govern much of our social life. The process of creativity is inherently uncertain, as any act of deviation faces potential sanctioning and can be recognized as "creative" only after the members of an evaluating audience come to judge it in those terms. The process is also inherently social, encompassing ideas, individuals, evaluating audiences and social norms, where ideas are formulated through (and not simply *by*) individuals, evaluated by one or more audiences and either integrated into or excluded from the current repository of practices or ideas.

Social psychologists, most notably Csikszentmihalyi (1996), have called for a more systemic approach to creativity that goes beyond the individual as a generator of novelty and incorporates the social dimensions of the creative process: the impact of social relationships, norms and values on the emergence of original ideas and their recognition. From this angle, the defining feature of creativity is that it is jointly determined by individual (micro) and collective (macro) factors. However, the nature of the interdependence between the levels and its role in shaping creativity remain poorly understood. Studies rarely venture beyond one level of analysis and the absence of dynamic, longitudinal research does little to illuminate the workings of the interdependence between individual and collective factors. Closing this gap passes through the recognition of the value of macro-level research and of the need to develop research methods encompassing both micro and macro factors, enabling dynamic modeling of the creative process. This chapter reviews the sociological approach to creativity, proposes a method that captures the interplay of individual, network and field-level factors, and illustrates its application through two prominent cases drawn from the history of the arts.

The Sociological Approach to Creativity

Sociologists agree with the assumption that creativity is lying at the nexus of individuals and the larger socio-cultural field (Csikszentmihalyi 1996), but are naturally focused on the field, rather than the individual. If we return for an instant to Mozart, a useful exercise is to consider the possible explanations for his extraordinary creativity. To what extent can we ascribe it to his inherited musical talent, playful disposition and strong intrinsic motivation, the professional mentoring by his father or the incessant touring across Europe that exposed him to diseases, but also to the latest developments in Italian, French and German music? Of course, we have no means of decomposing the variation into "individual" and "social" components or estimating with any reasonable accuracy the contribution of the unobservable part that most likely made Mozart's music so remarkably original. But there is little doubt that both components were important and that the form of their interaction was far from trivial.

Sociologists are naturally inclined to consider supra-individual factors in explaining creativity, including, but not limited to, career trajectories, social networks and institutional fields. Of these, the most attention to date have received social networks—the set of interpersonal relationships surrounding every individual. The network approach is suitable to modeling the dynamic component of creativity—the flow of information and influence between individuals related to each other via an acquaintance, a friendship, a professional engagement, a romantic involvement or any other form of social proximity. If we look with broader lens on the network of interpersonal relationships connecting the members of an intellectual community, we would observe a "core-periphery" configuration characterized by a hub of dense relationships in the center and layers of more dispersed relationships in the periphery of that network. The core or inner circle is the domain of "stars", having many relationships to other eminent members of the community, while most other members reside in the periphery, with few relationships of this kind. It is established that creativity comes to those who are well-positioned, who know of diverse possibilities, have a sense of trends and encounter each other face to face (Collins 1998, p. 74). Those at the core of the network have better opportunities to access and combine resources and ideas from many places and contacts (Collins 1998; Burt 2004). By virtue of their centrality in the network, they are better positioned to come up with new solutions by re-combining ideas and information from their multiple relationships. This line of reasoning is supported by studies of intellectual communities demonstrating that individuals on the periphery rarely produce ideas of consequence (Collins 1998).

However, there are reasons to question the argument that individuals linked to many others are better positioned to be creative. An established sociological tradition describes peripheral actors as key agents of change, unconstrained by the peer pressure and high expectations that characterize the center of the network, and as a result, being more likely to originate ideas that challenge the status quo (Coser 1965; Merton 1972). In this reasoning, those on the periphery have several advantages—they are not as attached to the dominant culture as those at the core and they act as boundary-spanners (Meyerson and Scully 1995) better able to import ideas or practices from the outside (Hargadon and Sutton 1997). As scholars observe, network centrality is more appropriate in explaining incremental innovations that unfold in a gradual way, but less so in cases of radical innovation that are rare, sweeping in scope and unpredictable: the periphery is the established source of radical novelty (Phillips 2011; Sgourev 2013).

Trying to reconcile the two perspectives, studies have suggested that an intermediate position—in-between the core and the periphery, is most advantageous, combining exposure to the information flow in the network with the freedom to experiment crucial for radical innovation (Cattani and Ferriani 2008). Along these lines, others have suggested that an indeterminate, rather than intermediate social position has the most creative potential (Padgett and Ansell 1993; Phillips 2011). Indeterminate are the positions displaying high centrality and high marginality at the same time, when individuals maneuver between the network core and periphery or are perceived by some to belong to the core and by others—to the periphery. This allows them to retain access, but to avoid constraints and to protect their leeway.

A different research stream examines the emergence of novelty at a higher level of analysis, in the context of multiple connected networks, approaching creativity not as an individual attribute, but as a systemic property. In this perspective creativity is the product of transformations in the structure of a system composed of interlinked social networks, based on political, economic, kinship or another type of relationship (Padgett and McLean 2006). Within a multiple-network architecture novelty emerges from intersections of social-relational flows, through mechanisms such as spillover, transposition and recombination. What this practically means is that it is not individuals that produce ideas, but the flow of networks through them; individuals become the vehicles for the transposition of practices or ideas across intertwined networks. Consider that career mobility typically leads to unintended spillover and recombination as the individual brings with her from the old to the new working place ideas, practices and relationships that mix with the pre-existing practices and relationships to give rise to brand new combinations or develop pre-existing elements in a new way. Career mobility represents a particularly fertile ground for creativity scholarship, similar to other forms of biographical transposition, such as marriage or immigration, when previously disconnected networks or practices become linked and start exercising influence on each other.

This approach posits that structural transformations condition the opportunity structure of individuals, reinforcing their incentives to be creative (Lachmann 2000; Padgett and McLean 2006). The emergence of novelty is a systemic characteristic—it results from the dynamic feedback among networks. In this view, creativity is a social process where ideas are transposed and transformed from one domain to another, in a self-reinforcing dynamic that often spirals out of individual control. For example, it is well-documented that new technologies form nested recursive systems, enabling and encouraging the discovery of additional phenomena by serendipitously "bifurcating" (Arthur 2009).

At the level of the social system or field, other important structural features to consider are the degree of its cohesion or fragmentation and the extent to which dominant rules are clear or ambiguous. Fragmentation denotes the process of proliferation of groups with their own ideologies and as a result, the weakening of the conventions that regulate collective behavior. Sgourev (2013) documents that the process of fragmentation was essential in the rise of modern art in the early 20th century as it created new, viable market niches, thereby lowering the costs of experimentation for emerging artists and also reducing the ability of conservative members of the systemic core to prevent the spread of the new art. Fragmentation favors creativity to the extent that members of fragmented fields, disposing of resource space for experiments on the systemic margins and facing weak pressure for conformity from the core, are more likely to depart from established conventions and are also less likely to be "penalized" for it.

The diversity of meanings and practices that fragmentation generates invites ambiguity—the lack of clarity and certainty by virtue of the coexistence of two or more distinct ways of interpretation (Engel 1967). Ambiguity is a key factor in creativity (Lingo and O'Mahoney 2010)—the confusion created by multiple meanings promotes the reinterpretation of ideas, social construction and invention that are essential in the generation of novelty (Weick 1995). Fragmentation and ambiguity are related in that the appearance of new market niches and the resultant ambiguity over standards of evaluation alter individual opportunity structures by stimulating experimentation, thus reinforcing fragmentation—feedback loops of this kind catalyze system-level creativity (Padgett and MacLean 2006).

To summarize, the sociological approach to creativity is distinct in its assumptions. Creativity is not predetermined by personality and by individual traits but is supra-individual. It is not individuals that produce ideas as much as the network "flow" through individuals (Collins 1998). In its core, creativity is a response to opportunities (or to their lack thereof). It develops at the interstices of social worlds—where heterogeneous networks or institutional fields intersect or collide. The individual is not devoid of agency, but his or her agency unfolds in a context of higher-level social processes, which provide or deny opportunities to be creative. These opportunities are distributed highly unevenly across individuals or over time—there is ample variation in how propitious the environment is for articulation of novelty. Furthermore, creativity cannot be assumed to be strategic and proactive in nature: individuals can be compelled by circumstances beyond their control to invent new things or new ways of doing things (Lachmann 2000). Ambiguity, heterogeneity and opportunism are thus the raw materials of creativity, which unfolds through mechanisms of recombination, transposition and mixing (e.g. Burt 2004).

The Conceptual Problem

In this perspective, the key conceptual problem to resolve is that of the connection between the different levels of analysis. There is a persistent divide in existing research between micro- and macro-level processes (Ibarra et al. 2005) with structural processes remaining disconnected from individual-level mechanisms. Cattani and Ferriani (2008) argue that existing research on creativity and innovation is limited either to the individual, the network or the field, with the important link between structure and agency (e.g. Emirbayer and Goodwin 1994) remaining conceptually under-determined. This is a critical shortcoming for creativity scholarship to address. To that end, it is necessary to better understand the triple interaction between the core elements of the creative process—the individual, the networks and the socio-cultural field. There is robust evidence for the importance of personality (e.g. Eysenck 1993; Vosburg 1998; George and Zhou 2001), peer networks (e.g. Collins 1998) and the socio-cultural field (e.g. Bourdieu 1984) in creativity, but what requires particular attention are the interdependencies between them—how personality traits interact with networks and field-level norms in shaping creative outcomes. This type of analysis encompasses the identity and personality of the main protagonists, the networks they belong to and the relevant developments in the organization of the socio-cultural field. The task is to establish the explanatory power that can be attributed to each of these levels and the feedback loops between them. The application and practical value of this inductive method of inquiry is illustrated here with the fascinating cases of Laclos' *Les Liaisons Dangereuses* and Diaghilev's *Ballets Russes.* These are not exhaustive accounts—the historical narrative ties in concisely the different levels and brings into relief some of the ways in which their interaction conditioned the emergence of novelty.

Dangerous Liaisons: Bridging Micro and Macro Levels

Bridging the gap between macro and micro levels in the analysis of creativity involves a dual process: showing how structural processes create opportunities and idea-conducive conditions for individuals and then how personality and identity make it possible for the individuals to harness the opportunities presented. From this angle, some apparent paradoxes become easier to understand—as when inability to progress on a career path pushes someone with no literary experience to author a rare masterpiece.

Choderlos de Laclos (1741–1803), the author of the scintillating and scandalous *Dangerous Liaisons* (1782) has the dubious honor of remaining considerably less famous than his book. This has much to do with the fact that this was his only book—despite the immediate success of what would become an all-time classic and a standard-bearer for 18th century fiction, Laclos never followed up on it. He preferred instead to dedicate himself to politics and to the fine art of military campaigns.

Marked by a multifaceted personality and a complex professional trajectory, Laclos was born into a family that was only recently granted nobility, for whom the natural way of acquiring the prestige that adhered to families with more established social pedigree was a military career. An able military engineer, Laclos became Artillery Captain at the age of 30. Having married an impoverished member of the bourgeoisie, he proved an exemplary husband in a happy marriage. That a "family" man with a military vocation would write what is still perceived as a sophisticated manual of intrigue and adultery is a paradox that invites closer examination—of his career, the book and the context that gave rise to it.

Considering his background and professional training, Laclos is no doubt a surprising author. However, his authorship is less surprising when considering the peculiar context of late 18th century France. One of the most important characteristics of the decade preceding the French Revolution is the growing discrepancy between the professional aspirations of the bourgeoisie and petty nobility, and the opportunities for career advancement available to them. The problems of social competition and blocked mobility, created by an increasing number of candidates for a limited number of places, grew in intensity through the last decades of the Old Regime (Goldstone 1993). Like many of his peers at the time, Laclos became increasingly frustrated by the inability to accomplish his ambitions within the chosen field. His humble rank within the aristocracy and lack of means and connections curtailed severely his prospects, delivering little more than a series of assignments to provincial garrisons. The situation was inadvertently exacerbated by the prolonged period of peace, of little promise to soldiers.

In an age of growing egalitarianism, blocked mobility is experienced more intensely, reflected in the escalation of discontent and intrigues, but also pushing those of a more opportunistic disposition into pursuing professional fulfillment elsewhere. It is hardly an exaggeration to argue that the intrigues described in the book are a representation of social practices and a state of mind that was characteristic of the times. With the help of the book search technology and databases provided by Google NGRAM, evidence for this contention can be easily obtained. Searching for the words *intrigue* and *liaison* in the French database[1] shows a remarkably steep rise in the frequency of their use begging in the late 1770s. Even if some of this can be attributed to the book itself, there is little doubt that in the decade before the French Revolution, scheming behavior of different kinds was increasingly pervasive, propelled in no small measure by the blocked mobility and pent-up frustration that it inevitably engendered.

The stumped reforms, low mobility and lack of opportunities encouraged indirect ways of goal achievement, but also career transitions, when recognition was increasingly pursued not *within*, but *across* professions. In this sense, the decision of an artillery officer to seek fulfillment as a writer is less surprising that it first appears. The fact, however, that there were few precedents for a career move of this kind meant that Laclos had the liberty and incentives to experiment, bringing completely new elements to fiction writing and revamping a tired literary genre. This is the structural underpinning of the creative breakthrough that was *Les Liaisons Dangereuses.*

As a work of fiction, it is very difficult to categorize. It belongs to the established epistolary form of a novel based on personal letters. This kind of sentimental novel originated in England with Samuel Richardson (*Pamela*) and blossomed in France (e.g. *Julie or the New Heloise* by Rousseau). What is truly innovative about Laclos's book is that it uses an accepted, somewhat outdated literary genre as a vehicle to convey progressive ideas associated with the Enlightenment, related to personal freedom and the absence of constraints (religious or moral). If the novel is centered on an established literary figure—that of the "libertine" (*Valmont*), Laclos imbues it with a new meaning, embedding it in the context of contemporary philosophical debates about the role of reason and individual freedom. Here the personality of the libertine is not reduced to the insouciant pleasure-seeker of days past but is characterized and animated by the emancipating forces of reason. The figure of the modern libertine is much more complex than that of its literary predecessor, as he or she pursues not simply pleasure, but freedom of constraints. As Vailland (1963) points out, in this understanding the libertine always

[1]The graph is available online at the following HTML address: https://books.google.com/ngrams/graph?content=intrigue%2C+liaison&year_start=1700&year_end=1900&corpus=7&smoothing=3&share=&direct_url=t1%3B%2Cintrigue%3B%2Cc0%3B.t1%3B%2Cliaison%3B%2Cc0.

plays the others and never lends himself or herself fully to anyone or anything. Not out of weakness, but out of strength, of a desire to assert the dominance of his or her character and avoid sanctioning by others.

The *Liaisons Dangereuses* straddles two epochs, drawing heavily on the tradition of the 18th century sentimental novel but introducing many new elements found nowhere else in past literature. It is a distinctive concoction of past and present, with new ideas in old disguise. The most striking new aspect of the book is that, as Malraux (1970) famously argued, the marquise de Merteuil and vicomte de Valmont are characters without a precedent—they are the first in European literature whose acts are determined by an ideology. According to Malraux, the foundation of this ideology is the belief that the gifted individual has the opportunity to distinguish herself as a result of her assessments of people and situations, and of the knowledge of how to manipulate the laws governing human interaction in order to achieve control over the actions of others. The objective of the modern individual is not satisfaction of desires, but taking charge of her life and systematic realization of her intentions through the skillful navigation of social networks and the calculated use of maneuvers to mislead and thwart others' plans.

It is here that the essence of Laclos' creativity is most apparent. The book is a testament to the importance of the core Enlightenment principle of Reason; it is shot through with references to a set of ideas that circulated at the time within friendship circles and at fashionable Salons, but the way in which they are articulated is specific to an author with an identity forged by a major career shift. The particularity of the novel is a result of the author's applying military expertise and language to fiction. An artillery officer and engineer responsible for military fortifications, Laclos was by profession, taste and education a geometer (Vailland 1963) and it was the geometer—rather than the Enlightenment man—who wrote this book. Unsurprisingly, Laclos wrote a novel in a military format, about the assault of a fortress in an amorous game. The method used by the key protagonists is precise and premeditated, it belies the state of mind of a skilful general on a field of battle whose aim is not simply to vanquish but never to lose control of the enemy's movements (Allan 2012).

The story of an unusual sentimental novel, conveying Enlightenment ideas in a military format is a befitting testament to the warps and twists that accompany the creative process. That *Les Liaisons. Dangereuses* is an odd and unexpected, but utterly irresistible concoction, was already felt at the time it was published. In hindsight it represents an early illustration of the fact that most genuinely creative advancements are unexpected, a result of spontaneous, unpredictable amalgamation and permutation of ideas and biographical lines (see Simonton 2004). The challenge for the structural scholarship on creativity is elucidating the trajectories of permutation and the feedback loops between individual and structural attributes. In this regard, it is important to understand how blocked mobility and career change served to reinforce an already ambiguous, contradictory identity that powerfully shaped the creative process.

It is a key principle in sociology that identity (the core features of the self) matters, as it makes us more responsive to some incentives than others and as it filters and refracts information and ideas in a way unique to each individual. Identities are generally stable and are reflected in everything we do. They do not update automatically when we change our profession, social class or circle of friends—we continue carrying with us elements from the past into the new workplace, residence or social network. Naturally, such transitions contribute to increasing heterogeneity in the system. But more importantly, they place individuals—for some period of time—in a transitionary state of mind, where new problems are viewed from an old perspective and old problems are reconsidered in light of new information. The probability that new, unexpected combinations of elements appear in this state of mind is anything but trivial. When inconsistent identities are reinforced by career transposition, the potential for creativity is further augmented—not only because of the spillover of ideas and practices across domains, but of the heightened tolerance for inconsistency and for transgressing boundaries inherent in such identities.

An indeterminate social position: in-between occupations, economic classes or social networks is counterpart to an ambiguous identity. Laclos' ambivalence towards the world that he depicts is to a certain extent a reflection of the indeterminate, contradictory social position of a petty aristocrat with frustrated professional ambitions. The same way that he could not stop being a military engineer when writing the book, he could not also stop being a member, albeit low-ranked, of the privileged class. If the novel is a critique of a society whose deficiencies Laclos is well familiar with, it does not augur the Revolution, as even in his criticism, the author remains fascinated with the aristocracy (Crépin 2004). The contradiction, noticed by literary critics, that Laclos denounces Valmont but wants to be like him *at the same time* (e.g. Malraux 1970) is a manifestation of the love-hate relationship to the world that he wants to destroy (Vailland 1963). The complex psychological drivers of the key protagonists mark an important new development, positioning the work closer to the 19th than 18th century literature, but this complexity emanates from a convoluted biographical trajectory, which made a writer out of a military officer, a politician out of a writer and to close the circle, a military officer out of a politician.

Bridging Different Worlds: Sergei Diaghilev and the Ballets Russes

The mechanisms discussed so far are not particular to one case; their broader relevance can be exposed in other settings with different protagonists. The turmoil and stasis characterizing the decade preceding the French Revolution bears strong resemblance to the decades preceding the Russian revolution. One emblematic figure of that period is Sergei Diaghilev (1872–1929)—a producer and an artistic visionary who revolutionized the performing arts in the early 20th century with the ballet company he created in Paris—*Les Ballets Russes* (1909–1929). The concept behind the *Ballets Russes*—the synthesis of the arts—gestated in the community of artists involved in the "*World of Art*" journal in Saint Petersburg in the last decade of the 19th century. After the unsuccessful revolution of 1905 in Russia dashed the hopes for reforms in the political and cultural domains, Diaghilev looked abroad. In 1909 he brought the Imperial Russian ballet to Paris, in 1911 he left Russia and established himself in Europe, forming his own ballet company, which existed until his death in 1929.

Diaghilev's creativity manifested itself most visibly in the manner in which he set about to renovate the formal language in ballet—the structure, vocabulary and technique of artistic expression. He was convinced of the necessity for ballet choreography to explore new paths and keep in line with contemporary developments (Grigoriev 1953). Hence, he chose the most visionary and avant-garde choreographers, visual artists and composers to make ballet performances relevant to the present. He assembled an unprecedented constellation of dancers, composers, designers, and painters, including Picasso, Debussy, Cocteau, Ravel, Prokofiev, Nijinsky, Stravinsky, Pavlova, Fokine and many others.

Diaghilev orchestrated a mutually inspiring collaboration between music, design and dance, where creativity thrived like never before. The *Ballets* transformed many domains of artistic life—revitalized opera, dance and scenography, shaped profoundly fashion, furniture and textile and made ballet the platform of great artistic innovation (Pritchard 2011). Designers and visual artists found a source of inspiration in the *Ballets Russes* to defy established boundaries and aesthetic conventions, creating extravagant costumes and set designs for the exciting productions. Fusing the most avant-garde, groundbreaking movements in dance, choreography, art, design, and costume, the productions of the *Ballets Russes* stretched the limits of the possible in art, astonishing audiences and transforming Western culture in the twentieth century (Rand 2009). They redefined for the early twentieth-century viewers what art could be, while visual artists used the dancers to help them in developing modernist vocabularies (Jones 2013).

A very important characteristic of the *Ballets Russes* is that it served as the interface between the creativity of individual artists and broader socio-cultural processes that transformed opportunity structures. Diaghilev was a broker between multiple worlds. He connected, coordinated and controlled a network of artists, including the best young dancers, choreographers, composers and painters. At the same time, his network of financial supporters and high-society patrons permitted him to finance lush performances that attracted a large and fashionable audience. The *Ballets Russes* left a lasting impact on the arts wherever they traveled, exposing audiences to a medley of modernist ideas, Russian culture and oriental motifs. Their nomadic existence, travelling from country to country, promoted a new kind of ballet in the countries visited, diffusing modernist ideas internationally (Lifar 1969).

Diaghilev's important brokerage role was made possible by processes of field fragmentation and the emergence of viable market niches for artistic experiments (see Sgourev 2013). However, it was his eclectic, multidimensional identity that enabled him to fulfill the role of a cultural broker so well. The eclecticism was nurtured in the small world of Russian intelligentsia, where boundaries were crossed out of necessity and where he mastered the art of mediating between genres and artists with different ideologies. His multidimensionality was crucial: his aristocratic origin connected him to high society, his artistic achievements appealed to members of the avantgarde, while his network enabled him to recruit very talented artists and performers, driven abroad by the conservative regime in Russia.

The conservative cultural context in Imperial Russia was important in two respects. First, it served inadvertently as the incubator of practices of "synthesis of the arts", as the underdevelopment of modern art forms impelled their unity as a means for survival. That the result was then successfully transplanted into the dynamic Parisian art scene is not devoid of irony. Second, the habitual repression of new ideas in the theatres radicalized talented artists by denying them opportunities for advancement and for creative expression, pushing many of them abroad. Inside Russia revolutionary ideas had been stirring for years and were already infiltrating ballet (McDonald 1975). The transposition of these radical ideas and practices of synthesis from Russia into the effervescent French art world catalyzed the development of modern art through the dynamic interaction of heterogeneous cultural elements.

The observation that the influx of sophisticated and ambitious outsiders with an established network played a key role in the acceleration of collective creativity agrees with Padgett and Powell's (2012) assertion of "immigration and homology" (the relocation, rewiring and absorption of networks into existing structures) as a core mechanism of "emergence". When entire subsets of new networks, are rewired into old ones, the rewiring transforms both sides, promoting processes of recombination. Thus, the wide use of folkloric motives in early 20th century art, such as the colorful primitivism of Gauguin or Cubist interpretations of African art, stimulated the Russians to mine the rich ore of their mythological past (Hodson 1987), while their explorations of primitive Slavic rites exposed to French audiences core tenets of modernism—such as how restricted, minimal movement liberates expression. The elements brought by the *Ballets* to Paris were Russian in origin, but were reinterpreted on foreign soil and enriched by interaction with local elements, obtaining a new force of action (Semenova 2010).

The role of structural factors in the flourishing of modernism in early 20th century Paris was paramount: the hybridity emanating from the transposition of competent and motivated outsiders into a munificent environment, and the melding of diverse elements proved the raw material for creativity. As Padgett and Powell (2012) point out, innovation is often triggered by unanticipated transpositions of people from one domain to another, who carry with them production skills and relational protocols that combine with and transform skills and protocols already there. The transposition highlighted here assumed two forms: across professions and across countries. In pre-revolutionary Russia and France the systemic blockage—stumped reforms and lack of opportunities for professional advancement, led to accumulating frustration and increased mobility across domains as individuals sought opportunities in a broader range than usual. An important consequence of the unsuccessful February and successful October Revolutions in Russia was massive emigration that scattered talent abroad. The *Ballets Russes* benefited from this development, not only preserving the creative energy of those leaving, but using it to provoke and catalyze artistic innovation. When artists passed through the *Ballets Russes*, it rewired established ways of not only making art, but of thinking about possibilities in art.

Conclusions

Creativity is never a solitary act, it is a complex social process where personality and identity at the individual level interact with structural factors at the level of the network and institutional field. It can be catalyzed by brokers operating in multiple contexts (Sgourev 2015) and by biographies that weave their way through networks and fields. It transpires in those unexpected combinations, such as when an artillery officer is denied routine career advancement and starts writing a sentimental novel or when a journal editor and failed theater director is pushed into exile, putting together opportunistically the most revolutionary company in the history of the performing arts. If widely believed that creativity is fostered by openness, blockage can prove an equally powerful catalyst, when inversing career paths and transposing elements across contexts. It is not always people who make unexpected combinations: these are sometimes made ***for*** them.

A recent newspaper article[2] highlighted the fact that all the key figures in German postwar art, were brought up in the East and emigrated to the West. Polke, Lüpertz, and Palermo were childhood refugees, the others were trained in the German Democratic Republic (GDR), but refused to conform to the socialist reality and left. These artists had to make a new start, accommodate to a new system, rethink the boundaries and possibilities of art. Certainly, biographical transposition of this kind is not a magic potion for creativity; however, when applied to talented and committed persons, it can give rise to self-interrogations and identity shifts that inform more profound and sustained artistic inquiry.

Unexpected transformations introduce contradictions, force individuals to improvise, wean them off established routines, promote emotional ambivalence—factors associated with the capacity to discover and forge new connections and recognize hidden patterns. In this regard, there is still much ambiguity over the nature of the socio-psychological triggers of exceptional creativity—to what extent they reside within or outside the individual? If there is little doubt over

[2]"Germany Divided'—Duerckheim collection at the British Museum" by Jackie Wullschlager, The Financial Times, published online on 31/01/2014. Retrieved on 04/05/2014.

Mozart's exceptional talent and the role of his father's guidance, one can also inquire whether the inability to find stable employment was linked to his remarkable audacity to defy conventions in his music. A self-perception of detachedness and the lack of obligations to a royal employer might have reinforced the willingness to take risks and reduced the cost of experimentation, which proved prohibitively high for even talented contemporaries of his.

Implications for Future Research

Case studies of this kind are instrumental in developing a systemic approach to creativity, featuring micro and macro analytical levels and their dynamic interdependence. However, their limitations in terms of generalizeablity are apparent. An important avenue for future research is the development of qualitative and quantitative research methods that analyze creativity at different analytical levels at the same time, capturing how structural factors create conditions for individual creativity, and how these conditions induce novelty in the context of particular identities and sets of individual characteristics.

Priority should be given to models that describe not creators, but how their ideas travel. These models should be designed to capture the plasticity of ideas by tracing "idea paths"—the trajectories whereby ideas emerge and subsequently mutate by changing features and forms. Understanding where ideas come from and how they evolve, elucidating the process and mechanisms of creativity, is a scholarly challenge of the highest order. It requires developing methods and paradigms that describe the creative act in its remarkably complex nature—every bit as convoluted and opportunistic as the cases narrated here showed it to be.

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Chanel's Creative Trajectory in the Field of Fashion: The Optimal Network Structuration Strategy

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Background

Creativity research has long been polarized between the "romantic" view that major creative achievements originate from imaginative and uniquely gifted individuals at the margins of an intellectual field (Coser 1965); and the competing view that emphasizes how individuals in the core of the field's social structure have access to more abundant resources and hence enjoy greater opportunities to mobilize attention and support for their work (Collins 1998). In this chapter, we probe the inherent tension between these two perspectives by combining research on the social side of creativity with organizational studies that have documented the role of marginality as a source of institutional change (Kraatz and Moore 2002; Leblebici et al. 1991) and creativity (Cattani and Ferriani 2008). As Bordieu (1993) pointed out, fields of cultural production are in an incessant state of struggle between *incumbents* and *outsiders*, who compete for symbolic attention and recognition based on subjective rules of merit as well as the vested interests and social objectives that they embody. The structural outcomes of this struggle have been variously conceptualized as dichotomies that classify cultural producers into incumbents and newcomers, insiders and outsiders, orthodox and heretics, core and peripheral players.

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Building on Cattani and Ferriani's (2008) study on the relationship between individual actors' creativity and their position along the core-periphery continuum of their field's network structure, we suggest that peripheral actors are more likely to produce unconventional work as they are less constrained by the field's norms and standards of evaluation. Unlike core actors, however, they do not have the ability to mobilize constituencies and solicit recognition for their work. As individual actors progress towards the core and become more embedded within the field's social structure, conformity to the field's institutionalized norms and standards is increasingly stimulated and even rewarded—which in turn constrains any attempts to deviate from them. In order to resolve this tension, we illustrate the properties of a network strategy which we term *optimal network structuration strategy* (McLaughlin 1998; Cattani et al. 2013). In its basic form, this strategy embodies the sociological notion of *optimal marginality* developed by McLaughlin (1998, 2000, 2001). Optimal marginality describes a distinctive social position that fosters creativity by combining embeddedness within an intellectual field with "*a sociologically created distance from intellectual orthodoxies*" (McLaughlin 2001, p. 272).

This strategy identifies a distinctive social position whereby the level of embeddedness in a field does not prevent the social distance required to avoid intellectual entrenchment. By pursuing an optimal network structuration strategy innovators can reconcile originality and resourcefulness without undermining their ability to make their work manifest and visible to the field. While the idea of "strategy" might suggest intentionality, we remain agnostic about the actual intentions behind an individual actor's behavior. In other words, our main argument revolves around the implications of occupying a particular position along the core-periphery continuum of a field's social structure, regardless of whether that position is also a matter of conscious choice.

We outline the key features of this strategy and study its implications within the context of the *haute couture* field. Specifically, we conducted—and drew insights from—an in-depth historical case study of Gabrielle "Coco" Chanel's creative trajectory as a fashion designer from the early years of her career to her rise to success and final consecration as fashion icon. The case method is well-suited for studying the kind of radical transformations Chanel introduced into the field of fashion because, unlike large-sample studies, it allows for a more detailed investigation of the processes operating at different levels of analysis, i.e., the individual, the audiences and the field.

Method and Data

A case study of Chanel's career as a fashion designer sheds light on a unique creative trajectory in a highly creative field. Scholars agree that Gabrielle "Coco" Chanel was the most famous and innovative woman in the history of fashion (e.g., Steele 1993). She was the only fashion designer to appear on *Time* magazine's list of the 100 most influential people of the 20th century (Horton and Simmons 2007). The use of a historical case study is appropriate when the phenomenon under investigation displays complex dynamics and context-specific meanings

(Hargadon and Douglas 2001). It allows for the distance that is needed to observe the complex interplay between the forces and actors involved as it unfolds over time (Kieser 1994). The historical case method is particularly appropriate for our study because the goal is not to produce universally generalizable results, but instead to demonstrate the potential of the theoretical approach presented. In particular, our study illustrates how the notion of optimal structural strategy can shed light on Coco Chanel's creative trajectory over time in the face of broader environmental developments (Siggelkow 2007).

We consulted several bibliographical sources and published books that describe in great detail Chanel's unconventional trajectory. Available sources are either biographical (Charles-Roux 2005[1]; also: Mackrell 1992; Madsen 2009; Chaney 2011); or historical (Morini 2010; Rennolds-Milbank 1985). But other sources on Chanel's life and career also provided additional contextual information, particularly the work by Steele[2] (1993, 2009) and sociologists of fashion (e.g., Bourdieu and Delsaut 1975; Crane 2000; Kawamura 2005). Finally, we consulted Morand's (2008) memoirs of Chanel, the main source on her life. Historical narration often identifies relatively simple patterns from complex accounts in order to facilitate comprehension of past choices and events. By using several sources, however, we can more confidently trust the congruence between our data and information (Smith 1975). Also, the triangulation resulting from using multiple sources further reduces the risk of biased points of view (Jick 1979). Even as an individual case study does not yield results that necessarily generalize to other cases, it nevertheless can help delineate concepts and propositions to inform theory on individual creativity.

Chanel's Creative Trajectory

Gabrielle "Coco" Chanel has been considered the leading designer during the period between World War I and World War II. In 1935, 20 years after the opening of her first boutique in Deauville, she ran a fashion house, a textile business, and a costume jewelry workshop, employing 4000 workers who produced 28,000 items per year; she also owned 10 % of Les Parfums Chanel SA, a very lucrative business (Grumbach 1993; Morini 2010). Yet, in 1939 she closed the House of Chanel and re-opened it fifteen years later. That Chanel was "*able to begin again in 1954, at the age of 71, and make a success of it, was something of a miracle*" (Steele 1993, p. 124). A socio-structural approach to creativity provides a useful lens to study the process by which Chanel first emerged from the periphery of the *haute*

[1]Edmonde Charles-Roux was the first biographer of Chanel (*L'Irrégulière ou mon itinéraire Chanel* 1974; *Le Temps Chanel* 1979) and she has been *Vogue*'s editor-in-chief from 1954 to 1970.

[2]Valerie Steele is director and chief curator of the Museum at the Fashion Institute of Technology.

couture field and then made a comeback after fifteen years of voluntary retirement. Tracing Chanel's life is crucial for understanding the unique conditions that shaped her creative trajectory over time.

Born to a humble family in Saumur in 1883, she was the illegitimate daughter of a laundress and a travelling peddler. At the age of twelve, after her mother's death, she was sent away to an orphanage where she spent nearly seven years (Charles-Roux 2005). In 1909, Chanel started her career as a milliner in Paris with the financial support of first Etienne Balsan and then Arthur "Boy" Capel, her two lovers. Initially, Chanel designed hats, simple and with no ornamentations, to react to the dominant *belle époque* fashion style. But her goal was also to change the rest of the women's attire through the introduction of casual clothes (Madsen 2009; Charles-Roux 2005). Chanel's humble origins proved decisive for the development of her unconventional style. For instance, her taste for black and white came from the time she spent at the Abbey of Aubazine, as the uniform worn by the orphans had inspired it. In addition, she created the first informal, loose, corset-less look, taking inspiration from the males' attire: English sailor's turtleneck sweaters, uniforms used for horse riding, baggy and comfortable pants have strongly influenced her masculine and sporty style. A few years earlier, the leading designer Paul Poiret (1879–1944) had started the revolution against the corseted silhouettes. While Poiret's fashion style was still highly decorated and colorful, Chanel decided to depart from his "*beguiling excesses, the flowing understatements of Vionnet and Lanvin, or the secure rectitude of Worth and Doucet*" (Madsen 2009, p. 69). Chanel's resentment against French society's established order gave her both the motivation and the energy to pioneer a new—at the time rather unconventional—sporty style. This style challenged the leading fashion designers who formed the core of the *haute couture* field (Steele 1993). She opened her first shops in Deauville (in 1913) and in Biarritz (in 1915), so becoming financially independent. In 1919, she opened her famous boutique in Paris. By creating the first informal, loose, corset-less look, Chanel initiated a revolution in fashion (Steele 1993). It soon became clear that Chanel's style had "*everything to do with elegance but is founded on elements once considered foreign to it: comfort, ease and practicality*" (Rennolds-Milbank 1985, p. 120). Chanel transformed not only the female silhouette, but also the textiles used for dressmaking by introducing knits, flannels and jersey, and turning them into fashionable *haute couture* fabrics (Mackrell 1992).

In light of our conceptual framework, the fashion field can be described to exhibit a core-periphery social structure comprising a small cohesive group of core actors and a much larger group of peripheral actors loosely connected to the core (Borgatti and Everett 1999; Cattani and Ferriani 2008). Typically, core actors are deeply embedded in the field's social structure and hence tend to share very similar ideas and habits. They tend to be key members of the field and to have developed dense connections among themselves, with many of them acting as network gatekeepers. This was the case of influent fashion designers like Jaques Doucet (1853–1929), Jean Patou (1880–1936), Jeanne Paquin (1869–1936), Madeleine Vionnet (1876–1975), Jaenne Lanvin (1867–1946), and Paul Poiret

(1879–1944), who dressed many Courts and whose fashion houses were visited by all great ladies of Paris and from elsewhere. By contrast, peripheral actors tend to reside closer to the margins of the field's network structure and are not as visible or socially engaged as those in the core. As the case of Chanel suggests, however, peripheral actors are more likely to depart from traditional ways of thinking, explore untapped areas and pursue more divergent ideas that may translate into more unconventional creative work (Walton and Kemmelmeier 2012). For instance, during her formative years at the Aubazine orphanage Chanel learned the art of sewing and developed an unconventional style, based on men's rules and garments: her first creations were the feminizing of the masculine fashions (Steele 1993).

Although her designs were highly innovative and more comfortable than the cumbersome outfits that the established designers were proposing, Chanel did not have the same influence to draw attention to and promote consensus around her work. Until mid-1920s, in fact, Chanel was not a famous fashion designer (Steele 1993; Bourdieu and Delsaut 1975) and struggled to obtain recognition, especially from critics and peers. Fashion magazines continued publishing "traditional" designs proposing eccentric and encumbering outfits, even as women increasingly had embraced the revolution that was already affecting their lifestyle and wardrobe. Also, professional dressmakers like Vionnet dismissed Chanel as a milliner (Morini 2010; Steele 1993; Charles-Roux 2005). Chanel indeed knew little about the technical aspects of dressmaking and relied on her *premieres*[3] as she was known as a fashionable personality, a woman of style, before becoming famous as a designer—a circumstance that would prove extremely important for her subsequent career.[4]

Legitimacy Building and Progression to the Core

As the social-psychologist Csikszentmihalyi (1996, p. 23) puts it, creativity "*does not happen inside people's heads, but in the interaction between a person's thoughts and a sociocultural context*." Whereas the individual generates new variation by interacting with the field, the field in turn conveys legitimacy back to the individual and thus determines which creative act is eventually retained and supported (Ford 1996; Cattani and Ferriani 2008). Indeed, what we call creativity "*is a phenomenon that is constructed through an interaction between the producer and audience … creativity is not the product of single individuals but of social systems making judgments about individuals' products*" (Csikszentmihalyi

[3]Short for *premieres mains*, "first hands", skilled dressmakers who translated Chanel's vision for everyone else and realized the garments.

[4]Chanel was the woman that other women wanted to look like, as she was the epitome of the modern woman (Steele 1993).

1998, p. 41). The thrust of this argument is that creativity stems from the interplay between the individual creative act and the enabling social context that decides whether or not the creative act should be endorsed and legitimated. From this perspective, creativity presupposes the existence of social judgments or evaluations from which attributions of creativity originate.

This view of creativity echoes current formulations of sociologists who consider legitimation as a collective process that implies the presence of both social objects (i.e., a creative work) and social audiences that evaluate them (Hirsch 1972; Crane 1976; Becker 1982; Zuckerman 1999; Zelditch 2001). As explained by Johnson et al. (2006, p. 57), legitimacy depends on "*the implied presence of a social audience, those assumed to accept the encompassing framework of beliefs, norms, and values, and, therefore, the construal of the object as legitimate*". Besides the initial investors who believed in Chanel's creativity and talent, important clients were the first social audience to recognize Chanel's work. These early clients included glamorous and influential people like the Baroness de Rothschild, the society lady Antoinette Bernstein, and the actress Cecil Sorel. Chanel had become in fact a fashion iconoclast modeling her subversive sport clothes, and society ladies were charmed by her creations and her individual style (Steele 1993; Rennolds-Milbank 1985). Their support enabled Chanel's transition from the periphery to the core of the *haute couture* field.

The real turning point in the recognition of her work was then reached during WWI. In an interview with Paul Morand in 1946, remembering that period, Chanel claimed: "*One world was ending, another was about to be born. I was in the right place; an opportunity beckoned, I took it. I had grown up with this new century: I was therefore the one to be consulted about its sartorial style. What were needed were simplicity, comfort and neatness: unwittingly I offered all of that. True success is inevitable*" (Morand 2008, pp. 42–43). Fashion was "behind the times" and it was difficult to modernize in the early 20th century (Charles-Roux 2005). But Chanel's style appealed to the women's new lifestyle. Her appeal was in fact her modernity: simplicity, shorter skirts, and new, more comfortable, materials (e.g., machine-knit jersey). The war initiated the whole process of liberation of women and offered a unique occasion to get emancipated: women were in fact asked to work in the industry as men went off to war, and found themselves with new opportunities for the first time. Women increasingly acquired an active role in the society and were also looking for a new social identity. As Crane noted, Chanel "*presented her clothes as suitable for a new lifestyle that was being adopted by young women during and after the First World War*" (Crane 2000, p. 150). In fact, she created the uniform for the modern bourgeois woman, an independent working woman like her. The consumers granted her design and fabric innovations immediate recognition. By the end of the summer of 1914, she earned 200,000 gold francs (Morand 2008; Morini 2010).

After WWI, the recognition from multiple audiences—the public, which acquired her functional-chic, yet very expensive, creations; the gatekeepers (e.g., society ladies and fashion critics), who applauded her creations; and the intermediaries (e.g., international buyers), who spread her style abroad—catapulted Chanel into the core of the *haute couture* field. Her sports clothes were probably the strongest influence in fashion and her peers—e.g., Patou, Lanvin, Vionnet—followed her creations by introducing a sport line in their own collections. Chanel's fashion rapidly expanded its influence to many areas of social life, becoming an important part of the revolution in manners and morals during the 1920s, the so-called "reckless twenties" (Madsen 2009).

The transition from the periphery to the core of the field places individual actors in a position where they can influence the process by which existing gatekeepers evaluate their creative work. Indeed, Chanel found herself in a position that enabled her to shape the norms and standards of the *haute couture* field in two ways. First, Chanel's recognition as a genuinely creative fashion designer was based on her own image: a fashion iconoclast and a modern woman who epitomized the liberated woman of the 1920s. In the Parisian society she was well-known as a fashionable personality: she was "*her own best model*" (Steele 1993, p. 120) and "*the woman that other women wanted to look like*" (Steele 1993, p. 123). The Baroness de Rothschild asserted that Chanel was "*not only a milliner of talent, but a* (fashion) *personality*" (Madsen 2009, p. 73). Second, Chanel leveraged her relationships with influential actors in the society—wealthy elites and celebrated artists—to spread her style and obtain recognition. In particular, she banked on her contacts with the artistic avant-garde[5]: the Diaghilev's entourage, the poet Reverdy, the musician Stravinsky, the cubists (e.g., Picasso) and, in general, the network of artists of her close, yet influential, friend Misia Godebska-Sert. With them, she contributed greatly to the development of a new expressive form for the 20th century (Morini 2010), an assertively modern style.[6] This cultural movement ultimately promoted a new set of aesthetic standards, emphasizing geometric forms, symmetrical patterns, simple shapes and modern materials (e.g., Hillier 1968), which eventually were used in all the applied arts (e.g., Steele 1993). In a nutshell, Chanel's style spread out and gained recognition because it synthesized all the predominant elements of her time: a simple and comfortable fashion style, and the abandonment of ornamentation—a trend observable in all the decorative arts. As her creative work matched the standards that gatekeepers employed in both fashion and art, Chanel first developed and then became the epitome of a look that the entire modernist movement—with its opposition to the past—shared as well. Chanel also assimilated the Art Deco movement's idea of "functionality" (i.e., function became an important requirement for all the Art Deco products) and turned it into a new creation: the "little black dress" (*la petite robe noir*), which became the uniform for women and a symbol of the modern age.[7] In 1926,

[5]For instance, in an important theatrical production with Diaghilev, "Le Train Bleu", she cut the hair of the ballerinas to bring her masculine style to the fore and used real casual clothes (those sold in her boutique) rather than costumes.

[6]The Art Deco spun off from French avant-garde movements like the Cubism and the *Ballets Russes*.

[7]The corseted silhouette moved to a narrow, relaxed, almost semi-fitted silhouette (i.e., the tubular clothing silhouette), more appropriate to women's new lifestyle.

American *Vogue* named the dress "*a Ford signed Chanel*" (American *Vogue*, 1st October, 1926). Functionality, modernity, simplicity were all characteristics of her style, yet they were also the product features of the Bauhaus, Gropius, Breuer and the Dessau School.

The Core-Periphery Trade-off

To the extent that the field rewards actors that conform to its norms and standards, and penalizes those that deviate from them, core actors have clearly little incentive to pursue unconventional work (Crane 1976). Yet permanence in the core is unlikely to pay off in the long run as cultural fields might evolve and even change, thus leading to a revision of the criteria by which individual actors' creativity is judged. In the case of Chanel, during the 1930s fashion was more varied than in the 1920s because taste was changing (Charles-Roux 2005). Fashion was based on an ornate and extravagant romance, driven by the fantasies of Hollywood and a desire to return to a more traditionally feminine image for women. Accordingly, the hemlines dropped again to just above the ankles, the market demanded more imagination, more glamour and a greater consistency with the Hollywood's imaginary (Chaney 2011; Morini 2010). Furthermore, new competitors came along threatening Chanel's supremacy, Madeleine Vionnet with sartorial skills and Elsa Schiaparelli with fantasy and imagination.

Realizing that her style had gone out of fashion, Chanel changed her simple designs by introducing more feminine silhouettes and the use of some decorations. In particular, the strongest competition came from Schiaparelli's innovative design, replete with playful references to surrealism, which was garnering critical acclaim and generating enthusiasm in the fashion world. In 1935, British *Vogue* dedicated the Christmas cover to Schiaparelli, and society ladies and Hollywood stars became devoted to her witty and outrageous designs (Chaney 2011). Although her creative talent was widely acclaimed and recognized, Chanel experienced a mid-career creative drought (Perry-Smith and Shalley 2003). Creativity research has pointed out that an individual's ability to produce creative work in the past is negatively related to the propensity to produce unconventional work in the future (Audia and Goncalo 2007). In the 1920s, Chanel's sport clothes represented the dominant style in fashion, but in the 1930s Chanel "*entered something of a creative slump*" (Steele 1993, p. 123). As she kept proposing her old designs, her creations were no longer in tune with the emerging trends in fashion and market demand (Morini 2010). Photographs of her clothes in the fashion magazines of the day show "*more conventional long evening dresses, even tea-gowns*" (Steele 1993, p. 124). And, as a result, to the "*modern eye, for the first time she looked a little dated*" (Chaney 2011, p. 315).

Entrenched in the prevailing conventions, core actors can become increasingly reluctant to explore new areas and their intrinsic motivation might even decline due to their continued adherence to a "winning style" (Faulkner and Anderson 1987).

As core actors become increasingly immersed in the field's network structure, it becomes "*unmanageable or extremely difficult to break free of the web of ties and to see beyond them to new ideas*" (Perry-Smith and Shalley 2003, p. 100). Feeling she was losing her leading edge, Chanel continued to design for the theatre by collaborating with Cocteau on his *piece* "Oedipus Rex" in 1937. But the critics considered her costumes—a strange interlacement of mummy-like wrappings—to be indecent and unimaginative (Charles-Roux 2005). Her 1937/1938 fall collection was also criticized: critics perceived her work as conservative and predictable, whereas the work of Schiaparelli and Vionnet as highly creative (Madsen 2009). This change in evaluation reflected corresponding changes in the gatekeepers' (e.g., fashion critics') norms and standards. For instance, in 1938 British *Vogue* noted how "*sex appeal is the prime motif of the Paris collection and sex appeal is no longer a matter of subtle appeal*" (Madsen 2009, p. 221). The excess of fantasy and luxury of the fashion style during the late 1930s posed a serious challenge to Chanel's sense of order and rigor.

The Optimal Network Structuration Strategy

Our sociologically grounded view of creativity recognizes that the generation of novelty and its recognition are two sides of the same coin. Specifically, we have described the tension between the production and the recognition by relevant audiences of divergent creative work as a journey along the core-periphery continuum of a field's social network structure. We suggest that individual actors can navigate this trade-off by forming ties that allow them to span both extremes (the core and the periphery) but without becoming embedded in either of them, a strategy which we term *optimal network structuration strategy*. In its basic form this strategy embodies the sociological notion of optimal marginality developed by McLaughlin (1998, 2000, 2001). Optimal marginality describes a distinctive social position that ultimately enhances creativity by combining embeddedness in a field with distance from the establishment of that field. The optimal network structuration strategy allows for greater exposure to fresh stimuli and insights that typically spill over from the periphery, while at the same time preserving the legitimacy that is indispensable for producing and sustaining new creative work (Cattani et al. 2013). Core actors can try to recharge their creativity and escape the conformity pressures that originate from the field core by moving close to the periphery.

As we noted before, in the late 1930s Chanel's creations looked too "conventional" (Collins 1998) and so she lost her avant garde edge. In 1939, at the beginning of WWII, Chanel was still running a profitable business that employed about 4000 workers: La Chambre Syndacale de la Couture Parisienne tried to convince her to stay open to support the national economy. Yet Chanel felt it was no longer a good time for making clothes and closed her fashion house. She realized that "*she had nothing to say to the fashion world, society had evolved in a way that was inconsistent with her ideas and, in order to avoid a slow exit from the market,* *it was necessary to break with it. Like an artist who stops creating*" (Morini 2010, p. 252, our translation).[8]

In her fifteen years of voluntary retirement, spent in Switzerland, Paris and New York, she continued to stay in touch with fashion critics and celebrities, and did not turn her back completely on the business activity: she owned 10 % of "Les Parfums Chanel" and commercialized fabrics under the brand "Chanel" (Morini 2010). In the postwar period, she felt the time was right for her simple and understated elegance. The Parisian scene was dominated by the so-called "New Look" proposed by Christian Dior, Cristobal Balenciaga and Jaques Fath who had imposed a very different style emphasizing seductive designs and dresses with artificial shapes, unveiling sumptuous collections. In 1954, thanks to the profits from her perfume *Chanel No. 5*, Chanel decided to come back to the *haute couture*. She felt the time was ready for her simple and understated elegance. While Dior's aim was "*to save women from nature*" (Steele 2009, p. 22), Chanel had always wanted to liberate women and to make them live naturally in their clothes. Before organizing her comeback collection, she wrote a letter to the fashion editor of *Harper's Bazaar*, Carmel Snow, in which she declared her willingness to return: "*No doubt I have already told you that sooner or later I'd resume my métier, which consists of creating a new style adapted to a new life-style, and that I was waiting for the opportune moment*" (Madsen 2009, p. 285). She created something unique that deviated from the New Look as the image that she "*was portraying was very different from that of Dior and he was one of the reasons that Chanel decided to come out of retirement*" (Kawamura 2005, p. 69).

The French press criticized Chanel's comeback collection, which apparently harked back to her prewar silhouette, though "*the Chanel suit of the 1950s was significantly different from the ones she had designed in the 1920s and 1930s*" (Steele 1993, p. 125). In fact, it became a successful radical opponent of the dominant style, i.e., the New Look. She offered little tailored suits that unexpectedly were sold quickly on the US market where women enjoyed her new designs (Steele 1993; Charles-Roux 2005; Morini 2010). Then *Vogue*'s editor Bettina Ballard championed Chanel's work, proclaiming in *Vogue* "*Chanel designs again*" (American *Vogue*, 15th February, 1954). Unlike other designers who were proposing complicated and exaggerated lines, Chanel introduced modern and simple lines.[9] Recognition came also from her peers: designers like Balenciaga, Patou and Lanvin proposed straight dresses with soft lines (Morini 2010). *Vogue* took note that the entire Paris *couture* was permeated with the easy, underdone sort of clothes that characterized Chanel's new look (Madsen 2009; Steele 1993). Appreciation for her new look also came from influential people and celebrities of her time such as Marie-Helene de Rothschild, Grace Kelly, Lauren Bacall, Ingrid

[8]It is worth noting that Chanel was the only one to close the fashion house: the couturiers of Paris went right on presenting two collections a year (Charles-Roux 2005).

[9]It is worth mentioning that it was more difficult for Chanel to impose her name again because after WWII she had the reputation of being a Nazi sympathizer (Steele 2009).

Bergman, Elizabeth Taylor, Rita Hayworth, Marlene Dietrich and Jacqueline Kennedy who became de facto ambassadresses of Chanel's style.

Once again, Chanel had succeeded in regaining the leading position within the *haute couture* field, as confirmed by the renewed support of fashion critics, society personalities, peers, buyers and the public (Charles-Roux 2005). She introduced many new creations like the pea jacket and bell bottom pants for women. In 1955, she presented another revolution in fashion design, the iconic "2.55" bag inspired by men's jackets for riding, that was the first *haute couture* shoulder bag, quite different from an ordinary handbag, with a chain. Between the 1960s and the 1970s, Chanel refined the "perfect tailored suit" looking for an ideal harmony between the pieces that compose the suit: a jacket, a skirt, and a dress or a sleeveless shirt; yet conceptually it was a unique garment. In 1957, she received a fashion award as the most influential designer in the 20th century from Neiman-Marcus, in Texas; but she refused two other important awards—the "Fashion Immortal" award from the *Sunday Times* and the *Légion d'Honneur*—because they had been given to other fashion designers (Mackrell 1992). In 1968, with up to 400 employees on her pay-roll, *Time* estimated that Chanel's fashion business, perfume included, was bringing home over $160 million per year (Madsen 2009). Chanel died on a Sunday, on January 10th 1971, at the age of 88. In light of the previous discussion, we then propose:

> **Proposition**: Core actors that face the risk of a creativity drought can reignite their creativity and enhance their ability to produce more divergent creative work in the future by moving towards the periphery of the field, while maintaining selected contacts with the core.

Discussion and Conclusions

Our conceptualization of Chanel's entry into the *haute couture* establishment reflects the dual pursuit of novelty and legitimacy that characterizes the ongoing tension between the core and the periphery of intellectual fields' social network structure. Actors positioned at the fringes of the field are freer to experiment with unconventional ideas because they are less constrained by role expectations or peer pressures and, therefore, more likely to champion dissenting ideas threatening the accepted canons of the field (Bourdieu 1993). Yet they have at best only limited (or even no) ability to mobilize audience attention and harness the symbolic and material resources needed for their ideas to gain acceptance within an established field. In contrast, core actors have easier access to both material and symbolic resources, but very often they lack the incentive to produce less conventional work due to their higher levels of assimilation into the field's dominant logic. These observations pose an interesting puzzle. If in fact peripheral actors are more likely to produce work that depart from existing norms and standards, but lack the resources required to get their work recognized, then it is unclear how they can succeed under such problematic conditions (Sgourev 2013).

In an attempt to address this tension, we examined the conditions that enabled Coco Chanel to transition from being an outsider—located at the margins of the French society—to being consecrated as an iconic and acclaimed figure within the world of fashion. The case analysis reveals that Chanel's creative trajectory—from the periphery to the core, then back to the periphery and finally again in the core—was the result of the interaction between the field (with its key audiences) and the producer (here Chanel).[10] In particular, Chanel obtained support from several key players. At the beginning of her career, Etienne Balsan and Arthur Capel, two wealthy men, provided financial backing and put her in contact with the Parisian high society. At the same time two famous actresses, Cecil Sorel and Gabrielle Dorziat (whom Chanel met in the circle of friends of Balsan and Capel), played an important role in launching Chanel's career by wearing her subversive hats in several plays (e.g., "L'Abbé Constantin" and "Bel Ami") and photographs for influential fashion periodicals (e.g., *Les Modes*, and American *Vogue*). Chanel also benefited from the backing of influent and glamorous society ladies, like the Baroness de Rothschild, Antoinette Bernstein and, most importantly, Misia Godebska-Sert—who was deeply involved in the artistic life of her age. Chanel also had another critical connection with the art world, in particular the modern artistic movement. Indeed, she collaborated with Jean Cocteau for 14 years and made the costumes for Sergei Diaghilev's *Ballets Russes*—arguably, the most avant-gardist productions of that period.[11] By not completely abandoning the fashion world during her 15 years of retirement, Chanel was able to move back to the core of the *haute couture*. She did so by capitalizing on her connections to key players such as Bettina Ballard and Carmel Snow, editors of *Vogue* and *Harper's Bazaar,* respectively.

Our core-periphery perspective on creativity provides a glimpse into the ongoing tension between the need for field legitimacy and creative freedom. Previous research found the existence of an inverted U-shaped relationship between an individual actor's degree of network coreness and creative performance, suggesting that an intermediate position between the core and the periphery tends to facilitate the recognition of creative work (Cattani and Ferriani 2008). Further elaborating on the implications of this result, Cattani et al. (2013) discussed a strategy that they termed *optimal network structuration strategy*. This strategy implies forming

[10]Her creative trajectory is in part also the effect of exogenous changes opening up unique opportunities for change. The decade between 1910 and 1920 subverted the previous social order and introduced new mores, granting unquestionable supremacy to Chanel's innovative designs. In fact, the growing Women Movement and, more importantly, WWI called upon women to step into new social roles for which Chanel's fashion turned out to be more suitable. Women then became devoted to Chanel's "modern" clothes.

[11]It is worth noting that the collaborations and the mutual influence between the fashion world and the prestigious Parisian art world contributed greatly to a substantial increase of the status of the fashion designers like in the case of Chanel and Schiaparelli (Crane 1993).

ties that link the two ends of the core-periphery spectrum, in an effort to increase the likelihood of making creative work manifest and visible to the field. Chanel's creative trajectory as a fashion designer, from the early years of her career to her rise to success and final consecration as fashion icon, provides an effective illustration of the main features of this strategy and its impact on individual creativity over time.

The implications of an optimal network structuration strategy are not limited to Chanel's case but hold more generally. This is clearly outlined in the case of Eric Fromm's contribution to the modern revision of Freudian theory (in particular, Freud's "libido theory" which represented the orthodoxy) within the psychoanalytic field. Fromm was perceived as a threat to orthodox psychoanalysis because "*he was not a marginalized intellectual but had access to sufficient alternative sources of resources to sustain himself and his ideas*" (McLaughlin 2001, p. 281). When he moved to Mexico, Fromm became a central player in the Latin American intellectual élite gaining access to both material and symbolic resources which helped him introduce innovations in the North American psychoanalysis field, even as he no longer was a central player in it. Similarly, the decision by film director Stanley Kubrick to reject the production logics of the Hollywood system (which he referred to as 'film by fiat, film by frenzy') and move to England in 1962 further illustrates the logic behind the optimal network structuration strategy. Despite the success of his Hollywood productions Spartacus (1960) and Lolita (1962), Kubrik grew increasingly frastruated because of the lack of creative freedom and the pressure to conform to the conventions inherent in the commercial logic that pervaded Hollywood (Cattani et al. 2013). In UK he established his own independent production company, but retained a critical linkage with Warner Bros. Pictures, the powerful Hollywood Major that continued to distribute his movies. Film historians and critics (e.g., Ciment 2003; Phillips 2001) now concur that Kubrick's cinematic creativity benefited from his decision, yet the maintenance of a distribution agreement with Hollywood's Warner Bros meant that his vision could reach out to worldwide audiences.

Our conceptualization adds to the growing body of research on the social side of creativity, which emphasizes the role of social networks in shaping individual creativity (Perry-Smith and Shalley 2003; Cattani and Ferriani 2008). Rather than focusing solely on the generative phase of creative work, our historical account also highlights the crucial interaction between creators and field audiences (peers, critics or users), who selectively accept or reject creative work. We thus move beyond the basic idea that social structures are important for creativity (Brass 1995) and explicitly examine the extent to which those audience are as important for the production of creative work as the individuals to whom that work is eventually credited (Csikszentmihalyi 1999).

Our study offers an illustration of the core-periphery dynamics. Based on our stylized illustration, individuals who are in a peripheral position, and so not yet assimilated into the existing conventions of the field, will struggle to achieve recognition for their creative work. For instance, in the art world this is typically the case of *mavericks*, who retain some loose connection with their field but no longer participate in its activities because they "*propose innovations the art world refuses to accept as within the limits of what it ordinarily produces*" (Becker 1982, p. 233). Chanel's case suggests how an optimal network structuration strategy may help avoid not only the fate of mavericks, who risk being marginalized and hence might fail to further their ideas, but also the fate of core actors, who might have become too embedded into the field's dominant logic and hence unable to depart from it. Accordingly, individuals who intentionally pursue an optimal network structuration strategy can carve out a social space that is removed from the field's normative pressures and exposed to fresh stimuli that typically originate from the periphery—so increasing the likelihood of generating original work but without undermining their ability to make it manifest and visible to the field (Cattani et al. 2013).

Although we emphasize the benefits of an optimal network structuration strategy, we also recognize how the success of radical innovations may have less to do with strategic action and intentionality than with changes in the institutional environments that are irreducible to clear causal links (Sgourev 2013). A more comprehensive picture of the micro and macro factors that shaped Chanel's successful entry into the field of fashion would entail a detailed account of the cultural and economic changes taking place in the early 20th century. Yet our goal was not to offer an overarching framework of how the tension between the generation and the legitimation of creative work is actually resolved. Instead, we sought to derive some stylized observations from Chanel's case history and use them to shed light on the conditions that facilitate the recognition of creative work. None of these stylized observations stands as evidence for a theory. They simply illustrate some patterns that a theory on this area of social life should account for.

Growing evidence suggests how major creative achievements increasingly are the result not of single individuals working in isolation but of a collective enterprise. For instance, in interdisciplinary and collaborative work has sharply increased over time in both artistic and scientific fields (Guimerà et al. 2005), so suggesting that incorporating social network theory and analytic tools promises to shed additional light on how creative work is generated and recognized. Consistently with the logic underlying an optimal network structuration strategy, the creativity benefits that accrue to individuals occupying an intermediate position along the core-periphery continuum can also be attained collectively when two or more individuals—some closer to the core and some closer to the fringe of the network—decide to collaborate. Individuals who are peripheral and therefore lack the legitimacy and influence necessary to gather attention around their work can build on their colleagues' social clout to gain legitimacy. Conversely, socially entrenched actors who are less likely to gain exposure to unusual sources of inspiration and novel ideas can benefit from their peripheral partners' perspective to avoid convergence toward conventional wisdom. In this case, even though "*the single individuals occupy extreme positions along the core/periphery continuum, they may complement each others' structural features by providing a context where the two extremes (core and periphery) meet each other by coming together to form a team*" (Cattani and Ferriani 2008, p. 828).

Understanding creative success requires more than studying those individuals who are typically associated with a novel product, social movement, or groundbreaking idea. In the end, it is the field participants—most notably, peers, critics and users—who decide whether a piece of work should be regarded as creative. For instance, while Picasso and Einstein stood out among their fellow peers, their unique contributions were made in concert with the intellectual and social networks that stimulated their thinking, as well as the social mechanisms that first recognized and then helped spread their work. Accordingly, we claim that a core-periphery perspective on creativity adds considerable value to the literature because it explicitly models the generation and legitimation of novelty as embedded in social structures of interaction. We believe that this perspective may open up unique opportunities for scholars interested in the intersection between creativity, legitimacy, and social structures.

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A Comparison of Creativity in Project Groups in Science and Engineering Education in Denmark and China

Chunfang Zhou and Paola Valero

Introduction

In recent years, in order to maintain a competitive edge and to respond quickly to market challenges, companies have become increasingly aware of the need for creative solutions. As a result, industry, particularly in the areas of engineering and science, has begun to focus on the ability of graduates to engage in "creative thinking" and innovation (Baillie 2002). Creativity is widely recognized as an essential part of science and engineering education. Universities are increasingly expected to provide more opportunities to foster the ability of creative students to meet the growing needs of industry. However, what is creativity? Although the literature is filled with various definitions of creativity, they all seem to capture the notion that creativity is the ability to find new ways to use existing knowledge to solve problems, and to produce novel works that are valued by society (Ogot and Okudan 2006). In short, creativity means to generate new and useful ideas (Amaible 1996).

Accordingly, many pedagogical strategies have been proposed and employed to promote creativity in engineering and science education. Encouraging students to learn through projects is one of the most popular of those strategies and it is employed around the world (Zhou 2012). Through projects, students are expected to gain interdisciplinary knowledge and multiple skills through solving real-life problems in group work; problem solving has been argued to be one of the key

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drivers of creativity in learning contexts (Sheppard et al. 2008). However, there are diverse learning models. For example, there is Problem-Based Learning in Denmark, the Netherlands, Australia, and Singapore, etc.; moreover, Project-Led Education is utilized in Portugal, while Project-Organized Learning is employed in China (Zhou et al. 2010).

This chapter will focus on two models: Problem-Based Learning (PBL) in Denmark and Project-Organized Learning (POL) in China. Generally, the two models have at least two common student learning principles: (1) problem orientation and project organization, and (2) a group work context. However, the role of teachers is different in the two models: In PBL, which is utilized in Denmark, the teachers are learning experts and are making the shift from teaching to facilitation. In contrast, in POL in China, teachers play three roles: group leaders, supervisors and professors in universities. They persevere in their "authority of knowledge". The different roles of teachers have arisen from different educational cultures in China (Confucian values and collectivism) and Denmark (Western values and individualism).

A comparative study of PBL in Denmark and POL in China will be explored in this chapter aiming to find out the similar and different influences of pedagogical strategies on the development of creativity in science and engineering education. The empirical resources are based on the results of a Master's study that was carried out with respect to POL in China (2004–2007) (Zhou 2007) and a Ph.D. study that was conducted with respect to PBL in Denmark (2008–2012) (Zhou 2012). As the findings demonstrate, this study provides a mirror for both POL in China and PBL in Denmark, through which both of the models can reflect on their advantages and disadvantages in fostering creativity. This contributes to the future improvement of the two models, as well as to implications for the development of creativity in science and engineering education in other cultural contexts.

Creativity Development Through Project Strategies in Science and Engineering Education

Calling for Creativity in Science and Engineering Education

Creativity is enjoying a global renaissance of interest, not only in academic disciplines such as sociology, psychology, science and education, but also in applied sectors such as design, business, and engineering. Students and workers are expected to apply what they learn in creative ways to ensure continued productivity, economic growth and social welfare (Bjøner et al. 2012). As Craft (2003) emphasized, since the end of the 1990s, creativity has become a growing area of interest within education, as well as within society as a whole. It reflects the globalization of economic activity, which has led to increased competition for markets.

Undoubtedly, creativity has been discussed as many different forms in diverse contexts that are more than in relation to engineering and science (Sternberg 1999). Collaboration in creative work affects and is affected by identity and motivation. Identity involves how people form themselves through what activities and roles they choose to 'make their own'; motivation focuses on the conditions and forces that affect how people direct their energy and resources on the conditions toward a purpose. Collaborators can build on each other's excitement as well as each other's ideas in a multiplicative way. Meanwhile, the question of whether creativity is a general ability or whether it is domain specific is an important topic that has led a great number of debates. However, even those who argue for the existence of domain-general creative thinking skills recognize that domain-specific thinking skills also play an important role in creative thinking. Therefore, creativity is both domain-general and domain-specific (Sternberg 1999).

However, the relationship between creativity and problem solving is much focused in the context of science and engineering. This is drawn from the reflection on the nature of practice of engineering and science (Zhou 2012). For example, Sheppard et al. (2008) suggested, in essence, the central activity in engineering practice is about to solve problems. As many engineering problems start off by being under- or ill-defined, so the setting work is both critical and difficult. Engineers need "creativity" that is as the ability to respond to challenges by combining in new ways "a broader range of interdisciplinary knowledge and a greater focus on systemic constructs and outcomes" (Sheppard et al. 2008, p. 55). Especially the definition of engineering creativity has been described (Zhou 2012): creativity is a vital factor in "good" engineering, and creativity in engineering clearly differs from creativity in the other domains. Engineering creativity results from creativity with a purpose that is to create products in the broadest sense of the word-including physical objects, complex systems, and processes. So engineering creativity can be as "functional creativity". Similarly, scientific creativity is topic addressed by many distinct theories such as the history of science, the philosophy of science, the sociology of science, and the psychology of science. The discussions among such disciplines are based on the fact that scientific creativity can be examined from four principle perspectives: logic, genius, chance and zeitgeist. Furthermore, once a scientist masters the logic of science and the substance of a particular discipline, creativity is assured (Simonton 2004). In other words, creativity is embedded in the process of defining, solving or analyzing problems by using the scientific logic.

Therefore, in the areas of science and engineering education, the ability to solve problems with a degree of creativity is highlighted as an essential characteristic for students. For example, Kind and Kind (2003) pointed out that students should appreciate that science is an activity that involves creativity and imagination to the same degree as many other human activities, and that some scientific ideas represent enormous intellectual achievements. Scientists like any other professionals, are passionate and involved human beings whose work relies on inspiration and imagination (Kind and Kind 2003). Similarly, Charyton and Merrill (2009) argued that the goals and objectives in engineering education are needed to be defined, clear and measurable. Creative engineers are needed to solve technological problems. To develop and nurture critical and creative problem solving skills, science and engineering education must provide opportunities for students to exercise these skills. Open-ended questions, problem finding, fluency (quantity of solutions), flexibility (variety of solutions), and originality (novelty) are vital components to enhance the analysis and synthesis of the information that is learned.

So the increasing need for creativity in science and engineering education has resulted in a series of actions aimed at changing approaches towards creativity. These actions include establishing a creative classroom environment (Peterson 2002), introducing creativity techniques in curriculum (Liu and Schöwetter 2004), and encouraging students to learn by solving real-life problems or through the completion of projects (Bjøner et al. 2012), etc. These actions stem from the common underlying assumption that creativity can be stimulated by a suitable environment and by using effective exercises in practice (Zhou et al. 2010).

The Social-Cultural Approach to Creativity

According to the literature (Jeffrey and Craft 2010), there were three major lines of creativity research development in the 1950s that focused on personality, cognition and how to stimulate creativity. This was supported by a philosophical debate in the 1970s that saw creativity as moving away from product outcomes and as being connected with imaginativeness. During the 1980s, a new line that of a social psychology and system theory was developed that took environmental conditions into account. Within these four lines of development (i.e., personality, cognition, stimulating creativity and social theories), there were specific foci: the person who creates; the creative process; environmental factors; and the outcome. During the 1990s, due to the development of the fourth line—social psychology of creativity—research into creativity became more comprehensive, integrating these specific foci, and began to focus more on the creativity of ordinary people within the educational system. Furthermore, the recent increasing interests in the cultural psychology of creativity consider creative acts in an interactive framework including self, other, new and existing artefacts. It promotes ecological studies of creativity and emic definitions that rely on how people themselves define creativity within different contexts (Glaveanu 2010).

In recent education, the social-cultural approach to creativity has captured increasing attention in literature that emphasizes the shaping role of the learning environment on the development of creativity (Craft 2005). The social-cultural theory posits that intellectual development is achieved through dialogue and that education is accomplished through interactions between students and teachers that reflect the historical development, cultural values and social practices of the societies and communities in which the educational institutions are located. Education and cognitive development are therefore seen as cultural processes whereby knowledge is not only possessed individually, but also is shared among members of communities: People construct knowledge and understanding jointly, through their involvement in events that are shaped by cultural and historical factors (Rojas-Drummond et al. 2008).

Therefore, according to the social-cultural view of learning, creativity offers opportunities to shape new knowledge and it can be viewed as a key driver for individual engineers and scientists to engage in activities with their peers; creativity is an inspirational force that generates new ideas or produces novel combinations of existing ideas that lead to further solutions or a deeper understanding (Zhou 2012). Moreover, creativity is usually generated in collaborative contexts; it is situation-specific, and it can be understood to emerge within dynamic processes of co-construction. These processes will produce novel—and appropriate—ideas regarding the problems that are faced in collective learning endeavors (Eteläpelto and Lahti 2008). However, cultural differences in the values that surround creativity raise issues for educators. As Craft (2005) emphasized, if the fostering of creativity is linked with culture, then the multiplicity of perspectives that learners bring to the creative process are highly significant in terms of engagement. This can pose practical and philosophical challenges due to the collision of potentially different values.

In addition, Ng (2001) summarized a number of cultural influences on creativity in the East and the West. The Confucian societies of the East put a greater emphasis on the social group vis-a-vis the individual. In such a tightly organized society, there are many social rules and regulations that govern the behavior of the person, who are socialized from childhood to fit in with the in-group. Failure to do so will result in social sanctions. Conflict with the in-group is strenuously avoided to maintain social order and harmony. Instead, discipline and conformity to tradition are emphasized, and children are expected to respect and obey their elders. By contrast, the societies of Western individualism put a greater emphasis on the individual over and above the social group. In such a loosely organized society, members are socialized from their youth to develop their uniqueness as a person and to stand on their own feet, rather than to become psychologically dependent on an in-group. They are expected to pursue their own interests and passions in life, rather than to comply with an in-group (Craft 2005). Ng's points illuminate the diverse manifestations of creativity in different cultural settings.

Learning Through Projects as a Strategy to Foster Creativity

Recently, learning through projects has been recognized as a good educational strategy to foster creativity (Bjørner et al. 2012). However, it has a long history. As far back as the early 1920s, Dewey (1938) supported "learning by doing". This sentiment is also reflected in constructivism, which explains that individuals construct knowledge through interactions with their environment, and the knowledge construction of each individual is different. Therefore, through conducting investigations, conversations or activities, individuals learn by constructing new knowledge that builds on their existing knowledge (Grant 2002). Moreover, group work, as a tool to promote learning and creativity, is becoming increasingly prevalent in education, particularly in the project context (Zhou 2012).

Projects relate basic principles and concepts to real problems; as a result, students have also welcomed working with real-life projects. As Blicblau and Steiner (1998) emphasized, projects reveal what young students can create and do when they are given the opportunity. They also pointed out that engineering students are strong in abstract conceptualization and active experimentation, and they are interested in practical uses for ideas and theories; thus, they are likely to create and work hard and effectively if they see an apparent use. Moreover, potential employers have also viewed the experience provided by project work as a highlight of courses; they use it as a major selection criterion in their recruitment. According to Zhou (2012), the role of projects in the development of learning and creativity has at least four aspects: (A) problem analysis and solving, (B) group learning, (C) interdisciplinary learning, and (D) project management. However, any kind of social context could be seen as one system, which means that the four dimensions are not isolated, but are mutually influential in stimulating a creative learning environment. Meanwhile, it should be noted that teachers' pedagogic strategies and attitudes can also have an impact on creativity—they are the key that ensures the strength of project work in the development of creativity (Ng 2003).

Research Methods

As mentioned previously, this study draws its empirical resources from two previous studies: one is a Master's study (2007) and the other one is a Ph.D. study (Zhou 2012). Both studies are related to creativity in project contexts in science and engineering education. However, the Master's study (Zhou 2007) was carried out in a Chinese context, and the Ph.D. study (Zhou 2012) was conducted in a Danish context.

In China, the research context is called Project-Organized Learning (POL). It is one of actions aiming to assist excellent future scientists and engineers with project work that has been taken in some universities in China. Usually, governments or industry supports the projects in universities. In general, the project groups consist of supervisors and their students from different levels and diverse backgrounds. The supervisors are professors in universities with responsibilities of leaders in these groups, as well as being experts in some fields of science and engineering education. Meanwhile, whether the students are qualified or not for entering the project group that is made decisions by the supervisors. However, there are always some new recruits entering groups and graduates who leave at every semester, so a high personal turnover rate exists in most of projects which are at least one-year-long with aims of solving real science and engineering problems needed in society. For students, learning is organized through practical problems and in collaborations among group members, which may develop skills of creative thinking along with the problem-solving process. However, the supervisors are in charge of moving on the projects and they assign the tasks to students. In other words, the students cannot plan or manage projects by themselves according to the rules of the educational project management systems in higher education in China. The students only own the opportunities of participating parts of projects and development of hand-on experiences in real-life projects but they do not have the ownership of learning in the project groups.

In Denmark, the context of a Problem-Based Learning (PBL) was focused on at Aalborg University (AAU), Denmark. AAU has a long tradition of educating scientists and engineers since 1976 when it was established. In the AAU PBL model, students' learning is founded on problem-based project work, in which approximately one half of the students' time is spent on project work in groups, whereas the other half is spent on more or less traditional lectures. All project work is made in groups, and the same model is followed from 1st semester until the completion of a masters' degree (10th semester). During the span of the university degree programme, the groups normally become smaller, starting with typically 6–7 students in the 1st year, and reduced to maximum 2–3 students in the final semester. In each semester, the project work is formulated with the framework of the given theme, related to the overall educational objectives, which can be a broad, open theme or a subject-related limited theme. The students are allowed to formulate their project proposal themselves, but there is always a supervisor who approves the proposal. The students are also encouraged to manage the projects by themselves and they share the leadership in the groups. The supervisor behaves as a facilitator that means she/he should provide necessary help to students in order to move on the project process instead of providing answers of problems directly. So it is a typical way of 'student-centred learning' that is also the core philosophy of PBL.

In order to provide a clear review of the two research contexts, Table 1 shows a summary about POL in China and PBL in Denmark.

The Master's study (Zhou 2007) was conducted during 2004–2007. The topic was the core competency of the science and technology groups in POL contexts in universities in China. The intention of the Master's study was to discover how the POL environment influences the core competency of the science and engineering groups in universities in China. According to that study, there are at least three key elements that influence the core competency of science and engineering groups in universities: (1) human resources, (2) academic products, and (3) creativity. Due to the specific aims of this chapter, only the empirical work related to how creativity is influenced by POL will be discussed. The data is derived from (1) a questionnaire survey of 126 group members from 25 groups ranging 12 fields in science and engineering in seven universities, and (2) eight interviews with group leaders (professors in universities, student group supervisors).

During 2008–2012, the Ph.D. study (Zhou 2012) was conducted in a Danish context based on the Master's study (Zhou 2007). The intention of the Ph.D. study was to discover how the PBL environment influences the creativity of

Table 1 Project-organized learning (POL) in China and problem-based learning (PBL) in Denmark

	Research contexts	
	POL in China	PBL in Denmark
Members of project groups	Supervisors and their students with diverse background and different levels	Only students with different roles in moving on projects
Group size	Usually from 5 to 10	Usually from 2 to 7, according to different levels of education
Ownership of projects	Supervisors	Students
Duration of projects	At least one year	A semester, or the longer period projects are divided into several semester projects
Ways of organizing groups	By supervisors, the qualified students are recommended to the groups, the tasks are assigned to students by supervisors; high level personnel turnover	By peer-arranged process of group building among students, the task are assigned by student group meetings; the personal turnover rate is usually stable
Roles of supervisors	At least three kinds of roles: project supervisors, group leaders and professors at university	Facilitators, meaning to facilitate students' learning process rather than to teach directly

student groups in science and engineering education. Aalborg University (AAU) in Denmark was chosen as the research context due to its long history with PBL. The data is derived from (1) 14 interviews (12 interviews with students and two interviews with student supervisors) and the observation, for three semesters, of a student satellite project in Electronic Systems, and (2) 53 interviews with students from Computer Science, Architecture and Design, Electronic Systems, and Medialogy at AAU.

In Table 2, a brief overview of the two studies is provided.

Both the Master's study (Zhou 2007) and the Ph.D. study (Zhou 2012) are concerned with the influences of the project environment on creativity in science and engineering education. However, there are differences in the learning cultures of China and Denmark—the Chinese learning culture is mainly influence by traditional Confucian values that emphasize collectivism, whereas the Danish learning culture is primarily influenced by Western values that are the basis of individualism. Considering both the similarities and differences of the two research contexts, this chapter will explore the different influences of POL and PBL on creativity in science and engineering education in China and Denmark based on a comparison of the findings from the two previous studies (Zhou 2007, 2012). The empirical material and findings from the two studies are re-interpreted in this study from the point of view of creativity and socio-cultural learning theories.

Table 2 The empirical resources: a Master's study and a Ph.D. study

	Research resources	
	A Master's study	A Ph.D. study
Topic	A study regarding the core competency of science and technology groups in universities in China	Group creativity development in science and engineering education in a PBL environment
Research context	China	Aalborg University, Denmark
Research time	2004–2007	2008–2012
Research questions	How does the project-organized learning (POL) environment influence the core competency of science and technology groups in universities in China?	How do engineering students develop group creativity in a PBL environment and what can PBL learn from group creativity study?
Relevance of creativity in project contexts	Creativity is one key element of core competency. The empirical work related to how creativity is influenced by POL was selected	The intention of the Ph.D. study was to find out how the PBL environment influences creativity of student groups in science and engineering education
Theoretical perspective	Social-cultural perspective toward creativity	Social-cultural perspective toward creativity
Research methods	Quantitative and qualitative methods	Qualitative methods
Research methods and data resource	Questionnaire survey (finished by creative climate questionnaire, CCQ[a]) with 126 members from 25 groups ranging 12 fields in seven universities in science and engineering education; interviews with eight group leaders (professors in universities, student group supervisors)	14 interviews and observation in a student satellite project (AAUSAT3[b]) in electronic system at AAU; 53 interviews with students from computer science, architecture and design, electronic system, and medialogy at AAU

[a]The CCQ was developed by Ekvall (1996) in Sweden, aiming to measure environmental conditions that may stimulate for hamper creativity in organizations. In the questionnaire, fifty questions were constructed to fit the ten factors including *challenge, freedom, idea support, trust/openness, dynamism/liveliness, playfulness/humor, debates, idea time, risk taking, and conflicts*. The Chinese version of CCQ was revised by Wu et al. (2000) in Taiwan

[b]AAUSAT3 is the third student satellite that was started in 2007 and was launched in late 2010. The mission of the satellite project was to carry out and operate the Automatic Identification System (AIS) play loads that were to be used by ships to communicate with each other. AAUSAT3 is engaged in a joint venture with several departments, including the Department of Electronic Systems, the Department of Mechanical Engineering, the Department of Computer Science and the Department of Energy Technology. Students from the first to 10th semesters were encouraged to participate in AAUSAT3, according to the different rates of the tasks

Findings

As mentioned previously, this comparative study focused on the similar and different influences on the pedagogical strategies that are used for the development of creativity in science and engineering education in Denmark's PBL and China's POL. Accordingly, two aspects have been revealed in the findings:

1. In both contexts, there are diverse environmental elements that influence creativity; there are both drivers and barriers to creativity; and there are interactions between the different elements that influence creativity.
2. Supervisors in the two contexts have different attitudes towards the development of creativity in students: Chinese supervisors do not encourage students to think of many ideas in project work; however, Danish supervisors try to motivate students to be open to solve project problems.

The above two points indicate the discussion in the following sections and also provide a summary shown in Table 3.

Table 3 A summary of research findings

	Research contexts	
	POL in China	PBL in Denmark
Similar influences of project strategies on creativity in POL and PBL	• In students' opinion, there are diverse environmental elements influencing group creativity in both contexts of POL in China and PBL in Denmark	
	• The influencing elements include group openess, diversity of group members' backgrounds, peer-support, group size, rewards, supervisor's help, and challenge of projects, etc.	
	• The conflicts/disagreements among members and the time schedule of projects sometimes are barriers to group creativity	
	• There are interactions between diverse environmental elements that underpins a systematic view of group creativity	
Different influences of project strategies on creativity between POL and PBL	The supervisors are tasked with the responsibilities of group leaders; they have strong authority of knowledge over the students; they tend to expect obedience or respect; and they do not welcome students to think of many ideas in project work in order to meet the deadline of projects on time	The supervisors encourage students to think of many ideas to solve the project problems. Students are co-owners of their learning process-they organize groups, construct group norms, set project milestones, finish project reports and initiate meetings among themselves. The supervisors work as expert learners, instead of group leaders

Students' Perceptions of Influencing Elements of Creativity in Learning Processes in Project Contexts in China and Denmark

According to the Master's study (Zhou 2007) and the Ph.D. study (Zhou 2012), many diverse elements have been found that influence creativity in both contexts. In the POL context in China, these elements include the challenge of project tasks, diversity, conflict, group size, group openness, risk taking, membership change, clarity of working goals, group resources, time schedule, rewards, newcomers' ability, etc. The limited time and resources for a project and the negative attitude of supervisors toward risk taking are barriers to creativity.

Similarly, in the PBL context in Denmark, the elements that stimulate creativity include common group goals, equal distribution of individual tasks, good relationships among group members, group members' clarity regarding the task, the support of peers, and the diversity of group members' backgrounds. Elements that influence the interplay between individual creativity and group creativity include individual confidence and attitudes toward creativity, work habits, group disagreement, communication skills, etc. From a student's perspective, time scheduling and group disagreement are barriers to creativity.

Moreover, interactions between the elements were found in both contexts. In the context of POL in China, project tasks stimulate students to be motivated toward creativity in student groups, and clarity regarding the individual task and its goal is needed to avoid overlapping efforts within the group. From a group leader's perspective, newcomers are expected to have the abilities that qualify them for group work, while group openness is helpful in ensuring that newcomers are accepted. The measure of rewards is one means to encourage group creativity. Group diversity is an important group-building principle due to various demands for the use of knowledge and skills in a project. Group diversity can, however, introduce conflict among its members. Small groups are therefore preferable, as they allow conflicts to remain minimal and their management requires less effort. Risk taking is not encouraged due to time schedules and the attitudes of supervisors.

Similarly, in the context of PBL in Denmark, the motivation of students towards creativity in student groups was stimulated by project tasks. Students welcomed group diversity to move the project forward effectively; this diversity also facilitated the emergence of peer-support networks and "complementary" collaboration. Accordingly, shared leadership and equal membership were needed. Individual positive attitudes toward the development of group creativity and the development of the confidence needed to be creative also stimulated group openness. The supervisors' facilitation, as part of the process of "student-centered learning", also encouraged group openness. Group disagreement was again sometimes a barrier to group creativity, as it consumed time.

Therefore, we can find similar influences of project strategies on the development of creativity in POL in China and PBL in Denmark. For example, there are common influencing elements, including the challenge of the task, the presence of common goals, the clarity of each member's task, the support of peers, group diversity, supervisor's strategy and support, and good relationships among members, etc. The time schedule is the main barrier to creativity in both contexts. Meanwhile, the interactions between the diverse influencing elements help us to understand the systemic influences of the learning environment on creativity. These similar influences undoubtedly indicate strengths of project strategies in both contexts to foster creativity that have implications for the introduction of projects to enhance students' learning in science and engineering education in other universities that continue to rely on traditional teaching and learning models—whether in the East or the West. However, when the projects are integrated into learning environments, systematic support from a teaching perspective should be considered due to the complex interactions of the diverse elements that influence creativity. Moreover, supervisors should play a positive role in the development of creativity by helping to overcome students' learning barriers, for instance, by prompting them to complete project work ahead of deadlines.

Different Attitudes of Supervisors Toward Students' Creativity in Denmark and China

In addition to the similar influences of project strategies on creativity in POL in China and PBL in Denmark, different influences can also be identified—for example, supervisors' different attitudes toward students' creativity in the two contexts.

In POL in China, the supervisors are university professors who are tasked with the responsibility of group leaders; they have the strong authority of knowledge over the students. Governments or companies support the projects and the supervisors are responsible for finishing the project reports. Accordingly, students only have the opportunity to participate in projects, rather than to design, plan, or manage projects on their own. The supervisors assign most of the students' tasks and they recommend new students to join the groups. The students are required to finish the tasks prior to the milestones and they are not encouraged to develop many new ideas through risk taking due to limited project resources, strict project management rules and project deadline pressures. In addition, the supervisors tend to expect obedience or respect: expectations that are influenced by the Confucian tradition.

On the contrary, in PBL in Denmark, the supervisors encourage students to think of many ideas to solve project problems. Students are co-owners of their learning process—they organize groups, construct group norms, set project milestones, finish project reports and initiate group meetings or supervisor meetings among themselves. The students in a PBL environment, therefore, share leadership in terms of project management—every group member assumes part of the responsibility for the project's progress. The supervisors work as expert learners, instead of as group leaders. However, this positive attitude toward creativity sometimes can cause trouble for students. For example, students engaged in AAUSAT3 suggested that some knowledge should be taught directly due to the pressure caused by highly challenging tasks and constrained time schedules. The supervisors, however, felt that the "best way to teach creativity is to give students enough space to try". As a result, although the students were supposed to interact with each other with sufficient remaining time for thought and reflection, they were often concerned instead about "losing their way".

The different attitudes of supervisors toward students' creativity in the two contexts reveal the disparate learning cultures in China and Denmark. One reason for such differences is the different project management systems in POL in China and PBL in Denmark. Another reason is the different influences of educational values in China (collectivism) and Denmark (individualism). These two reasons lead to different degrees of ownership by students in the learning that is involved in their project work, which further leads to different experiences of creativity among students in the two contexts, despite the fact that a project is the common element in the both learning environments.

To summarize, the above findings draw two pictures of creativity development in project contexts in science and engineering education through which we can identify both similarities and differences in the educational pedagogical influences on creativity in China and Denmark. Meanwhile, the two pictures also provide POL in China and PBL in Denmark with the opportunity to rethink both their advantages and disadvantages in fostering creativity. Also, they indicate the need for future improvements and provide implications for the fostering of creativity through project strategies in science and engineering education in the future. Therefore, in the following section, the discussion will focus on how to improve project strategies that foster creative learning cultures for students.

Discussions: Fostering Creative Learning Cultures Through Project Strategies

Based on the cases of POL in China and PBL in Denmark, the strength of using projects to develop creativity in science and engineering education has been underpinned. Therefore, a metaphor can be used in this instance to view the project as "an extra group member", which indicates that the project is a key part of students' learning in project contexts and that it plays an important role in student learning. Group creativity is developed out of "conversations" between students and the "extra group member". The conversations are "back and forth" processes—the "extra group member" "asks" students to meet task challenges, "calls for" group discussions, and "speeds up" group decision making; the students react in collaborative ways to "answer" the "extra group member". During such processes, interplay between individual creativity and group creativity occurs.

However, relying solely on the role of the "extra group member" is not enough for the development of creativity. As Lin (2011) suggested, a supportive climate for the development of creative abilities and qualities is created through the interaction between inventive and effective teaching (by a creative facilitator) and creative learning (by an active learner). As the "extra group member", the project can stimulate the process of interaction between the creative facilitator and the active learner. However, during such a process, there are many elements that interactively influence creativity in a certain pedagogical context, as the findings in this chapter demonstrate. Furthermore, it should be emphasized that creativity is culture-specific, which means that the conceptualization and development of personality in general, and of creative personality, in particular, cannot be isolated from the social, historical, and cultural milieu in which an individual was born, was brought up, and has been living (Rudowicz and Yue 2002). Accordingly, when the advantages or disadvantages of a certain pedagogical strategy regarding creativity development are discussed, the context of its culture must be considered.

In the case of POL in China, the problems regarding the project management system in higher education that are revealed in this chapter are barriers to the development of creativity in students. Those problems are deeply rooted in the Chinese Confucian value system, which highlights the sensitivity to hierarchy and the maintenance of social order via micro-units of society, such as families and organizations. As Tong and Mitra (2009) emphasized, Confucianism attempts to establish harmony in a complex society of contentious human beings through a strong and orderly hierarchy. The tenets of Confucianism are the main basis of collectivistic values in Chinese society. According to Goncalo and Staw (2006), although collectivistic values may promote feelings of harmony and cooperation, they may also extinguish the creative spark that is necessary for innovation. For example, collectivistic firms place greater emphasis on organization-wide objectives and make greater efforts to promote cooperation among employees in the achievement of their collective goals. Those factors similarly arise in the case of POL in China, in which students are required to reach the common goals of the project before their deadlines. The supervisors assign the task to the students and design group norms to establish a well-managed project process that will maintain organizational order. At the group level, collectivistic values may, to some extent, promote an increase in the pressure for conformity. The pressure to conform can help to maintain a certain level of group cohesion and may sometimes be necessary for the group to be productive; however, such pressures can also create limitations for groups that seek creativity (Goncalo and Staw 2006). As O'Reilly and Chatman (1996) stressed, the potential for greater social control in a culture is based on strong interpersonal ties and the acceptance of group norms. Because individuals are seen as striving to be accepted and approved by others in a collectivistic culture, there may be greater potential for social control in organizations that display such a culture. Unfortunately, it is precisely this increased level of conformity that may also undermine creativity in organizations that promote collectivistic values (Goncalo and Staw 2006).

Furthermore, in Confucian cultures, which are traditionally based on a hierarchical society, teacher-centeredness, and total class instruction, students are committed to listening without speaking. They are supposed to respect hierarchical relationships between teachers and students, which means that students accept information from teachers readily and they rarely express their opinions or ask questions. In turn, this leads to passive and compliant classroom behaviors in students. The students expect the teacher to initiate communication, and they speak only when asked to by their teacher (Kim 2007). Therefore, Confucianism is based on authoritarian principles, with technical expertise and position-based power being the basis for this authority (Martinsons and Martinsons 1996). The authoritarian principles also are the basis for building relationships between students and supervisors in the case of POL in China. Due to deadline pressure and the limited resources for projects, supervisors do not encourage students to spend much time exploring different ways to solve the same problem. The students carry out the suggestions of their supervisors, following their strong authority and leadership. Some studies show, however, that teachers who see themselves as the ultimate authority, and expect obedience and respect, rather than challenges from students, will not be effective in inspiring creative thinking by students (Ng 2003).

Therefore, in order to improve the strategy of POL in China for the development of creativity in the future, the key is to recognize the barriers to creativity that are rooted in the Confucian cultures. For Chinese students in science and engineering education, there should be more opportunities for questioning, reflection and risk-taking in solving project problems. In other words, students should study more independently, with more ownership in their learning. Further, it is important for them to be increased opportunities for the creativity of young scientists or engineers to be appropriately balanced with analytic and practical skills. As Sternberg and Williams (1996, p. 3) emphasized:

> Everyone, even the most creative person you know, has better and worse ideas. Without well-developed analytic ability, the creative thinker is as likely to pursue bad ideas as to pursue good ones. The creative individual uses analytic ability to work out the implications of a creative idea to test it… The creative person uses practical ability to convince other people that an idea is worthy.

Accordingly, the job of supervisors is to create challenging situations for learning based on the project problems in which the students are able to drawn on and balance different abilities and to discover for themselves how they can use their creativity within particular problem-solving contexts (Jackson and Sinclair 2006). Thus, in the case of POL in China, supervisors must change their prior conceptualization of their teaching roles and working styles, which are influenced by the traditional Confucian culture, towards a new recognition of the principle of being facilitators of creative learning processes. They need to take off the "masks of knowledge authority", sit among groups of students and encourage students to challenge one other. They also need to share leadership with their students in project management. However, to support such changes, certain measures relating to reforms in the project management systems in higher education in China should be adopted to stimulate creativity and innovation. For example, eliminating the elements of bureaucracy in organizations is helpful to eradicate hierarchical structures and to establish relatively equal relationships between staff and between students and teachers. Meanwhile, some measures relating the facilitation of staff development regarding the teaching of creativity also should be considered. Only when educators pay more attention to creativity will students have more opportunities to be creative.

In comparison with POL in China, the PBL model in Denmark is better suited to foster creativity. As the findings demonstrate, "student-centered learning" is one of the most important principles in PBL, so some effort has been made toward installing a creative learning environment in which young students are free to express their creativity. The previously published work (Ng 2003) pointed out that if teachers work from the assumption that their role is to help all students to reach their inner potential, they will encourage and reward creative behavior in learning. Furthermore, in individualistic cultures, people are viewed as independent and as possessing unique sets of traits that distinguish them from other people. Highly creative individuals were found to have traits such as independence of judgment, autonomy and self-confidence that allowed them to break away from their social and occupational groups to propose novel ideas that might not be readily accepted (Goncalo and Staw 2006). Thus, individualistic values have been regarded as more supportive to creativity than collectivistic values (Craft 2005), a view that has been underpinned by the findings in this chapter. Similarly, based on the results of a study on the relationships between individualism-collectivism and group creativity, Goncalo and Staw (2006) concluded that collectivistic values may extinguish the spark that is necessary for creativity in groups. The barriers to creativity in collectivistic groups cannot easily be surmounted by simple demands for creativity. While individualistic groups may at times appear to be divisive and even unruly, such a cultural orientation may actually help groups to meet the requirement for innovation in the workplace.

Therefore, the individualistic values in the Danish context provide the PBL model with supportive conditions to foster creativity in science and engineering education. However, every learning and teaching situation is underpinned by a complex set of conditions that relate to the inter-relationship between student, teacher and task. This means that any teacher, to achieve maximum impact, must be deliberately aware of these relationships and the ways in which they are likely to have an impact on any kind of provision and learner response (Goncalo and Staw 2006). Some supervisors at AAU neglect these complex relationships. For example, in the case of AAUSAT3, when the students were supposed to interact with each other and have enough time to think, they were sometimes concerned about "losing their way". This was due to a dilemma caused by the highly challenging project work and the deadline pressures at AAUSAT3. This also reveals the complexity in the "student-centered learning" context that is used to foster creativity in PBL in Denmark. On one hand, students enjoy the ownership of learning and the motivation of the group process; on the other hand, they acquire appropriate ways to guide the proper direction of their efforts. Accordingly, the role of supervisors, beyond creating a risk-free intellectual social environment, is to provide students with age-appropriate problems that challenge their thinking. To achieve the maximum impact, supervisors also should be more deliberately aware of the complex relationships between student, teacher and task and the possible responses from students.

From an intercultural perspective, the comparison between POL in China and PBL in Denmark also helps to place a mirror between the two models to enable them to learn from each other. For example, "student-centered learning" should be introduced in science and engineering education in China as a potential means of overcoming the disadvantages of POL in fostering creativity. Supervisors in PBL in Denmark can learn certain methods used in POL in China to provide necessary knowledge directly, to some extent, to assist in solving complex project problems. Supervisors in both models should particularly be aware of the pressure on students that is caused by project deadlines. These potential measures may help PBL and POL to improve by overcoming the cultural or pedagogical barriers to the development of creativity.

So the future strategies of fostering creativity in science and engineering education should be made towards the mixed efforts with at least two aspects: one is to break barriers of its own educational culture to creativity development based on self-evaluation of the culture; the other one is to learn from advanced strategies those are employed well in the other countries that can improve its own educational culture. In other words, the best creative techniques and the strongest creative personality cannot compensate for a culture that crushes creativity. Higher education can only lead students to superior levels in creative achievement through a self-evaluation of the culture in which the educational pedagogy is used and the elements that are blocking the populace, as well as through the construction of a more fertile creative soil.

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Part III
Creativity in Design and Engineering

Creativity in Engineering

David H. Cropley

Introduction

The *Sputnik Shock* that occurred on October 4, 1957 (Dickson 2001) was pivotal to the process of linking **creativity** (the generation of effective novelty), **innovation** (the exploitation of effective novelty) and **engineering** (the design and development of technological solutions to problems) in a systematic and scientific way. After the launch of Sputnik I, US lawmakers began to look more deeply for the underlying causes of the Soviet Union's strategic achievement. The US Government understood that highly skilled people were essential to technological progress, and the Congress addressed this through the National Defense Education Act (NDEA[1]) of 1958. The NDEA was designed to rectify a shortage of graduates in mathematics and engineering. However, the key step in linking creativity, innovation, engineering and technology was the hypothesis that the Soviet threat in space was not only a *quantitative* problem (e.g. a shortage of engineers in the US) but also a *qualitative* one. There was a belief that Soviet engineering achievements, and their Sputnik I success, resulted from superior *creativity* (Cropley and Cropley 2009). This led to attention moving, for the first time, from *economic* issues that underpin the growth and development of technology, to the particular *qualities* of a product that make it creative, the *qualities* of the people and organizations that make the technology, and the processes by which they achieve the development of new and effective technological solutions to problems. In other words, Sputnik I prompted a focus on *psychologically oriented creativity research*.

[1]http://en.wikipedia.org/wiki/National_Defense_Education_Act.

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The shift to a qualitative explanation for engineering creativity was aided by the fact that a scientific foundation linking creativity, engineering and technology already existed. In 1950, the psychologist J.P. Guilford delivered a pivotal presidential address to the American Psychological Association's annual convention. Guildford (1950) argued that human intellectual ability had been defined too narrowly in terms of factors such as speed, accuracy and correctness—what he termed *convergent* thinking—and needed to be understood in a broader sense, to include factors such as generating alternatives and seeing multiple possibilities. Guilford saw intellectual ability as involving *both* convergent *and* divergent thinking.

Engineers, in fact, are no strangers to the need for both forms of thinking: *analysis* and *synthesis*. Horenstein (2002), for example, reminds us that *design* requires both: "…if more than one solution exists, and if deciding upon a suitable path demands … making choices, performing tests, iterating, and evaluating, then the activity is most certainly design. Design can include analysis, but it also must involve at least one of these latter elements." (p. 23).

In fact, the relationship between creativity and engineering runs much deeper. Creativity is concerned with the generation of effective and novel solutions to problems. Engineering is concerned more specifically with generating *technological* solutions to problems. Despite this, engineering is still frequently seen as predominantly analytical in nature—"a common misconception … is that engineering is "just" applied math and science" (Brockman 2009, p. x). It follows that successful engineering design must focus on both analysis (convergent thinking) and synthesis (divergent thinking) in the creation of technological solutions. Concentrating on one at the expense of the other risks the integrity of the solutions (products) themselves, and the skill-base of the engineers involved in the creation of these solutions. Engineering, in short, is fundamentally a process of creative problem solving.

The Importance of Creativity to Engineering

Few would disagree that creativity is an essential element of 21st century life. In relation to engineering, this was explicitly identified as long ago as 1959 by Sprecher (1959), while Mokyr (1990) discusses the more general importance of creativity and innovation to national prosperity. There is widespread agreement that creativity is a vital component in the success and prosperity of organizations. Despite this, it is also clear that many leaders, managers, professional practitioners and educators are either apathetic to creativity or, uncertain of how to foster and exploit it in practice. This situation is not unique to engineering, and is typically the result of a lack of practical understanding of what creativity is, of how it can add value to the solution of real problems, and of what needs to be done to foster it. This in turn results from several misconceptions. For example, creativity has been, in the past, thought of Olken (1964) as a trait that people are born with—“you either have it, or you don’t” (p. 149). At the same time, it is frequently conceived of too narrowly, as exclusively concerned with aesthetics—“creativity is about art, isn’t it?” creativity is also regarded frequently as simply a matter of *thinking* and especially *free and unconstrained* thinking. Benson (2004), for example, reports anecdotal evidence suggesting that primary school teachers see creativity as simply a matter of letting children “do their own thing” (p. 138) and that creativity is “developed mainly through art and music” (p. 138). Other researchers have noted similar conceptual hurdles. Kawenski (1991), for example, writing about students in an apparel design course, found that “In the first place, their romantic notions led them to believe that creative thinking consisted of just letting their minds waft about dreamily, waiting for the muse to strike them.” (p. 263). The result of this is that creativity is often associated with lack of rigor, impulsive behaviour, free expression of ideas without regard to quality, and other “soft” factors. In engineering, there is then also the hurdle that these soft factors may be dismissed as “not *real* engineering”.

In recent years, it seems as though there is little cross-fertilization and sharing of ideas taking place between psychology and engineering. The strong connection between creativity and engineering, which existed immediately after the Sputnik Shock, seems to have dissipated. Buhl (1960) exemplifies this, but also highlights the fact that the early cross-fertilization seemed to fade away, so that from the 1970s onwards the connections between creativity and engineering were largely broken.

Engineering, in relation to creativity, may have been a victim of its own success. By the late 1960s, the success of the Apollo Space Program may have engendered a feeling among engineers in the United States, as well as other Western countries, that the concerns identified by the Sputnik Shock had been solved. US and Western engineers had comprehensively demonstrated their technical abilities, and the West could stop worrying about creativity in engineering!

The challenges of the early 21st century—health, security, climate, population, food—remain, and finding effective and novel technological solutions is more important than ever. We know creativity is vital to engineering success, but we struggle to understand why or how, and therefore, the role of creativity is often ignored, especially in engineering education.

At the same time that engineers forgot about creativity, another factor was conspiring to make it harder to re-establish the connection. As the study of creativity grew within the field of psychology, a gradual shift in our understanding of the term *creativity* took place. Creativity became tied strongly to the arts (Cropley and Cropley 2013) in the public eye (pp. 12–13), and this contributed to the difficulty of reconnecting creativity to engineering. Any manager or teacher working in engineering, and interested in creativity, must now actively “unhook” creativity from the arts (McWilliam et al. 2011) before they can absorb the wealth of material that is available on the subject.

It seems that before any reconnecting and rebalancing of creativity and engineering can take place, it is first necessary to dispel some of the myths and misconceptions of creativity. What is creativity, and how should we understand it?

What Is Creativity?

The most significant factor that is holding back the development of creativity in engineering is the fact that, beyond the field of psychology, creativity is poorly understood. Baillie (2002) illustrates this problem perfectly. She stated, "It is however not clear how creativity can be nurtured or fostered in students or how it can be assessed. What is creativity? What blocks it and what facilitates it?" (p. 185). These questions have been the focus of research for more than 50 years, with results widely published and readily available!

Florida (2002) noted that creativity involves the production of "meaningful new forms". He highlighted the fact that such forms involve:

- physical objects that can be made, sold and used;
- theorems or strategies that can be applied in many situations;
- systems for understanding the world that are adopted by many people;
- music that can be performed again and again.

Embedded in this approach to creativity is the emphasis on products and the idea that the product must be *public* (other people come to know about it and find it useful in some way) and *enduring* (its application or use persists for some time—in some cases for a very long time). This means that the creativity of ephemeral remarks or fleeting ideas is of lesser interest. The emphasis on *meaningful new forms* is especially relevant for practical settings such as engineering.

The Definition of Creativity

Two basic components are needed by engineers entering the field of creativity to answer the question *what is creativity*? These not only answer the fundamental question, and remove the basic blocks to reconnecting creativity with engineering, but also ensure that progress is made with a minimum of duplication. The first component is a clear, and widely accepted, definition representing the consensus that has emerged over decades of creativity research. Such a definition should be broad enough to satisfy the needs of any domain. Plucker et al. (2004) have captured all the essential ingredients in the following: creativity is "the interaction among *aptitude, process and environment* by which an individual or group produces a *perceptible product* that is both *novel and useful* as defined within a *social context*" (p. 90).

The *Five* Ps of Creativity

The second component needed by engineers for the reconnection with creativity is to recognise that creativity is characterised in terms of 4Ps: Person, Product, Process and Press (environment). This conceptual framework was first described by Rhodes (1961) and provides an excellent framework for understanding the *who*, *what*, *when*, *where* and *how* of creativity in engineering.

Phase—The Stages of Creativity

Even divided into the 4Ps, this framework for understanding creativity may be still too diffuse to provide a concrete framework for recognising and fostering creativity in engineering. Creativity in engineering is concerned with solving problems; however, the solutions engineers devise do not emerge in a single step. Engineers understand that there is a sequence of stages that is followed starting with the recognition that there is a problem to be solved, and followed by the determination of possible ways of solving that problem, narrowing these down to one, or a few, probable solutions, before selecting the best option for development and implementation. Creativity in engineering is embedded across this sequence of stages. To understand creativity in engineering, it is first necessary to understand how the 4Ps *intersect* with the stages that we know characterise engineering problem solving.

The answer to this issue is therefore a fifth P—*Phases*. These are the steps involved in the generation of novel and effective engineering products. Guilford (1959) described creativity as problem solving, and defined it as having four stages:

- *recognition* that a problem exists;
- *production* of a variety of relevant ideas;
- *evaluation* of the various possibilities produced;
- drawing of appropriate conclusions that lead to the *solution* of the problem.

Table 1 sets out these four steps in sequence. Importantly, Guildford's stages are also characterised very clearly in terms of contrasting phases of convergent and divergent thinking.

Guilford's model corresponds closely to Wallas's (1926) well-known four-phase model: In the phase of *Preparation* a person becomes thoroughly familiar with a content area, in the *Incubation* phase the person "churns through" or "stews over" the information obtained in the previous phase, in the phase of *Illumination* a solution emerges, not infrequently seeming to the person involved to come like a bolt

Table 1 Stages of creative problem solving (Guilford 1959)

Stage	1	2	3	4
Description	Recognition that a problem exists	Production of a variety of relevant ideas	Evaluation of the various possibilities produced	Drawing of appropriate conclusions that lead to the solution of the problem
Summary	Problem recognition	Idea generation	Idea evaluation	Solution validation
Characteristic	Convergent	Divergent	Convergent	Convergent

from the blue, and finally comes the phase of *Verification*, in which the person tests the solution thrown up in the phases of *Incubation* and *Illumination*. More recently, the Wallas model has been refined by adding three additional phases (*Activation*, *Communication*, *Validation*) (Cropley and Cropley 2008; Cropley 2006a, b) conceptualizing creativity as involving *seven* consecutive *Phases* (Fig. 1).

The Phases of creativity captured in the Extended Phase Model shown in Fig. 1, and the fundamental oscillation between stages of convergent and divergent thinking, tie strongly to the steps of Engineering Design as the mechanism by which products and systems are realised. Dieter and Schmidt (2012) remind us that "… it is true that the professional practice of engineering is largely concerned with design; it is often said that design is the essence of engineering" (p. 1). Citing Blumrich (1970), they characterize the process of design as "to pull together something new or to arrange existing things in a new way to satisfy a recognized need of society" (p. 1). Dieter and Schmidt (2012) describe the essence of design as *synthesis*.

Horenstein (2002) contrasted design with other essential activities in engineering by focusing on the process of solving problems. The core of engineering practice is therefore design, but that design activity involves two stages: a stage of creative synthesis, followed by a stage of logical analysis. The first stage is synonymous with divergent thinking (Guilford 1950), while the second is synonymous

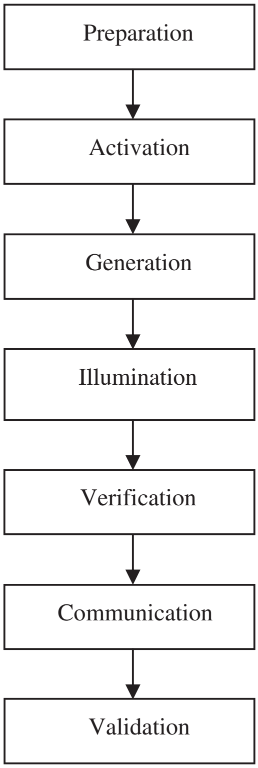

Fig. 1 The extended phase model of the creative process

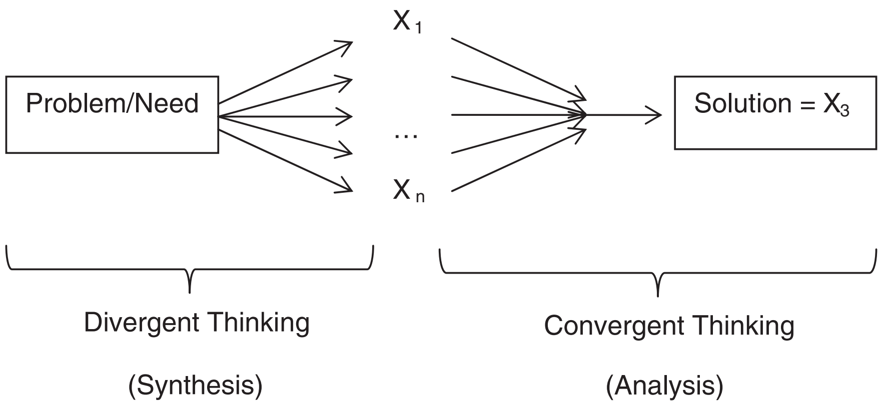

Fig. 2 Convergence and divergence in problem solving

with convergent thinking. This may be illustrated as shown in Fig. 2 and we usually think of this process proceeding, as illustrated from left to right.

Buhl (1960) notes many important, and recurrent themes both in creative, and engineering, problem solving. These include the non-linear progression that the process frequently follows. However, the most prescient of Buhl's (1960) points is that "It is necessary to understand all the factors which tend to prohibit or retard the work at each phase, and to understand what things tend to increase the possibility of an unusual answer" (p. 15).

Here is where creativity and engineering come together. As engineering design moves through a series of stages, these involve either convergent or divergent thinking. We also know that four factors—*Person*, *Product*, *Process* and *Press*—either help or hinder creative problem solving (and therefore engineering problem solving) in each of the phases. Understanding engineering creativity therefore involves understanding this interplay between Phases and the 4Ps. This is discussed in the following sections.

Person—*Who* Are the Creators?

The *Person* addresses the factors relating to the psychology of the individual actor involved in the creation of the *Product*. Research has shown that personal properties (e.g. optimism, openness, self-confidence), motivation (both intrinsic and extrinsic) and feelings (e.g. excitement, hope, fear) are distinct dimensions of the Person that each have a bearing on creativity (Cropley and Cropley 2013). Furthermore, these dimensions of the Person interact with each other in a variety of ways such that different combinations have unique consequences for creativity. Table 2 summarises these properties mapped to each stage of the Extended Phase Model (Fig. 1).

Table 2 Examples of creativity-enabling personality traits

Phase	Motivation	Personal properties	Feelings
Preparation	Hope of gain willingness to work hard	Optimism self-discipline openness	Interest curiosity
Activation	Preference for complexity problem-solving drive (intrinsic) dissatisfaction with the status quo	Critical attitude willingness to judge and select self-confidence	Dissatisfaction excitement hopefulness
Generation	Freedom from constraints tolerance for ambiguity willingness to take risks	Relaxedness acceptance of fantasy nonconformity adventurousness	Determination fascination
Illumination	Trust in intuitions willingness to explore ideas resistance to premature closure	Sensitivity openness flexibility	Excitement
Verification	Desire for closure desire to achieve quality	Hardnosed sense of reality self-criticism	Satisfaction pride in oneself
Communication	Desire for recognition (intrinsic) desire for acclaim or reward (extrinsic)	Self-confidence autonomy courage of one's convictions	Anticipation hope fear
Validation	Desire for acclaim mastery drive	Toughness flexibility	Elation

Engineering creativity is therefore fostered by supporting the creativity-enabling personality traits that are active in the different phases of the problem solving process.

Product—*What* Do They Create?

The *Product* addresses the output of the creative activity. It is no surprise that psychologists are interested in the creative *person*, however, it is also widely accepted that an essential core of creativity, whether in art and poetry, or engineering and science, is the tangible artefact. This definition of *Product* can be extended to any product, process, system or service that is *both novel and useful* (Table 3) (Cropley and Cropley 2005).

Mackinnon (1978) concluded that "analysis of creative products" is "the bedrock of all studies of creativity" (p. 187), and indeed, Morgan (1953) came to a similar conclusion. While more recent definitions of the creative product debate the existence of higher order characteristics (Cropley and Cropley 2005) the foundation of definitions as far back as Stein (1953) is a combination of novelty and usefulness. For an object, for example, to be regarded as creative, it must be original and surprising, and it must solve a real problem or satisfy a real need.

Table 3 Different types of creative product

Product type	Product characteristics
Artefact	A manufactured object
Process	A method for doing or producing something
System	A combination of interacting elements forming a complex, unitary whole
Service	An organized system of labour and material aids used to satisfy defined needs

Table 4 The hierarchical organization of products

Criterion	Kind of product				
	Routine	Original	Elegant	Innovative	Pseudo or quasi-creativity
Effectiveness	+	+	+	+	−
Novelty	−	+	+	+	+
Elegance	−	−	+	+	?
Genesis	−	−	−	+	?

Four criteria define the creativity of a product (Cropley and Kaufman 2012; Cropley et al. 2011): relevance and effectiveness; novelty; elegance and genesis. Products can be classified using these four dimensions arranged in a hierarchy ranging from "routine" products (characterised by effectiveness alone) to "innovative" products (characterised by effectiveness, novelty, elegance and genesis), with "original" and "elegant" products between these poles (Table 4). In the table, a plus sign means that a criterion is associated with this kind of product, while a minus sign indicates that it is not. The classifications in Table 4 also demonstrate the idea of pseudo- and quasi-creativity, where the only *necessary* property of products seems to be novelty. The table shows that products *higher* in the hierarchy incorporate all of the properties of products at *lower* levels, but add something to them. According to this classification, *routine* products are not creative, because the second necessary criterion (novelty) is absent. However, this does not mean that these products are not useful, or that they are not common. In engineering, many products perform important and valuable functions, yet are devoid of creativity, in the sense that they do not possess novelty.

Process—*How* Do They Create It?

Process addresses the styles of thinking that result in creative products. Although more complex than suggested here, two main thinking styles are commonly associated with creativity. It was Guilford (1950) who laid the groundwork for understanding the roles that convergent and divergent thinking play in the production of creativity. While divergent thinking is often exclusively associated with creativity, it is important to recognise that convergent thinking is also critical, particularly in the context of problem solving and engineering. Engineers will immediately recognize this as a feature of the design process. The core of engineering design therefore involves two fundamental stages: a stage of creative synthesis (i.e. divergent thinking), followed by a stage of logical analysis (i.e. convergent thinking).

Table 5 sets out processes typical of divergent thinking, and lists the associated results of these processes.

Divergent cognition (Boden 1994) involves not only the generation of many possible ideas or solutions, but also involves seeing connections between disparate pieces of information (e.g., recognizing patterns, relating diverse concepts, combining unrelated ideas). One particularly interesting aspect of divergent thinking, especially in an engineering context, is the process of *making associations*. In fact, Mednick (1962) argued that what is necessary for producing novelty is that such associations go beyond the traditional, conventional or orthodox, and are *remote*. He described the formation of remote associates and their connection to novelty production in the following way: In the course of their lives, people learn a number of possible responses to any given stimulus. Responses most frequently linked with a particular stimulus in the past are likely to be selected as appropriate if the stimulus is encountered again (i.e., they are common). On the other hand, responses seldom paired with the stimulus in the past have a low probability of being chosen (i.e., they are uncommon or *remote*). This means that when a particular stimulus recurs in a new situation, people typically select a common, *familiar* response. These responses and quick, reliable and efficient, but they are routine, and lack creativity. For example, *Chicken* is a common associate to the stimulus *Egg*, since these two ideas often occur together. A person with a high preference for common associates might associate *Green* with *Grass*. This is not a problem until a situation *requiring* novelty is encountered.

In engineering problem solving, the impact of both forms of association (common and *remote*) can be seen when examining the functions of common objects. A paper clip's common association is with the function *clip paper*. The name of the object reinforces this common association. When asked to devise alternative uses for a paper clip, engineers must first overcome *functional fixedness*—that tendency to associate objects with their *customary* function. These common associations do have, however, certain advantages to engineers. They represent the *routine*

Table 5 Characteristics of divergent thinking

Typical processes	Typical results
Thinking unconventionally	Alternative or multiple solutions
Seeing the known in a new light	Deviation from the usual
Combining the disparate	A surprising answer
Producing multiple answers	New lines of attack or ways of doing things
Shifting perspective	
Transforming the known	Opening up exciting or risky possibilities
Seeing new possibilities	

Table 6 Characteristics of convergent thinking

Typical processes	Typical results
Thinking logically Recognizing the familiar Combining what "belongs together" Homing in on the single best answer Reapplying set techniques Preserving the already known Seeking accuracy and correctness	Greater familiarity with what already exists Better grasp of the facts A quick, "correct" answer Improvement of existing skills Closure on an issue

solutions that are sufficient for many situations. Standardized electronic components, for example resistors and capacitors with known values, are extremely useful in speeding up design and manufacturing processes. The penalty, however, is that the habit of forming common associates can become so ingrained that it is difficult to make the transition to *remote* associates in situations where novelty is required.

In any discussion of *Process*, it is also important to recognize the fact that creativity does not come from nowhere. It rests on a foundation of knowledge and requires effort. To be a creative engineer, you first need to be a capable, *technical* engineer! The characteristics of convergent thinking (Cropley 2006a, b) that are vital in supporting the overall process of creative problem solving are summarised in Table 6.

Divergent thinking is both necessary and appropriate at certain stages of the engineering problem solving process. Equally, convergent thinking is necessary and appropriate at other stages of the process.

Press—*Where* Does the Creativity Happen?

The *Press* examines the role of organisational and social factors on creativity. More specifically, *Press* can be considered to address both: (a) how the "climate" can either facilitate or inhibit creativity, and; (b) how the "environment" reacts to the production of creativity. *Press* touches on not only factors such as management support for creativity (e.g. rewarding creativity, encouraging risk-taking), and how the physical environment may foster creativity (e.g. through the provision of plants and adequate lighting in the workplace), but also on the way that society tolerates radical deviations from norms (are creative people ridiculed or hailed), and even the rules and standards that govern professional activities such as engineering.

In the institutional environment—for example, an engineering firm—it is helpful to define, more precisely, the aspects of the organisation that influence creativity:

- *material institutional structures and facilities* such as work stations, laboratories, information-processing facilities, libraries, classrooms and workshops, etc. These are found in businesses, factories and the like, but also in schools and universities;

- *people*, not only managers or instructors, but also fellow workers or students;
- *immaterial institutional factors* influencing the interactions between material structures and people, such as traditions, standards, norms and customs;
- *psychological institutional factors* influencing these interactions, such as roles, relationships, social hierarchies, interaction rules, communication pathways, and the like.

Figure 3 shows this organizational Press in more detail.

The *Press* can act either to foster or to inhibit creativity. A *congenial* environment provides the specific conditions that permit, release, encourage or foster the creativity of individual people or of groups. These include:

- the *amount* of divergence or risk-taking that is tolerated/encouraged;
- the *kind* of variability that is tolerated/encouraged (for instance, routine extensions of the already known vs. radical deviations);
- the *resources* that are made available (not only material, but also human) to support production of novelty;
- the *rewards* (or punishments) that are offered to people who diverge from the usual.

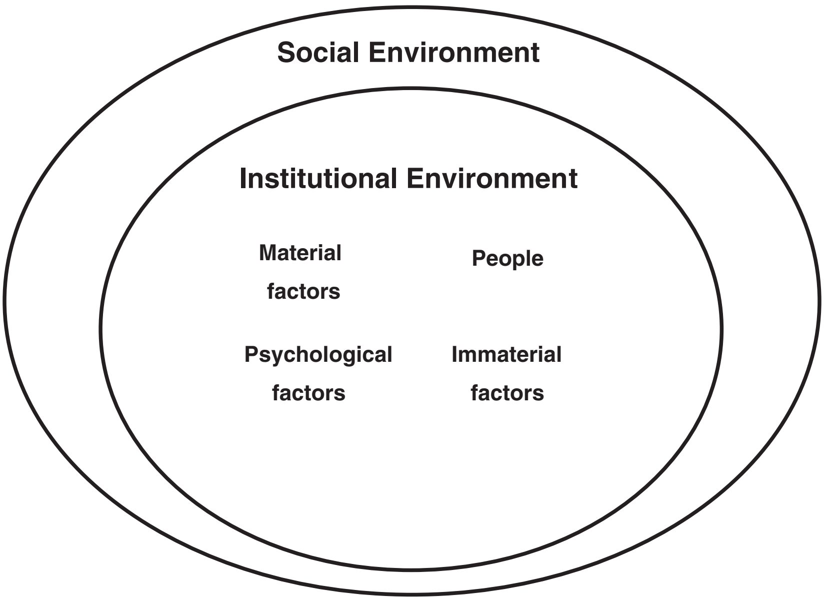

Fig. 3 Factors of the institutional environment

Paradoxes of Creativity

To understand the interaction of creativity and engineering, one critical factor must be acknowledged. Each of the 4Ps described in previous sections is not *uniformly* good or bad for creativity (Cropley 1997; Cropley and Cropley 2008). For example, Horenstein's (2002) description of engineering, cited earlier, makes it clear that the steps involved in designing and developing an engineering solution involve *different* cognitive skills. Sometimes it is necessary, in other words, to think analytically, and sometimes synthetically. This suggests a paradox in engineering creativity. Cognitive processes that appear to be mutually exclusive, are *both* necessary for creativity. How can creativity in engineering be developed and fostered if it requires us simultaneously to think both convergently *and* divergently? Discussions of creativity, therefore, are confronted by a number of apparent *Paradoxes*: Aspects of the processes of creativity, the personal properties associated with it, the conditions that foster its emergence and the products it yields seem to be mutually incompatible. Similarly, a lack of structure and management pressure in the environment may encourage creativity some of the time but inhibit it at other times. Properties of the individual—a willingness to take risks, for example—may be favourable to creativity at some points in the process, but unfavourable at other times. The solution to this paradox lies in the fifth P—*Phases*. Engineering creativity takes place across distinct phases. It is possible to build a model of creativity in engineering that identifies the relationships between the Person, the Process, the Product and the Press, *at each Phase*, and specifies exactly what conditions favour or inhibit creativity, at each point in the problem solving process.

The Innovation Phase Model

Resolving the paradoxes of engineering creativity—the apparent need for simultaneous, but conflicting, qualities of the person for example—is achieved by recognising that each of the 4Ps can move between two poles (Cropley and Cropley 2011). The best example is *Process*—both convergent and divergent thinking are required at *different stages* of the engineering problem solving process (see Table 7). In some stages, for example the *Generation* phase, divergent thinking is most favourable to the overall process of creativity. In other phases, for example *Illumination*, convergent thinking is most appropriate. Mapping the creativity-enabling state of each of the 4Ps against the seven Phases of the process resolves the paradoxes of engineering creativity (see Table 7). Phase by phase, Table 7 shows that the conditions that foster creativity and innovation *change*. What is good for creativity and innovation in, for example, the *Activation* Phase, may actually hinder innovation in the *Verification* Phase. The key to successful engineering creativity and innovation therefore is to adapt to the favourable conditions, at each stage of the process.

Table 7 The innovation phase model (IPM)

Dimension	Phase	Invention					Exploitation	
	Poles	Preparation Knowledge, problem recognition	Activation Problem definition, refinement	Generation Many candidate solutions	Illumination A few promising solutions	Verification A single optimal solution	Communication A working prototype	Validation A successful 'product'
Process	Convergent versus divergent	Convergent	Divergent	Divergent	Convergent	Convergent	Mixed	Convergent
Person (motivation)	Reactive versus proactive	Mixed	Proactive	Proactive	Proactive	Mixed	Reactive	Reactive
Person (properties)	Adaptive versus innovative	Adaptive	Innovative	Innovative	Innovative	Adaptive	Adaptive	Adaptive
Person (feelings)	Conserving versus generative	Conserving	Generative	Generative	Generative	Conserving	Conserving	Conserving
Product	Routine versus creative	Routine	Creative	Creative	Creative	Routine	Routine	Routine
Press	High demand versus low demand	High	Low	Low	Low	High	High	High

The Innovation Phase Model has been tested empirically through the Innovation Phase Assessment Instrument (IPAI) described in Cropley and Cropley (2012) and Cropley et al. (2013). In addition to demonstrating that teams and organisations may be well-aligned, or misaligned to the different poles that favour creativity across the different phases, the IPAI also highlights the relationship between creativity and innovation. The former is a necessary pre-requisite to the latter, and while other researchers frequently explore innovation from an economic or organizational viewpoint, the focus of the research described in this chapter remains fundamentally psychological—what aspects of personality, emotions and motivation help or hinder engineers engaged in creativity and innovation? What cognitive processes do they draw on to aid in their creativity? What institutional and social factors help or hinder their efforts to design and develop novel products and systems? How do we assess whether those novel products and systems are, indeed, creative?

A framework for understanding creativity and engineering—the Innovation Phase Model—is a necessary pre-requisite for embedding these concepts in engineering practice. However, without substantial change to engineering education, these concepts are unlikely to have beneficial impact.

Educating Engineers for Creativity

The failure of engineering education to adequately address the need for creativity is reflected in the 1996 report of the Alliance of Artists' Communities (1996) which concluded, that American creativity is at risk. The problem is not confined to the United States of America, and goes beyond the artistic or aesthetic focus areas of the report. For example, employers surveyed in Australia in 1999 noted that three-quarters of new university graduates there show skill deficiencies in creativity, problem-solving, and independent and critical thinking. Also in Australia, in 2013, the annual *Graduate Outlook Survey*[2] indicates that "Critical reasoning and analytical skills/Problem solving/Lateral thinking/Technical skills" is high on the list of selection criteria for employers, and yet, when asked to rate the employability skills of graduates *actually hired* in 2013, employers indicated that only 57.3 % exceeded average expectations in problem solving. Tilbury et al. (2003) also reported on an employer survey in Australia which concluded that Australian graduates *lack creativity*.

In the United Kingdom, Cooper et al. (2002) concluded that the education system discourages innovation. As an example, The British General Medical Council noted that medical education is overloaded with factual material that discourages higher order cognitive functions such as evaluation, synthesis and problem

[2] http://www.graduatecareers.com.au/wp-content/uploads/2014/03/Graduate_Outlook_2013.pdf.

solving, and engenders an attitude of passivity. Bateman (2013), meanwhile, reports on results of UK employment survey data in the area of computer science and IT, suggesting that graduates in this domain miss out on employment opportunities due to a lack of creativity.

A similar picture is reported widely in the United States in various sources. Articles in Time and Forbes Magazines, for example, suggest that employers are frustrated by the fact that new graduates are emerging from universities lacking skills in creativity and problem solving.

The problem is not unique to higher education. Over a period of decades, research has shown that, while most teachers claim to have a positive attitude to creativity, in classrooms in many different countries, properties and behaviours actually associated with creativity are frequently frowned upon. The evidence summarized by Cropley (2001) is that teachers discourage traits such as boldness, desire for novelty or originality, or even actively dislike children who display such characteristics. Therefore, despite widespread calls for creativity, there may be limited efforts to foster its emergence, or even dislike of people who display it.

The situation in *engineering* education seems to be no different. The United Kingdom's Royal Academy of Engineering published the report *Creating Systems that Work: Principles of Engineering Systems for the 21st Century* in June 2007 (Elliott and Deasley 2007). Among six principles that the report states are necessary for "understanding the challenges of a system design problem and for educating engineers to rise to those challenges" (p. 11) is an ability to "*be creative*". The report further recognizes the key role that creativity plays in successful engineering and defines creativity as the ability "to devise novel and … effective solutions to the real problem" (p. 4)! Baillie (2002) similarly noted an "…increasing perception of the need for graduates of engineering to be creative thinkers…" (p. 185).

Cropley and Cropley (2005) reviewed findings on fostering creativity in engineering education in the United States of America, and concluded that there is little support for creative students. It is true that there has been some effort in recent years to encourage creativity in colleges and universities: For instance, in 1990 the National Science Foundation (NSF) established the Engineering Coalition of Schools for Excellence and Leadership (ECSEL). This had the goal of transforming undergraduate engineering education. However, a subsequent review of practice throughout higher education in the United States (Fasko 2001) pointed out that the available information indicated that deliberate training in creativity was rare.

Kazerounian and Foley (2007) restate the fundamental problem: "If creativity is so central to engineering, why is it not an obvious part of the engineering curriculum at every university?" They suggested that this is because it is "not valued in contemporary engineering education" (p. 762), but the problem runs deeper than that. Why is the compelling pressure for creativity in engineering education largely ignored? Cropley (2015) suggests at least three problems are causing creativity to be ignored in engineering education: (a) engineering degrees are focused on narrow specializations; (b) teaching focuses too much on the acquisition of factual knowledge; (c) educators lack a detailed understanding of creativity.

Solutions to these problems require many changes. A starting point is Sternberg (2007) who outlined three things promote the *habit of creativity* (p. 3). These should serve as general principles for curriculum and program design in engineering. First, students must have the *opportunity to engage in creativity*. These must be embedded throughout programs and courses in an integrated and mutually reinforcing manner. Second, students must *receive positive encouragement* as they engage in tasks requiring creativity. Third, students must be *rewarded when they demonstrate the desired creativity*.

Sternberg (2007, pp. 8–15) further outlines twelve strategies (Table 8) that guide the development of the creativity habit. This is not to suggest that every aspect of engineering learning must be transformed. There will remain many areas of the curriculum that are best served by convergent approaches—there is, after all, still only one right answer to the question "what is 2 + 2?". However, wherever practical, these strategies should be used to guide the development of creativity as a desirable and vital graduate quality.

There is a great deal needed to transform the understanding of creativity in engineering, and to embed creativity in engineering education. An important starting point is the recognition that creativity is already well defined, and that there is an accessible and useful framework for understanding the factors that foster, and inhibit, creativity. Perhaps the single most important factor for progress in engineering creativity is to avoid reinventing the wheel, and to build on the body of knowledge—much of which sits in the discipline of psychology—that has been developed since the late 1950s.

Table 8 Twelve keys for developing the creativity habit (Sternberg 2007)

Summary of habit key
Redefine problems
Question and analyse assumptions
Do not assume that creative ideas sell themselves: sell them
Encourage idea generation
Recognize that knowledge is a double-edged sword and act accordingly
Encourage children to identify and surmount obstacles
Encourage sensible risk-taking
Encourage tolerance of ambiguity
Help children build self-efficacy
Help children find what they love to do
Teach children the importance of delaying gratification
Provide an environment that fosters creativity

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Creativity in Student Architects: Multivariate Approach

Christiane Kirsch, Todd Lubart and Claude Houssemand

Introduction

Personality Profile of the Typical and the Creative Architect

Numerous authors have considered the question of what defines creativity in architecture. These studies were conducted, to a large extent, at the Institute of Personality Assessment and Research (IPAR) nearly 50 years ago. The tested architects were chosen according to a process of peer nomination. It is interesting to point out that most of the outcomes and conclusions (i.e., Barron 1972; Gough 1975; Helson 1999; MacKinnon 1965) remain valid (Runco 2007). Whereas there are some features that define the population of architects as a whole, others distinguish its most creative members (MacKinnon 1962a).

Architects can be considered as an interesting population for creativity research as they embody the prototype of the creative person (MacKinnon 1965) with manifold expressions of original behavior (MacKinnon 1962b). They are not only considered as artists but also as scientists and businessmen (Barron 1969; Hall and MacKinnon 1969; MacKinnon 1962b, 1965; Piirto 1992). Indeed, architects

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merge personality features of different creative populations: artists versus scientists and businessman versus aesthete (Piirto 1992). At times, the architect needs also to switch to the roles of lawyer, advertiser, author-journalist, educator, and psychologist (MacKinnon 1962b). Whereas the social appreciation of design is determined by artistic qualities, industrial utility and feasibility relies on scientific qualities. Finally the marketing of the product requires pragmatism, reliability and interpersonal abilities (Barron 1969; Hall and MacKinnon 1969; MacKinnon 1965). This leads the architectural industry to be considered as a prototype of creative fields. Ingenious ideas are not only manufactured but also turned into profit later on (Brown et al. 2010). It relates architectural products to the consensual definition of creativity, according to which creative outcomes not only need to be original but also functional (i.e., Lubart et al. 2003). Whereas the originality component can be referred to the artistic delight of the architectural design, the functionality refers to the fact that the building must be technologically sound, efficiently planned and must fulfill demands of commodity (MacKinnon 1962a, 1965). Hence the architectural outcome is both personal and impersonal, in the sense that external criteria of clients' demands and of industrial feasibility need to be met (MacKinnon 1962a).

Generally speaking, the findings of IPAR, discussed in MacKinnon (1978), highlight the superior role of intellectual competencies and the valuing of intellectual pursuits in successful architects.

> Being productive and having high standards, a wide range of interest, high intellectual ability and a high valuation of the role of intellect in human affairs, a definite sense of personal independence, and an internally consistent ethical basis for action (Barron 1969, p. 71).

However, intelligence is an essential but not a sufficient condition for creativity in architecture and should consequently not be overestimated (MacKinnon 1962a).

Regarding personality, researchers compared creative architects to representative architects (non-selected for creativity) and to the general population on a number of typical and atypical personality traits. They were assessed through the Minnesota Multiphasic Personality Inventory (MMPI), the California Psychological Inventory (CPI), the Myers-Briggs Type Indicator (MBTI), the Adjective Check List (ACL), the Fundamental Interpersonal Relations Orientations-Behavior questionnaire (FIRO-B), the Strong Vocational Interest Blank (SVIB), the Barron-Welsh Art scale, the Welsh Figure preference Test (Welsh 1959) and the Allport-Vernon-Lindzey Study of Values (A-V-L) (Barron 1963, 1969; MacKinnon 1961, 1962b, 1965).

Generally speaking, the personality assessment of architects essentially focused on psychoticism, ego-strength and openness to new experiences (Barron 1963, 1969; MacKinnon 1961, 1962b). Whereas psychoticism is the predominant personality trait for creativity in the *Big Three* approach, openness dominates in the *Big Five* approach (Batey and Furnham 2006).

Regarding *psychoticism*, on average creative architects were found to be more deviant than representative architects who again were found to be more deviant than the general population. These findings of the *Big Three* approach are based on the psychiatric measures of the MMPI: Schizophrenia, Depression, Hypochondriasis, Hysteria, Psychopathic Deviate, Paranoia, Psychasthenia and Hypomania (Barron 1965, 1969; MacKinnon 1961, 1962b).

Furthermore, an unusual pattern of association was found between *psychoticism* and *ego-strength*. In architects higher psychoticism and enhanced personal effectiveness coexist (Barron 1963, 1965, 1969; MacKinnon 1961, 1965). Barron (1963) described creative individuals in general as both more tormented and more resilient than the general population. Referring to architects, Barron definitely considered them as productive and highly capable of coping, even though they occasionally experience emotional conflicts. Indeed, architects spend considerable energy in keeping themselves together but still their creative drive keeps them going (Dudek and Hall 1991).

MacKinnon (1962b, 1970) concluded from a study on well-known male architects that some kind of paradox is inherent to the creative personality: “It would appear that the creative architect has the capacity to tolerate the tension created in him by strong opposing values, and in his life and work he effects a reconciliation of them” (MacKinnon 1962a, p. 490).

Empirically speaking, in comparison to the general population, architects are simultaneously higher on MMPI psychopathological dimensions and MMPI/CPI ego-strength scales (Barron 1963, 1965, 1969; MacKinnon 1961, 1965).

Differences in CPI *ego-strength* also became apparent between groups of different creativity levels in architecture (Barron 1963). The CPI ego-strength scales include self-acceptance, capacity for status, and achievement through independence, flexibility, social participation, and personal dominance (Barron 1969). MacKinnon (1960) observed that the creative architect typically considers himself/herself to be destined to do what he/she is doing, or intends to be doing, in life. The creative architect possesses “a marked degree of resoluteness and almost inevitably a measure of egotism; but over and above these, there is a belief in the foregone certainty of the worth and validity of their creative efforts” (MacKinnon 1960, p. 34).

To conclude, the determining role of ego-strength in architects has been repeatedly highlighted (Barron 1963, 1965, 1969; MacKinnon 1961, 1965; Piirto 1992). This pronounced emotional stability becomes even more important if mild psychopathological tendencies come into play.

Transcending the domain of architecture, successful creators in general combine logic and intuition, discipline and playfulness, introversion and extraversion, realism and imagination, objectivity and passion, femininity and masculinity (Csikszentmihalyi 1996), and rationality and irrationality. Creators integrate and acknowledge these complexities and disorders into their nature and consciousness instead of suppressing them (MacKinnon 1962a, b).

For Runco (2007), these seeming antinomies of the creative personality refer to the complexity of creative potential. Whereas none of the above mentioned traits individually leads to creativity, their fruitful interaction can do so. Indeed it is only at first sight that these traits seem antagonistic and the term “paradox” might not be the appropriate expression.

Beside these seemingly antagonistic traits, for Runco (2007) the creative person is essentially characterized by an intrinsic *openness* towards inner and outer experience. Hall and MacKinnon (1969) stated that the creative architect expresses pronounced openness to new experiences and ideas, insightfulness and a drive to explore the underlying potential of objects and circumstances.

> The more creative a person is the more he reveals openness to his own feelings and emotions, a sensitive intellect and understanding self-awareness, and wide ranging interests… (MacKinnon 1962b, p. 33)

Indeed, in the *Big Five* approach openness to new experiences is the personality trait most consistently associated to creativity (Feist 1998). Openness gets interpreted as an overreaching personality domain, including most of the personality features commonly associated to creativity (McCrae 1987; McCrae and Costa 1985), like esthetic sensitivity, broad interests, independence of judgment and tolerance of ambiguity (McCrae 1987).

Higher openness to inner and outer live as well as to richness and complexity of experience is reflected through comparatively higher scores on the femininity scale on the MMPI, the CPI and the SVIB (Barron 1965, 1969; MacKinnon 1962b, 1965, 1970) and through a marked preference for complex and asymmetrical figures on the Barron-Welsh Art Scale and the Welsh Figure preference Test. The multitasking ability of creative individuals relates to their preference for the challenge of disorder to the barrenness of simplicity (MacKinnon 1962b, 1965). Furthermore, on the SVIB and A-V-L, higher openness is revealed through wide-ranging interests and prevailing theoretical and esthetic values (MacKinnon 1962a).

Finally, on the MBTI openness is expressed by the fact that, generally speaking, creative architects are Intuitive rather than Sensitive, Perceptual rather than Judging and Introvert rather than Extrovert. In this respect creative architects do not only differ from the general population but also from their less creative colleagues (Barron 1965, 1969; MacKinnon 1962b, 1965, 1969, 1970).

MacKinnon (1963, 1965) established profiles of three groups of architects. They differed significantly in their level of rated creativity (I: most creative; II: medium creative; III: least creative). They were compared on personality, ego, function, and self-image (MacKinnon 1963).

MacKinnon (1965) related these profiles to Rank’s (1945) three stages of identity development in the social and interpersonal domain. The three personality structures are represented by the creative type, the neurotic type, and the adapted type (Rank 1945). These three personality types can indeed be associated with the three architect samples: Architects I with the creative type, architects II with the "neurotic"/conflicted type and architects III with the adapted type (MacKinnon 1965).

Runco (2007) highlighted the striking difference in the proclivity of creative architects to overtly admit personal flaws. This means that they are more honest about themselves and use less defensive or self-enhancing strategies. MacKinnon refers this to their higher level of self-actualization and lower level of self-control. It is a common finding that self-actualization goes along with higher self-acceptance and creativity (e.g., May 1975; Runco et al. 1993).

Architects I embody the prototype of the self-actualized person. They are in harmony with their ideal self and they are characterized by strong ego, positive will and action (MacKinnon 1965). In contrast, architects III are mainly controlled by their super ego and their high conscience (MacKinnon 1963, 1965). Concerning the Adjective Checklist (ACL) self-report personality inventory, Architects I primarily described themselves as *imaginative*, whereas Architects II and III respectively referred to *civilized* and *conscientious* (MacKinnon 1965).

Some ACL scales that generally correlate to creativity are *lability, autonomy* and *endurance* (Runco 2007). According to MacKinnon (1963, pp. 259–269), *lability* mainly refers to:

> An inner restlessness and an inability to tolerate consistency and routine… though there is a facet of high ego-strength in this scale, an adventurous delighting in the new and different and a sensitivity to all that is unusual and challenging.

Runco (2007) revealed that creative architects display various *autonomy*-related personality features, which are particularly important for originality. These include independence, introversion, antisocial tendencies and unconventionality. To MacKinnon (1965), unconventionality is reflected through deliberate professional marginality. Not only they do not keep themselves updated about recent findings of their colleagues but they also purposely transgress the boarders of their own research field. Finally, they seek mainly to live up to their own standards and do not feel responsible to fulfill objective requirements of their professional field.

Whereas lability and autonomy are positively associated to creativity, the opposite is true for *endurance*. For MacKinnon (1965) this outcome seems surprising. However, creative architects might display another kind of endurance, not the one that is based on continuous and uninterrupted effort. Indeed, Gruber (1988) considered creative people to be able to share their attention between divergent occupations and to switch deliberately between them. However, according to MacKinnon (1965) this does not mean that they leave tasks unfinished. Inversely, it gives them an advantage over rigidly organized people. After an intentional break, their refreshed mind is more likely to come up with an already incubated idea. This kind of endurance can be related again to their higher ego-strength.

Batey and Furnham (2006) summarized the profile of creative people in arts, science and everyday life. Piirto (1992) considered architects as crossbreed creators, fusing diverse creative profiles. More specifically, the personality of architects was considered to form the intersection between artists and scientists (Barron 1969; Hall and MacKinnon 1969; MacKinnon 1962b, 1965; Piirto 1992).

It is indeed not surprising that past research (Barron 1995) highlighted that architects considered careers in arts or science before definitely committing themselves to architecture.

Given this background, in the present research architects are considered as reuniting features of artists and scientists (Barron 1969; Hall and MacKinnon 1969; MacKinnon 1962b, 1965). Accordingly, the investigation focuses on those traits that both populations display simultaneously: fluid intelligence, openness, psychoticism and ego-strength (Batey and Furnham 2006). Indeed, analyzing the profile of the broad-spectrum creator should allow researchers to establish a universal model for the prediction of creativity.

Multivariate Models of Prediction of Creativity

Explicative approaches of creativity have long been based on distinct research traditions. It was only in the 1980s that the analysis of creativity started to be oriented towards a multivariate paradigm (Lubart et al. 2003). This approach incorporates cognitive factors, personality features, emotional variables and motivational aspects in general models for the prediction of creativity. Eysenck (1993) was one of the first researchers attempting to establish such an integrative model.

Eysenck (1993) proposed that genetic determinants influence the hippocampal formation. Subsequently, the dopamine level increases and the serotonin level decreases. This special neurophysiological state influences in return some specific cognitive mechanisms. It lowers latent inhibition, which again leads to reduced cognitive inhibition.

Latent inhibition is expressed by the loss of the initial capture of attention of a stimulus. This happens after repeated exposure to it (Gray and McNaughton 1996). Cognitive inhibition is the actual protection of working memory against irrelevant information during a specific task accomplishment (Nigg 2000). Cognitive inhibition gets inferred through the experimental effect of negative priming. This effect arises after a stimulus has been ignored by a person. Shortly afterwards the processing of that previously ignored stimulus is impaired (Tipper 1985).

In the following stage, according to Eysenck (1993) these cognitive characteristics have an implication on psychoticism. This personality feature is characterized by a "large associative horizon". The superior extreme of the psychoticism scale is represented by personality disorders and psychoses. Thus in the worst case, psychoticism expresses itself in schizophrenia or manic depressive illness. However, it is important to keep in mind that only psychoticism as a personality trait favors creativity whereas genuine psychosis hinders it (Brod 1997; Jamison 1989). Finally, motivational variables, cognitive variables and sociocultural variables sustain the translation of latent creativity into genuine creative achievement (Eysenck 1993).

This model not only distinguished between psychoticism and psychotic disorders but also between trait creativity and creative achievement. Whereas trait creativity is viewed as normally distributed, creative achievement follows a J-shaped distribution in the population. Correlations between both forms of creativity were not expected to be exceptionally high.

Returning to the goal of modeling creativity, Eysenck (1993) explained the progress from genetic factors to the concrete expression of creativity. However, he was completely conscious about its highly hypothetic, speculative and preliminary nature. He agreed with the general conception of an infinitely long and complex path from DNA to cognitive inhibition and psychoticism, which relies on the expression of enzymes and neurotransmitters. This should nevertheless not distract researchers from trying to empirically validate this model, in order to reinforce and specify its conceptualization.

This kind of model has received support, at least on a theoretical basis, because it allows the complexity of creativity and its partial domain specificity to be taken into account. The difference between componential theories/models and stage theories lies in a different comprehension of the connection between the incorporated factors. Whereas, in stage theories one phase is an essential condition for the next one, components within a componential model are more independent from each other, and are not based on linear progression but allow for interactions (Runco 2007). In this respect, the model of Eysenck (see Fig. 1) can be essentially considered as a stage theory, albeit including some componential aspects.

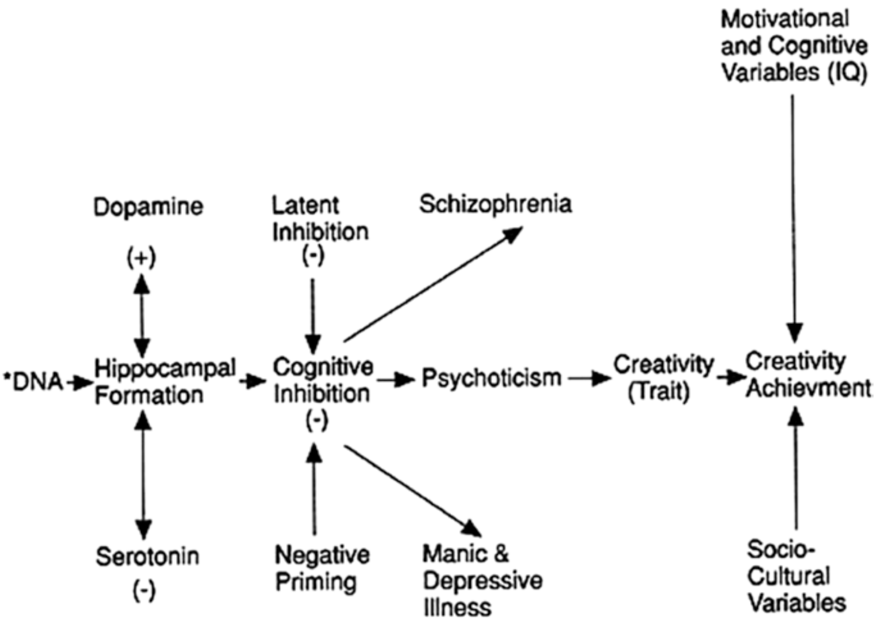

Fig. 1 Hypothetical causal chain of DNA towards creativity (Eysenck 1993)

So far only a few empirical studies on the exact nature of components in multivariate models, their relative position, their thresholds, their mutual compensations and their eventual interactions have been realized. This is largely due to their absence of detailed specification and the difficulty of assessing simultaneously the multiple components empirically. Lubart (1999) encourages future research to address this topic.

Research Aims and Hypotheses

In the present study a simplified version of Eysenck's model will be tested (see Fig. 2). It focuses on the shared personality features between artists and scientists (fluid intelligence, psychoticism, ego-strength, and openness) (Batey and Furnham 2006). These are exactly the same features that got repetitively assessed in architects. As both openness and psychoticism are integrated in the suggested model, the present study merges features of the Big Five and the Big Three approach.

In the present research, openness is considered as an elementary tendency underlying psychoticism and personality in general. This choice is based on the conception of openness as a basic exploratory tendency (DeYoung et al. 2002), strongly associated to reduced latent inhibition (Peterson and Carson 2000; Peterson et al. 2002). Together with *extraversion*, *openness* gets considered as a *Plasticity* dimension (DeYoung et al. 2002). Reduced cognitive inhibition permits an increased appreciation of latent information (Peterson 1999), due to a heightened cognitive permeability and cognitive flexibility (Peterson et al. 2002). As latent inhibition and cognitive inhibition are not included in the present assessment, openness is used as a proxy for these.

Creative achievement in form of real life scientific or artistic accomplishments will not be presently assessed. However, trait creativity will be measured through psychometric tests which require participants to produce creative work "on demand" in a task. This measurement approach is often employed when the

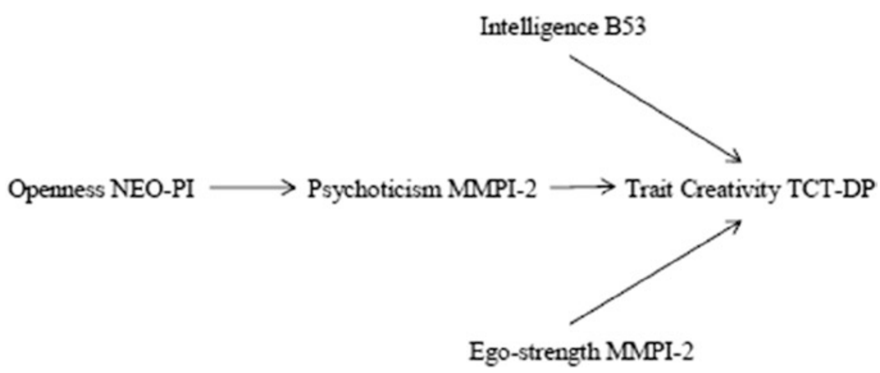

Fig. 2 A reduced multivariate model of creativity based on Eysenck (1993)

sample is not professionally active, as is the current case because the study concerns architecture students rather than working professional architects. Hence, in contrast to former research, the interest lays in the profile of the typical upcoming architect and in the discovery of the main traits that underlie their creative potential.

Based on the literature review and the above model (see Fig. 2), the following hypotheses are suggested:

- Openness is a positive predictor of psychoticism.
- Openness is a positive predictor of trait creativity, when controlling for fluid intelligence and ego-strength.
- Psychoticism is a positive predictor of trait creativity, when controlling for fluid intelligence and ego-strength.
- Fluid intelligence is a positive predictor of trait creativity, when controlling for psychoticism and ego-strength.
- Ego strength is a positive predictor of trait creativity, when controlling for fluid intelligence and psychoticism.

Methods

Participants

Data collection was realized at ENSAL (Ecole Nationale Supérieure d'Architecture de Lyon/National school for architecture in Lyon) France. The sample included 140 participants (65 women, 75 men, $M_{Age} = 21.96$, $SD = 4.37$, age range: 18–52 years). The vast majority was represented by students (98.57 %) and only a small minority by professionals and teachers (1.43 %). Whereas one part of the students was exclusively studying architecture (75.71 %), others were following a combined engineering/architecture program (22.86 %).

Instruments

In the present research *trait creativity* was assessed by the Test for Creative Thinking-Drawing Production (TCT-DP) (Urban and Jellen 1996). In this test, participants must complete a one-page drawing that includes several graphic elements disposed in a particular way on the page. The TCT-DP is a constraint production task that can be conceptualized as a convergent-integrative measure of creative potential (Lubart et al. 2010). It addresses a more holistic and gestalt-oriented approach to creativity. Being normed for a wide range of age and ability groups, this test has been applied and validated in numerous studies across different countries and can be considered as culture fair (Urban 2005).

The traditional scoring method is based on 14 criteria, representing the underlying test construct: continuations; completion; new elements; connections with a line; connections with a theme; boundary breaking, fragment-dependent; boundary breaking, fragment-independent; perspective; humor and affectivity; four kinds of un-conventionality and speed (Urban 2005). In this approach, only the total score meaningfully represents the level of creativeness, because the "Gestalt" is more than the sum of its parts (Urban 2005).

Lubart et al. (2010) revealed two main factors in the traditional scoring method of the TCT-DP, an originality component and an adaptation component. These factor scores are retained for further analyses. The Originality Factor (FO) contains the number of new items added to the composition, contacts and thematic connections established between the initial graphic elements, use of unconventional, non-stereotyped content or graphic forms, creation of a humoristic or emotional atmosphere and the use of three-dimensional drawing techniques. The Adaptation Factor (FA) consists of the number of graphic elements used among the initial elements proposed as well as their meaningful integration and the use of the element outside the frame.

In addition to the scoring system proposed by Urban, two further scoring methods have been suggested (Lubart et al. 2010): Statistical Originality (SO) and the Consensual Assessment Technique (CAT). Statistical Originality is based on the statistical frequency of ideas within the sample (Lubart et al. 2010). The CAT was originally developed by Amabile (1982). Strategically selected expert judges blindly rate the creativity level of the production according to some criteria. Validity (Caroff and Besançon 2008) and inter-rater reliability (from 0.70 to 0.90) have been demonstrated (Hennessey and Amabile 1998; Runco 1989). In the present research, creativity was rated by three independent judges, who showed a Spearman-Brown corrected inter-rater reliability of $\alpha = .91$.

The CAT addresses directly the core of creativity without passing through the evaluation of its different subcomponents, which are supposed to individually contribute to the level of globally perceived creativity. This makes the score largely independent of any theoretical conception and avoids the necessity of specific coding instructions (Kaufman et al. 2007). Interestingly, judges intuitively refer to three specific criteria for their creativity rating: (1) originality (novelty in the drawing content), (2) compliance with task constraints (use of the graphic elements provided) and (3) quality of productions (mastery of artistic techniques) (Lubart et al. 2010). This indirectly confirms the validity of the consensual creativity definition.

Openness was assessed through the NEO-FFI Openness to new experiences dimension (Costa and McCrae 1992). In reference to the NEO-PI, openness is defined as sensitivity towards fantasy, feelings, aesthetics, ideas, actions and values (McCrae 1987).

Psychoticism and *ego-strength* were assessed by means of the Minnesota Multiphasic Personality Inventory (MMPI-2; Hathaway and McKinley 1996). Whereas psychoticism was assessed through the subscale Psychopathic deviate (Pd), ego-strength was assessed through the subscale Ego-strength (Es).

The Pd-scale represents the degree of self-recognition in neurotic or psychotic disorders. More specifically, it represents the profile of people who have been repetitively in trouble with the law, yet without suffering from serious mental disorders and without being culturally or intellectually disadvantaged (Hathaway and McKinley 2000). Already Eysenck (1995) acknowledged the MMPI as an appropriate measure of psychopathological tendencies.

Originally developed by Barron (1953) to estimate the aptitude of patients to efficiently follow psychotherapy, the Es-scale is a measure of adaptability, resilience, personal resources and effective life management. It stands as an indicator of general mental health, expressed by the capacity to efficiently deal with critical life situations and to competently solve problems. People high on Es are spontaneous; they have a good contact to reality, a feeling of personal success and of physical health (Hathaway and McKinley 2000).

Intelligence in terms of reasoning capacity was assessed by the short version of the Evaluation of Logical Reasoning (B53) (Bonnardel 1971). In this test, inductive reasoning and spatial aptitudes are evaluated by means of non-verbal items, where the test taker is supposed to discover the logic behind a series of figures. Inductive reasoning is crucial for classification, for learning, for problem solving and ultimately for creation. Indeed, Karlins et al. (1969) determined the importance of spatial orientation for creativity in architecture.

Results

The descriptive statistics of the measured variables are presented in Table 1.

Results were considered as statistically significant at $p \leq 0.05$. Based on the observed correlations (see Table 2), a slightly different path model of prediction of creativity was proposed. It did not exactly correspond to the hypothesized model in Fig. 2, which did not fit the data and is consequently not presented here.

The adapted version of the model was tested using *Mplus* 5.2 software (Muthén and Muthén 1998–2007), which refers to the wellknown structural equation modeling (SEM) approach.

For determining the adaptation of the model to the current data, the following fit indices were calculated: the chi-square statistic and its related *p*-value, the comparative fit index (CFI), the Tucker–Lewis index (TLI), the root mean squared error of approximation (RMSEA), the standardized root mean squared residual (SRMR), and Akaike's information criterion (AIC). Good model fit is indicated by a ratio of less than 3 between the chi-square and the degrees of freedom (χ^2/df), by a CFI and an TLI above 0.90, an RMSEA below 0.05, and an SRMR under 0.10 (Kline 2005).

Finally, considering the higher replication probability, the model with the smallest AIC was retained (Kline 2011). Table 3 represents the fit indices of the selected path model. It did however not perfectly fit the data.

Table 1 Means and standard deviations for personality and cognitive variables

Variables	M	SD
TCT-DP total score[a]	28.39	9.81
Originality factor FO[b]	16.44	6.75
Statistical Originality SO[c]	2.23	1.92
Originality[d]	18.67	7.31
Adaptation factor FA[e]	11.94	4.58
CAT[f]	3.88	1.44
Reasoning B53[g]	25.60	4.87
Openness[h]	177.35	14.41
Psychoticism[i]	18.90	3.63
Ego-strength[j]	28.29	4.70

Note Minimum and maximum values for each scale: [a]theoretical range = +3 to +56; [b]theoretical range = +1 to +38; [c]theoretical range = 0 to +8; [d]theoretical range = +2 to +42; [e]theoretical range = 0 to +18; [f]theoretical range = +1 to +7; [g]theoretical range = +10 to +32; [h]theoretical range = +107 to +214; [i]theoretical range = +10 to +29; [j]theoretical range = +16 to +38

Table 2 Correlation matrix of personality and cognitive variables

Variables	1	2	3	4	5	6	7	8	9	10
1. TCT-DP	1	.91**	.18*	.89**	.80**	.01	.22**	−.05	−.02	.11
2. FO		1	.16*	.97**	.48**	.09	.23**	−.03	.01	.03
3. SO			1	.41**	.16*	.15*	.08	.10	.04	.00
4. Originality				1	.49**	.12	.23**	.00	.02	.03
5. FA					1	−.11	.14	−.05	−.05	.19*
6. CAT						1	.07	−.01	.06	.05
7. Reasoning B53							1	−.03	−.01	.14*
8. Openness								1	.15*	.05
9. Psychoticism									1	−.16*
10. Ego-strength										1

Note *p < .05 level; **p < .01 level. TCT-DP: Test for Creative Thinking-Drawing Production; Originality factor FO; Statistical Originality SO; Adaptation factor FA; CAT: Consensual Assessment Technique

Table 3 Fit indices for model 1

				RMSEA				
Models	χ^2/df	CFI	TLI	Estimate	90 % CI	p	SRMR	AIC
1	7.46	0.95	0.90	0.22	0.15–0.28	0.00	0.18	3878.98

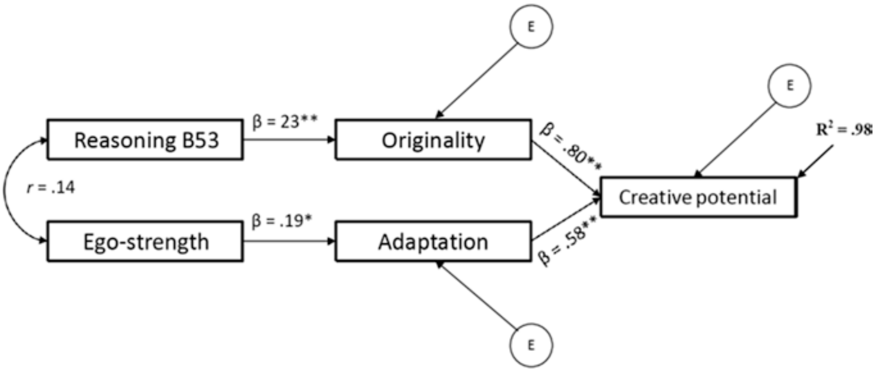

Fig. 3 Cognitive and personality variables predicting creativity. Legend for the observed variables: *Originality* Originality factor FO (composite score); *Adaptation* Adaptation factor FA (composite score); *Creative potential* TCT-DP (composite score of FO and FA)

Discussion

In the following section, the hypotheses underlying the predicted multivariate model (see Fig. 2) are going to be discussed separately. Furthermore, the divergence between the predicted model (see Fig. 2) and the resulting model (see Fig. 3) is highlighted and discussed.

- Openness is a positive predictor of psychoticism.

This hypothesis got partially confirmed. Openness was indeed a positive but not a significant predictor of psychoticism ($r = 0.15$, $p > 0.04$).

However, as the suggested model (see Fig. 2) was not entirely supported, the direction of the relationship between openness and psychoticism remains unclarified. Furthermore, neither the Big Five nor the Big Three approach could be validated in the present sample as neither openness nor psychoticism was significantly related to trait creativity (see Table 2). Accordingly, no statement can be made to the dominance of one approach over the other.

- Openness is a positive predictor of trait creativity, when controlling for fluid intelligence and ego-strength.

This hypothesis was not supported. Openness did not turn out to be a positive predictor of trait creativity; neither in form of the traditional TCT-DP scoring method nor of SO and the CAT (see Table 2). As the outcome was not influenced by the respective scoring technique, this result is surprising.

This questions the Big Five approach, in which openness is considered as the cardinal personality characteristic for creativity (Batey and Furnham 2006). Generally speaking, openness has been repeatedly associated to creativity on a theoretical and an empirical basis (Dollinger and Clancy 1993; Dollinger and Clancy Dollinger 1997; Dollinger et al. 1996a, b, 2004; Johnson 1994; McCrae and Costa 1997; Ostendorf and Angleiter 1994; Urban 1990, 1995; Urban and Jellen 1996).

The prevailing role of openness for scientific and artistic creativity was confirmed in a recent meta-analysis from Feist (1998), in which openness was found to particularly affect fluency and flexibility. Considering the large amount of past research, the missing link between openness and creativity in the present study is astonishing. It is even more surprising that apart from all creativity scores, openness is not significantly correlated to either variable. Hence, the probability of a third variable intervening in the link between openness and creativity is rather unlikely.

- Psychoticism is a positive predictor of trait creativity, when controlling for fluid intelligence and ego-strength.

This hypothesis was not supported. There was no clear correlation to creativity emerging in the present sample. The scoring technique of the TCT-DP cannot be considered as a justification for the missing relation, as it was consistently observed using all three evaluation techniques (see Table 2).

This also questions the Big Three approach, according to which psychoticism is the determining personality characteristic for creativity (Eysenck 1993, 1995; Batey and Furnham 2006).

Furthermore, it stands in contradiction to the apparently complex personality of architects, combining high ego-strength with high psychoticism (Barron 1963, 1965, 1969; MacKinnon 1961, 1965). Apparently, psychoticism is not an indispensable feature for creativity in architects. This challenges the notion of the architect as partial artist and would rather associate the architect to a creative scientist.

Considering the missing correlation between psychoticism and creativity (Originality and Adaptation), psychoticism was not included as a predictor of trait creativity in the path model in Fig. 3. The same logic applies to the non-significant correlation between openness and psychoticism and between openness and creativity. The inclusion of both predictors (psychoticism and openness) in the model would not make sense and would only weaken the adaptation of the model to the data and its corresponding fit indices.

- Fluid intelligence is a positive predictor of trait creativity, when controlling for psychoticism and ego-strength.

This hypothesis was partially confirmed. Whereas reasoning was a positive predictor of Originality ($r = 0.23$, $p < 0.01$; $\beta = 0.23$, $p < 0.01$), the association with Adaptation was not significant ($r = 0.14$, $p = 0.05$). Empirically speaking, this result is in line with Benedek et al. (2012) who found intelligence to be only a significant predictor of Ideational Originality ($\beta = 0.51$, $p < 0.01$) and not of Adaptation. Furthermore, intelligence is known to favor creativity, only in terms of ideational originality (Benedek et al. 2012; Nusbaum and Silvia 2011; Silvia and Beaty 2012) and not in terms of ideational fluency or flexibility (Benedek et al. 2012).

This outcome seems also intuitively and theoretically plausible. In reference to main intelligence theorists, “successful novelty” is the hallmark of the definition of intelligence (Gardner and Sternberg 1994; Gregory 1981; Spearman 1927;

Sternberg 1985). However, the core of intelligent behavior is located in the generation of subjectively novel solutions and not only of groundbreaking new discoveries, as one could instinctively assume (Kaufmann 2004). This kind of intelligence definition supports the uncovered link between fluid intelligence and originality in the present research.

However, it was expected that intelligence would be important for adaptation to task constraints and the missing link is somewhat surprising. Indeed, the consensual definition of intelligence highlights the importance of flexible adaptation to the environment. More precisely, intelligence is defined as "capacity for goal-directed, adaptive behavior" (Harper Collins 2015).

Furthermore, intelligence is supposed to be a protective factor against psychotic disorders. In this sense, it should also promote adaptation to task constraints in a creativity task, as adaptation goes along with mental balance. Poor mental adjustment can lead to the realization of bizarre productions, which lack the component of contextual adaptation.

- Ego strength is a positive predictor of trait creativity, when controlling for fluid intelligence and psychoticism.

This hypothesis was partially confirmed. Ego-strength has only shown to be a significant predictor of Adaptation ($\beta = 0.19$, $p < 0.05$). This makes sense in the light of conceiving emotional stability as favorable for adaptation to task constraints. Indeed, ego-strength is a protective trait against psychological disorders and an excessively large associative horizon. It equilibrates the potentially harmful effects of psychoticism.

However, in this specific sample of architects, psychoticism was not linked to trait creativity. Ego-strength even clearly outdid the role of psychoticism (see Table 2). Hence, there was no need to counterbalance its potentially unbalancing effects. Presently, it seems merely that ego-strength prevents people from realizing bizarre drawing compositions, which would well be innovative but not adapted to the context.

Conclusions and Perspectives

The initially predicted model (see Fig. 2) was not entirely confirmed and an alternative version was proposed instead. Neither the Big Five nor the Big Three approach to creativity has found support in the present sample, as neither openness nor psychoticism was significantly related to creativity (see Table 2). These missing links cannot be due to the scoring technique of the TCT-DP, as they were consistently observed using all three techniques (see Table 3). Thus, no conclusion can be made about the relative importance of openness or psychoticism and the direction of the relationship between openness and psychoticism remains unclear.

A possible explanation for the lack of fit of the initially hypothesized model (see Fig. 2) could be due to some methodological choices. Results may have been different by measuring trait creativity in a more integral way and by including an assessment of creative achievement in the form of real-life architecture projects. The evaluation of trait creativity could be completed by adding a creative personality measure, e.g., Gough's Creative Personality Scale. These methodological limitations could provide an explanation for the missing support of both the Big Five and the Big Three approach.

Although the predicted model was not found to work for the TCT-DP creativity sum score, a model based on some hypothesized relations did function when considering originality and adaptation separately. Apparently, it makes sense to distinguish between both facets of the creativity definition when establishing multivariate population-specific models. Indeed, both components seem to be differentially related to the relevant cognitive and personality characteristics.

In this architecture population it seems that fluid intelligence is important for generating a maximum of innovative ideas whereas ego-strength takes the role of selecting among these ideas those which fit the context. This latter selection allows distinguishing creative productions from bizarre productions. The role of intelligence even outweighted that of ego-strength. Indeed, fluid intelligence was not only related to ideational originality but also to the TCT-DP creativity sum score (see Table 2). This sum score was composed of both facets: originality and adaptation. Accordingly, the role of intelligence is notable for creativity in architecture.

In the same line, the role of ego-strength was stronger than that of psychoticism. Whereas, ego-strength was significantly linked to one facet of trait creativity, this was not the case for psychoticism (see Table 2). Moreover, the correlation between psychoticism and ego-strength turned out to be significantly negative ($r = -0.16$, $p < 0.05$). This contradicts the common notion of conflicted personalities in architects, in which psychopathological tendencies and personal effectiveness are supposed to coexist (Barron 1963, 1965, 1969; MacKinnon 1961, 1965).

Perhaps these kinds of personality conflicts can be particularly ascribed to highly creative architects and do not extend to the typical architecture student. Presently, it seems that creative capacities are rather spurred by emotional stability, impulse control and intelligence. This questions the vision of the architect as partial artist and would tend to bring the description closer to the category of scientists. Eventually, the common conception of the architect has to be revised and adapted.

To summarize, the proposed model (see Fig. 3) merges features present in Eysenck (1993) with suggestions from other work (e.g., Lubart et al. 2010) to result in an integral, innovative and specified prediction of creative potential. In upcoming research, the revealed model can be gradually enlarged and completed, approaching thereby a genuine latent model underlying the prediction of creativity in different domains of achievement: artistic, scientific and everyday life.

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Improving Self-efficacy in Solving Inventive Problems with TRIZ

Niccolò Becattini and Gaetano Cascini

Introduction and Aims

The construction of a Knowledge Society is a shared goal to achieve the capability to face the challenges of incoming future. Beyond the establishment of a system of people's social relationships ensuring innovation and sustainability, one of the main goals to pursue concerns the improvement of creative thinking. This is one of the key abilities of individuals to achieve a high degree of participation in such a society, by getting, using and developing new knowledge independently. Lytras and Sicilia (2005) depicted the building of a Knowledge Society as accomplished through *knowledge* and *learning*. These are seen as two different perspectives of the same whole, through which the world (Objects, Processes, Strategies, Systems, Performances) should be understood. A Knowledge and learning flow characterizes the three main "actors" of the Knowledge Society: the individual, the team and the organization (whatever their specific declination). The behaviour, therefore, plays a relevant role since, on the one hand, it gets changed by a process of adaptation to environmental situations, referred as learning by behaviourists. On the other hand, it affects the learning process by stimulating or inhibiting it, according to the feedbacks received by the situation itself.

In this regard, Bandura (1977) introduced the concept of "self-efficacy", as the individual's perception (belief) that "*he or she can successfully perform in a particular setting*". In more recent studies Bandura (1997) claimed self-efficacy as a necessary requirement for creativity. Similar relationships have been also recognized by Lubart (1994), Breghetto (2006) and Prabhu et al. (2008). Moreover,

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a low self-efficacy has been seen as a potential source of frustration that reduces perseverance and motivation in difficult and demanding tasks. Designing is an activity where perseverance and motivation have a prevailing importance, as it is based on highly cognitive-demanding tasks. To this purpose, both self-efficacy and the general attitude of designers have a paramount role in being effective and efficient when tackling a design problem.

From a slightly different perspective, also the curricula in academia are progressively trying to address some of the main challenges of the knowledge society. Courses on knowledge management and intellectual capital are more common in trans-disciplinary areas of studies, ranging from engineering to law. At the same time, also the topics of design creativity and inventive problem solving get progressively integrated as subjects in engineering courses. This is done as a way to both foster the quick development of new (technical) knowledge and to address the incoming challenges of complexity and sustainability. The overall goal of such courses is to equip the future engineers with improved technical competences and cognitive skills, which may represent a strategic asset for the development of their professional careers.

According to these premises, this work aims to show how a class covering TRIZ and OTSM-TRIZ topics, can improve students' self-efficacy in solving inventive problems. This is considered as a crucial aspect to face challenging situations, such as the ones involving the learning of new concepts and the creative application of knowledge to face unexpected situations. Moreover, the study also aims to understand how the topics of the course trigger a change in the students' attitude during design tasks. Both the improvement of self-efficacy and the change of attitude towards a more creative behaviour can be considered as essential ingredients for building a Knowledge Society.

The next section will better shape the context of this study and the relevance of the topic in the field of creativity in design, together with updated references to already existing studies about self-efficacy in design. Then, in order to clarify how the content can affect both self-efficacy and attitude in solving inventive problems, the authors present the content of the above course with reference to the questions of the survey here proposed as a means of investigation. The methodology and the outcomes of the survey are presented as aggregated data and critically commented. The last chapter summarizes the main concluding remarks and depicts further directions for improving the analysis and conduct further studies.

Creativity and Self-efficacy in Design

Creativity, in literature, is commonly described as a complex phenomenon where different factors interact with each other. These factors are known as the 4Ps of creativity: Product, Person (People), Press, Process (Rhodes 1961). Creativity, indeed, can be found in the personality of the individual or group (People) that generate a creative idea (Product). Furthermore, the sequences of thoughts

(Process) leading to a brilliant idea may, as well, follow specific cognitive operations that are deemed to be creative. Moreover, the environment (Press) exerts several actions on the other factors: it may trigger the demand for new and more performing products of creative thoughts and, on the other hand, it can provide meaningful stimuli or mental barriers affecting the efficiency and the effectiveness of the creative process, being it individually or collectively carried out.

Whatever is the approach to design, being it structured and systematic (Pahl et al. 2007) or purely driven by intuition and enlightenment (Osborn 1963), it aims to satisfy, or even generating, new demands addressing a problematic situation that originates from changes in a given environment and that generates discontentment in a certain set of people (Roozenburg and Eekels 1995).

The process of matching the problem state to a goal state (Simon 1973) may follow different paths, according to the expertise and the attitude of the designer (Cross 2004): it may proceed for successive approximation from the problem state to the goal state (Cross 2008), or by reformulating them through several iterations between the problem and the solution state (known as the Co-evolution of problem and solution) (Dorst and Cross 2001). Whatever is the path, three main cognitive processes characterize it: Exploration (as a usually divergent search for solution concepts); Combination (as the harmonization of two parent concepts in a new one embedding some characteristics of both); Transformation (as a radical reformulation of the design state space, thus meaning both problem and goal state) (Boden 2009).

Nevertheless, design and creativity cannot be considered as two completely overlapped entities. Design problems do not necessarily require a creative leap to define a suitable solution. Standard problems, also called routine design problems, can be tackled by means of well-established procedures, so that the designer can merely execute a set of predefined instructions till the solution comes up. On the contrary, problems whose solution is not straightforward, that are poorly defined and for which there are no specific solving algorithms or procedures, require a significant contribution of the designer's knowledge and skills of abstraction and analogy (Becattini 2012).

More specifically, inventive problems are those requiring an invention, an idea generated through a creative act resulting in something useful, non-obvious (thus, potentially triggering surprise) that also owns some characteristics of novelty. It is worth noticing that these overall characteristics appear both in the definition of an invention according to the patent laws and in the dimensions through which creativity is measured by scholars in the field.

From a situation requiring an inventive problem, there is usually no paved road, nor directions or transportation means to get to a suitable and feasible solution concept. This is one of the typical situations in which a strong creative self-efficacy is more necessary.

The belief that improving the self-perception of being effective allows people to actually achieve better performances as been pointed out by Bandura (1977). Some other scholars looking in the same direction also refer to this empowerment source as self-confidence.

Recently IDEO's founder David Kelley (Kelley and Kelley 2013) has tackled the same issue from a slightly different perspective, introducing the lack of creativity in individuals as caused by the self-induced fear of behaving creatively. He considers the exposition of not-yet-creative subjects to techniques and exercise dealing with creativity as the key to remove such fears, improving the owned creative confidence and, thus, obtaining better design results.

In the last decade, several studies have witnessed the increasing importance of self-efficacy in design tasks, being it related either to the problem solving skills in situations requiring inventive leaps or to the personal attitude (inborn or induced) towards a more creative way of thinking.

Belski et al., e.g. (Steiner et al. 2011; Harlim and Belski 2011, 2013) have investigated the impact of TRIZ courses on the personal belief of students or users with respect to their perceived problem solving skills and performances. This investigation has been successfully replicated on a large number of testers (more than a hundred, along the years) in order to extract meaningful statistical data. Through the analysis of the results retrieved from the survey and after personal interviews, they found that TRIZ influenced students' self-efficacy and, as a consequence, their motivation when facing problems and their willingness to face them in the future. Moreover, they considered self-efficacy as crucial for the development of problem solving skills in a long-term perspective (which is also one of the goals to be reached by the Knowledge Society).

In an empirical perspective, the group of scholars working under the supervision of Badke-Schaub at TU Delft has recently presented their correlation analyses aimed to verify the existence of hidden relationships between gender, background, creative behaviour and creative self-efficacy (Brockhus et al. 2014). This study shows that a positive correlation exists between creative self-efficacy and creative performances (i.e. more original, higher amount and higher variety of ideas).

The present work aims to understand the impact of a course strongly characterized by TRIZ and OTSM-TRIZ content in empowering the problem solving skills and shaping a more efficient and effective attitude for designing creatively. The next paragraphs will clarify both the content of the above course and the method through which the investigation has been carried out.

A Course on Systematic Innovation and Inventive Problem Solving

The authors' experience specifically refers to a course on methods for Systematic Innovation in the overall perspective of Engineering Design and Problem Solving. The course is widely infused by TRIZ, the Russian acronym for the Theory for the Solution of Inventive Problems developed by Altshuller (1984), and OTSM-TRIZ, the Russian acronym for the General Theory of Powerful Thinking (Cavallucci and Khomenko 2007) contents.

The overall purpose of the course is to improve the conceptual design abilities of students. The course content aims to foster their creativity with means capable to drive exploration, combination and transformation cognitive processes (Boden 2009), with the purpose of producing better ideas. Moreover, the course aims to turn students' behaviour in design from an intuitive to a systematic approach. This approach exploits analogy-making through methods and tools for abstraction that are applicable in multidisciplinary contexts.

More specifically, the course covers a rather wide range of topics, concerning both the analysis of technical inventive problems and the synthesis of solutions capable of addressing them. Furthermore, the course also presents models describing a creative problem solving process, in order to support the cognitive activities that a designer faces when solving an inventive problem or, more in general, when a specific creative solution needs to be found.

The content of the class on TRIZ and OTSM-TRIZ is briefly summarized in the following paragraphs. For a short introduction to those contents, please refer to (Cascini 2012).

Descriptive Models

These models allow the description and the analysis of concrete or abstract entities (e.g. in terms of their characteristic parameters or attribute, as for the OTSM-TRIZ ENV model). They can also address the way technical systems work, together with the relationships among their constituting elements (e.g. TRIZ and OTSM-TRIZ Functional models). Functional models, in particular, also allow the representation of technical systems just in terms of their overall purpose, focusing on their capability to transform an input into a desired output (e.g. EMS and IDEF0 models) (Becattini 2013).

Problem Models

These models can be considered as descriptive representations of one or more specific facets of the problematic situation to be addressed by the designer. They aim to both abstract the problem at hand [e.g. TRIZ Substance Field Model and OTSM-TRIZ contradiction model (Cascini 2012)] and highlight the mutual relationships between problems and solutions (OTSM-TRIZ Network of Problems) (Becattini et al. 2014). The abstract representation of the problem is crucial in order to apply general-purpose solving instruments and trigger analogies to the mind of the designer. A hierarchical and causal map of problems and solutions, in turn, supports the identification of priorities and more promising directions for problem solving.

Problem Solving Process Model

These models support the proper structuring of a problem solving process so that it can proceed systematically without limiting the creative contribution of the individual. The TRIZ System Operator is claimed by Altshuller (1984) as a model embedding the way creative people think. It introduces a systemic view on situations and/or on technical systems by considering them as a whole, by the specific features or components characterizing them and in the context in which they occur or work. Moreover, the System Operator also embeds a time perspective for the three hierarchical levels generically subdivided into past, present and future. This system-thinking model enables broad-spectrum reasoning (Becattini et al. 2013) and therefore exploration. The OTSM-TRIZ Hill, Funnel and Tongs Models (Becattini et al. 2012; Cascini 2012) provide three different perspectives on the inventive problem solving process. The Hill model depicts the cognitive effort to generate a meaningful solution concept, along the problem solving process, with reference to the degree of abstraction of the problem. The Tongs model describes the mechanisms through which a problem can be abstracted in terms of one or more contradictions, i.e. design conflicts that emerge as a barrier where the two claws, representing the problematic situation and the ideal (i.e. goal) state, touch each other. The Funnel model, in turn, shows the convergent essence of such structured problem solving process: the progressive overcoming of design conflicts, being generated by personal needs or natural laws, leads towards a fully defined and working solution, reducing useless and inefficient trial and error approaches.

Solving Instruments

TRIZ and OTSM-TRIZ include several approaches in order to synthesize solution concepts after an appropriate analysis and abstraction. Checklists of substances and fields, as well as the Pointer to Effects (Altshuller 1984), which are potentially exploitable resources to solve problems, and the 76 Inventive Standards (Tetris Project 2009) can be more easily addressed to problem shaped as Substance-Field Models. Separation and Inventive principles, in turn, are properly shaped in order to tackle TRIZ contradictions. The formers aim to separate the two plainly non-mutually compatible exigencies in space, time, on condition or at a micro/macro level, so as to satisfy them both. The latters, besides, are a set of 40 solving concepts at abstract level that have been formulated after the analysis of regularities in patents. Their purpose is to stimulate cognition and trigger inventive ideas. Students are also introduced to the overall logic of ARIZ, the Algorithm of Inventive Problem Solving (Cascini 2012), an articulated procedural method embedding some of the already mentioned TRIZ models and solving instruments.

Furthermore, in order to tackle inventive problems for complex systems, the overall logic of the OTSM-TRIZ Problem Flow Network is presented, together with a tailored algorithm for the prioritization of design problems in a complex set. The algorithm allows the adoption of the abovementioned classical TRIZ solving instruments without losing the overall perspective on the system complexity (Khomenko et al. 2007).

Self-efficacy Survey

Consistently with what has been presented in the previous sections, the improvement of students' self-efficacy has a paramount importance, because it directly affects the perseverance in facing uncomfortable situations, such as the ones characterized by great uncertainty and fuzziness as it happens in innovation activities.

Moreover, it has also been already mentioned that several scholars have recently considered the changes in self-efficacy of people involved in design activities. Among those studies, Steiner et al. (2011) carried out an analysis for understanding the changes in the students' perception of their problem solving skills after attending an engineering course on Theory of Inventive Problem Solving (TRIZ), thus embedding some of the TRIZ models and tools as its contents. They developed a test composed by the following set of six statements:

1. I am very good at problem-solving;
2. Problem-solving skills are of vital importance;
3. I am never intimidated by unknown problems;
4. I am unable to tackle unfamiliar problems;
5. So far, I have resolved every problem I faced;
6. I am certain that I am able to resolve any problem I will face.

Since this test has proved to provide successful outcomes in a very similar context, the authors have replicated the same test both at the beginning and at the end of the 2012–2013 edition of their course on Methods and Tools for Systematic Innovation (MS curricula in Mechanical Engineering at Politecnico di Milano), and asked the 30 students who attended the course to express their agreement to the statements according to a 4-level qualitative scale. This choice allows the authors to carry out at least preliminary comparisons with already existing studies in the field. Moreover, the 4-level scale is the reference adopted by Politecnico di Milano for all the courses quality assessment surveys.

Figure 1 graphically depicts the overall approach the authors have followed in order to carry out the study on self-efficacy. In order to retrieve meaningful feedbacks also for what concerns the changes in students' attitude, eight additional statements have been also formulated to extend the analysis on the perceived efficacy of specific tools and concepts proposed within the course. This new set of personalized questions, beyond the estimation of the overall tendency about the change of attitude in inventive problem solving activities, allow the authors to retrieve useful feedbacks to refine, if needed, the course structure.

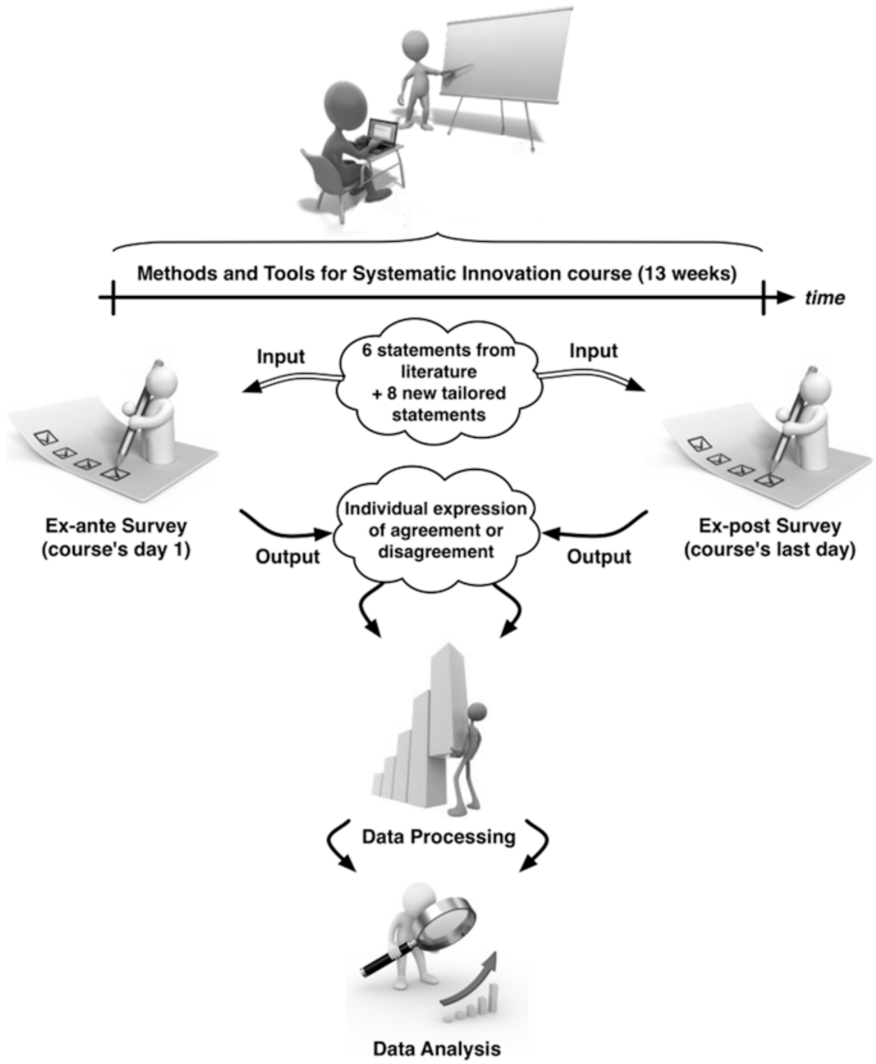

Fig. 1 Approach to evaluate change in students' self-efficacy and problem solving attitude

Please note that the eight new statements have been also formulated with a strong polarization of the opinion, to both reduce the risk of potential interpretation ambiguities and obtain clearer information by means of the expressions of agreement/disagreement.

The following statements should be interpreted in the context "While solving a design problem I've never faced before, …":

7. *I always take into account similar problems in different fields of technique.*

This statement aims to capture the attitude of the interviewee towards analogical reasoning. This is an expected consequence of the practical experiences in using problem models, whose aim is to support abstraction, so as to ease the emergence of relevant analogies. Stronger agreements after the course represent a desired result.

8. *I always neglect all the elements that are not directly involved in the problem.*

The statement focuses on the perception of the acquisition of system-thinking skill, also considering the context in which a problematic situation occurs. It aims to assess how much the System Operator logic has been assimilated as an effective thinking scheme (e.g.: consider the system, its parts/components and the contexts it operates in, also according to a time perspective, in order to consider potentially relevant opportunities for solving problems). Stronger disagreement at the end of the course reflects an improved trust in system-thinking.

9. *I never follow a predefined strategy.*

Too rigid paths can lead to dead-ends and design fixation. However, the systematic approach of the course aims to enforce the conviction that an efficient creative designer follows an overall strategy to be adapted to the problem at hand and do not proceed by trial and error. The approach of firstly considering the overall goal to be achieved and then synthesize solutions moving backwards represents one of the strategies taught during the course. A pre-post increased disagreement shows a more convinced attitude towards a method-based approach to design.

10. *I always consider the best desirable solution even if not technically feasible.*

The capability to identify design conflicts depends on the clarity through which a goal state (or ideal state) can be framed. This statement is meant to appreciate the attitude to define dreaming solutions, as for the TRIZ concept of Ideal Final Result (IFR). This is one of the keys to overcome mental inertia and to envision existing problems where they are not evident. Stronger agreements in the final survey imply a more marked attitude towards the envisioning of ideal solutions.

11. *I always consider the impact of design choices on all the requirements.*

The impact of design choices and the propagation of changes are topics that critically affect the design of complex technical systems. The statement aims to assess the changes in design attitude towards having a hierarchical perspective for the system parts (as for the System Operator logic) and the relationships between problems, sub-problems and partial solutions (as for the Network of Problem logic). To higher agreements corresponds a positive shift in the direction of hierarchical reasoning.

12. *The focus is always on the structure/layout of the technical system.*

As engineers are typically oriented to analytic decomposition of systems and thus more focused on the system parts than to its context, this statement aims to measure the individual attitude towards a consideration of the problem to be solved. This should also reflect, in case of a stronger disagreement at the end of the course, the increased attitude towards the understanding of technical systems at different level of description, e.g. their overall functional purpose, their working principles and, of course, its structure.

13. *It is necessary to find the best compromise among system requirements.*

This statement is meant to estimate the change of attitude about the need of refusing design trade-offs since they cannot boost the evolution of a technology. In other terms, it looks towards the empowered or weakened tendency of facing design conflicts (Technical or Physical Contradictions, in TRIZ terms) with less fear and more confidence of generating a breakthrough concept. Results showing an increased disagreement reflect a shift of the problem solving approach towards dialectic thinking, focussing on incompatible needs that should be both satisfied at all.

14. *I always try to modify the system as less as possible.*

Small changes in the system presenting the problem are usually associated with a more brilliant reorganization of already available resources. The exploitation of available resources to solve an inventive problem represents one of the most creative activities, because it forces the designer to increase the amount of design constraints to deal with. Moreover, a more appropriate use of resources represents one of the driving concepts of TRIZ, as it is one of the three postulates the theory is based on. A pre-post increased agreement witnesses an attitude change in the direction of firstly rejecting solutions requiring new and external resources.

All the 30 MS students of the course on Design Creativity and Inventive Problem Solving voluntarily participated the above self-efficacy survey. The next section presents the results and the main evidences emerged by the related analysis.

Results of the Surveys and Related Statistical Analysis

The self-evaluations by the students have been collected and processed according to the four levels of judgment about agreement/disagreement. Figures 2 and 3 respectively show the overall results for the already existing set of questions and the newly defined ones, as they emerged from students' opinion. For what concerns the first statement it is noticeable that the amount of answers expressing disagreement decreases of almost a half and this trend is also enforced for the second statement, where the total amount of at least partially disagreeing participants is slashed of more than the 70 %. An analogous shift can be recognized also for what concerns the third statement, even if the opinion here looks more balanced.

Furthermore, the outcomes about the fourth statement show an overall trend of improved self-efficacy, especially for the marks reporting a strong disagreement (x3), which results in a drop of more than 50 % of agreeing answers.

An improved self-efficacy can be also seen from the graphs related to the statements 5 and 6. Both the perception of past problem solving performances and the self-confidence about future problem solving effectiveness are improved at the end of the course. In the first case, answers of agreement are almost doubled (Pre-post: 10–18).

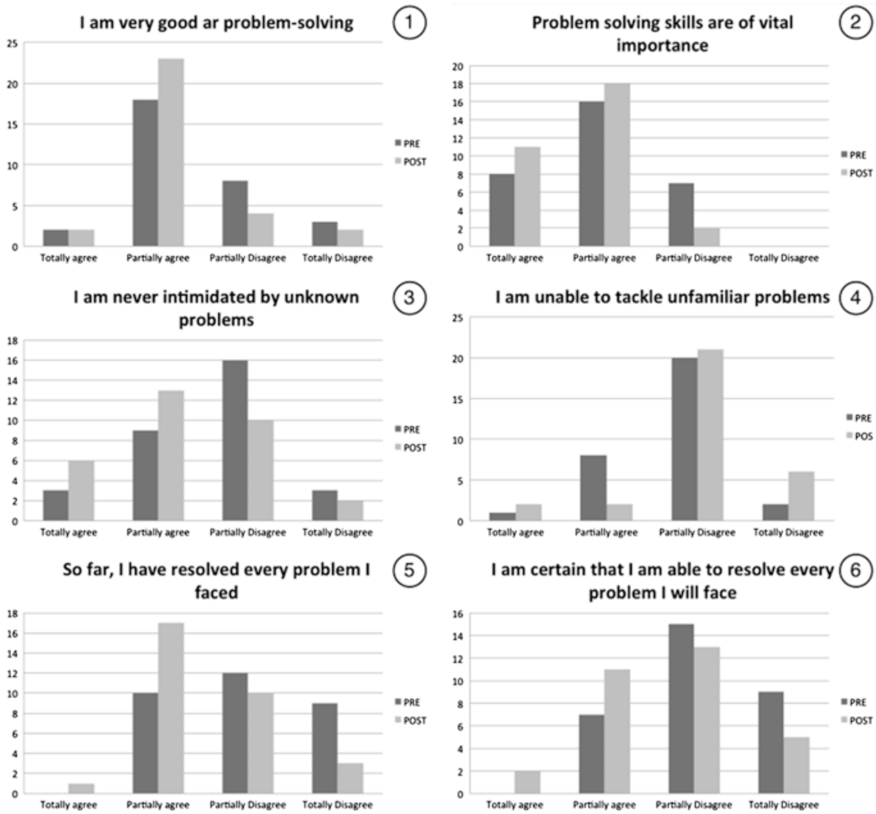

Fig. 2 The first 6 statements on problem solving self-efficacy: distribution of answers

Future expectations, in turn, show an analogous positive trend towards an improved self-efficacy (≈+50 %), but with a smaller number of agreeing answers (Pre-post: 7–13).

Statements 7 and 9 have both polarized answers at the end of the course. In the first case no one disagrees at the end of the course, Statement 9 shows that just one participant is still (but strongly) convinced of a better effectiveness of complete randomness instead of a problem solving strategy.

At the beginning of the course no one answered with a strong disagreement about overlooking aspects that are, at least apparently, not related with the problem at hand (Statement 8). Five participants, at the end of the course have changed their mind and one of them radically shifted from an opposite to the other (not evident from Fig. 3). An analogous consideration can be done for the answers to the tenth statement: none of the participants strongly agreed to consider also the best but unfeasible solutions. In the final survey, four students marked a strong agreement.

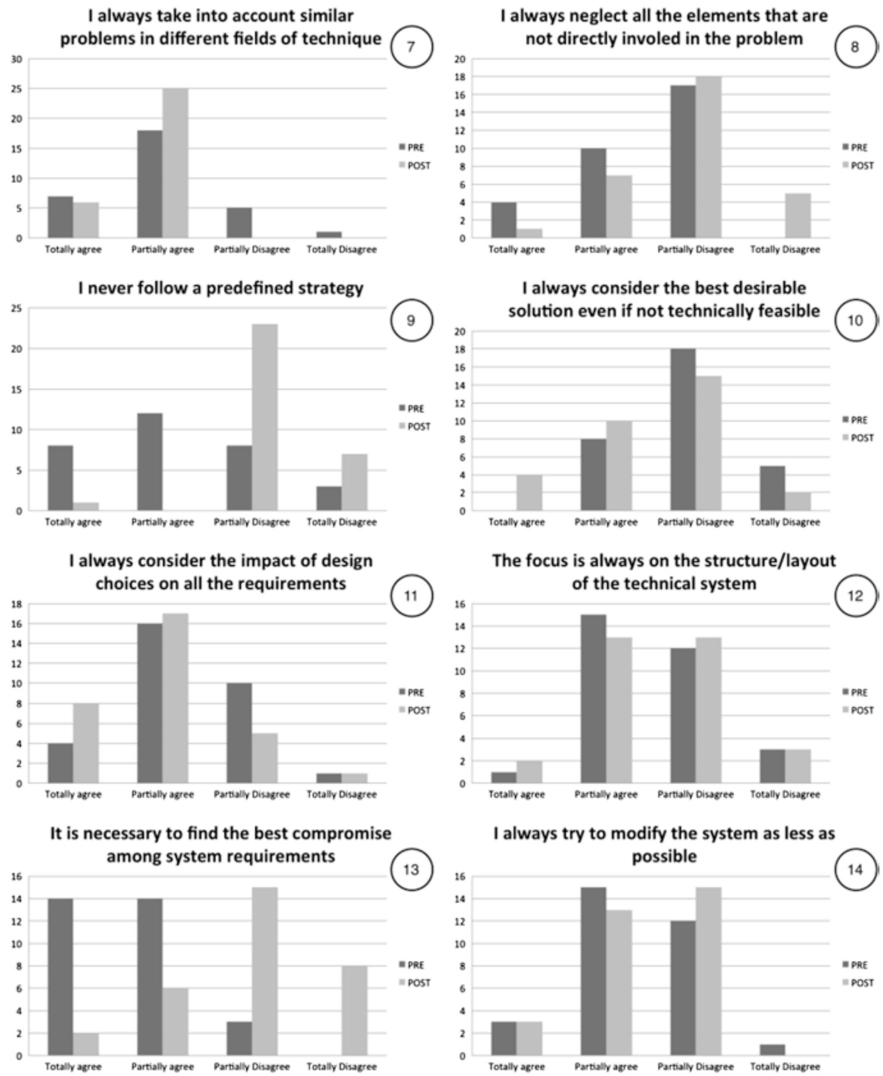

Fig. 3 The 8 personalized statements developed for capturing the change of problem solving behaviour in students consistently with the contents delivered along the course: distribution of answers

Statements 12 and 14 are those who show an almost stable behavior between the beginning and the end of the course, without any significant shift.

On the contrary, the most evident result emerges from the graph about the Statement 13. Not surprisingly, the most effective change in students' attitude is due by one of the core concept of TRIZ concepts: the contradiction. The refusal of compromises or trade offs among design requirements leads to design conflicts, which are the keys for designing more effective solutions. The answers are

Table 1 Metrics for the conversion of judgment on agreement into scores

Judgment	Score
Definitely not	2
More not than yes	5
More yes than not	7
Definitely yes	10

radically polarized between the ex-ante and the ex-post results. Twenty participants shifted from agreement to disagreement and the overall numbers of disagreeing answers has grown of almost 8 times (Pre-Post: 3–23).

As witnessed by Rampichini et al. (2004), the conversion of student ratings into quantitative scores represents a common practice that aims to ease the analysis and the dissemination of this kind of results. As for this premise, the qualitative results of Figs. 2 and 3 have been conveniently converted into quantitative scores. The purpose is to carry out a preliminary quantitative analysis, even if not fully rigorous from the statistical perspective, in order to enrich the discussion with more supporting arguments. Such a conversion, presented in Table 1, is consistent with the work by Chiandotto and Gola (2000) in the field of academic course evaluation by students in Italian Universities. This choice purposefully weighs as more relevant the changes from and to the extreme values, as they are stronger indicators of change than central shifts.

The results of the two surveys are presented in Table 2 as descriptive statistics, with already converted numerical values.

Table 2 Summary of the results of the surveys at the beginning and at the end of the course on innovation and problem solving

ID	Ex-ante		Ex-post		Expected Δμ variation	Measured Δμ
	μ	σ	μ	σ		
S1	6.19	1.87	6.61	1.63	Δ > 0	0.42
S2	7.32	1.80	7.94	1.63	Δ > 0	0.61
S3	5.77	2.00	6.61	2.16	Δ > 0	0.84
S4	5.48	1.50	4.87	1.93	Δ < 0	−0.61
S5	4.77	2.00	5.97	1.74	Δ > 0	1.19
S6	4.58	1.86	5.55	2.08	Δ > 0	0.97
S7	7.19	1.89	7.58	1.20	Δ > 0	0.39
S8	6.29	1.72	5.13	1.80	Δ < 0	−1.16
S9	6.77	2.43	4.48	1.63	Δ < 0	−2.29
S10	5.03	1.60	6.10	2.01	Δ > 0	1.06
S11	6.58	1.78	7.29	1.95	Δ > 0	0.71
S12	*5.84*	*1.73*	*5.87*	*1.88*	*Δ < 0*	*0.03*
S13	8.16	1.79	4.94	2.21	Δ < 0	−3.23
S14	*6.35*	*1.70*	*6.32*	*1.56*	*Δ > 0*	*−0.03*

Rows in italics highlight the answers whose results are not consistent with the expected variations

The first column of Table 2 collects numerical references to the statements presented in the previous paragraphs. The next four columns collect the descriptive statistics for the ex-ante and the ex-post data, as already numerically converted data. The last two columns respectively present, first, the expectations at the end of the course in order to get self-efficacy and attitude improvements for all the areas of investigation and, second, the actual difference of the average values between the two surveys. It is worth noticing that almost all the changes measured after the ex-post survey moves into the expected directions. S12 (*The focus is always on the structure/layout of the technical system*) and S14 (*I always try to modify the system as less as possible*) are the only two exceptions, even if the changes are of very small magnitude. These results potentially support the substantial equilibrium emerged from the collection of discrete data as for Fig. 3.

On the contrary, several statements recorded large differences between the two surveys. S5 and S6, among the statements strictly related to the estimation of self-efficacy, have shown an improvement with reference to both the past experiences with personal problem solving performances and the future expectations about them.

Statement S8, S9, S10 and S13, among the ones related to the change of attitude towards inventive problem solving, have shown a marked improvement consistently with the expected direction of change. They are mostly related to improved system-thinking skills (thus enhancing exploration and reducing design fixation) and to the perceived benefits of a more structured strategy to tackle design problems.

Both the ex-ante and the ex-post surveys have been conducted in order to keep track of the interviewees and the questionnaire they filled. This allows a fully representative statistical analysis of the pre-post effects. In this way, the ex-ante and ex-post surveys can be coupled together individually per each participant. The following preliminary analysis is carried out on the basis of the qualitative results as they have been converted in quantitative data. These data are here analysed as they were continuous variables, so as to carry out a coupled t-test and gather early evidences of statistical significance to be further checked with more appropriate approaches.

The null hypothesis (H_0) under test states that there is no significant difference among the average values of the perceived self-efficacy or inventive problem solving attitude between the ex-ante and the ex-post survey. In other terms, a confirmation of the null hypothesis implies that the course content did not impact the self-efficacy of students.

On the contrary, the alternative hypothesis (H_a) states that the average values are significantly different from a statistic point of view and therefore a specific change in self-efficacy depends on the content delivered during the course.

As mentioned before, the results about the statements S12 and S14 show that the overall goal of improving students' self-efficacy and changing their attitude towards a more structured but creative behaviour in solving inventive design problems has not been fully met. Nevertheless, the statistical test shows that the differences between the average values are not statistically significant. In other terms, the differences between the average values of agreement for these questions are so small that it is highly probable that the fluctuation of the values depends on random factors (confirming, again, the conclusions of the qualitative analysis) (Table 3).

In statistical terms, the differences in the average agreement for the statements S7, S1, S4, S2 and S3 (in decreasing order of statistical significance) between the two surveys do not provide sufficient element to clearly infer if the course has significantly impacted those self-efficacy and attitude elements. A paired test on ordinal discrete data may be better suited to verify it.

The t-test has also shown that the changes about the agreement on statements S5 and S6 may significantly depend on the course. These results highlight that the course impacts the self-perception of problem solving skills by triggering a more confident evaluation of past and expected future performances. Nevertheless, it should be taken into account that the students were requested to express their agreement with respect to very strong (polarized) statements. Furthermore, the gap in the two evaluations (respectively +1.19 and +0.97 on a scale between 2 and 10) clarifies the impact of the course in enforcing an, at least, adequate level of self-efficacy in an inventive design situation requiring problem solving skills, as already pointed out for what concerns the answers gathered in clusters.

For what concerns the results about S8, S9, S10, S11 and S13, the differences between the ex-ante and ex-post average value are so marked that it is statistically possible to accept the alternative hypothesis, thus implying that the course have significantly affected the attitude of the interviewees.

The greatest changes, showing a complete overturn of the situation between the beginning and the end of the course emerge for S9 and S13. It means the students have, on the one hand, treasured the experience of following a rational design strategy, rather than addressing the design inventive problem with a messy trial-and-error approach (from a more than sufficient agreement −6.77 to a marked disagreement −4.48, with reference to the statement *I never follow a predefined strategy*). On the other hand, the students have also interiorized the importance of addressing inventive problems as design conflicts, in order to apply appropriate instruments capable of overcoming the contradiction at their core and produce more novel and breakthrough solutions. The change in the average value, in this case, is the highest recorded in absolute value; from a very strong agreement counting 8.16 on a maximum of ten to a clear disagreement scoring 4.94.

Similar considerations are also valid for S8, S10 and S11. The analysis shows that the course impacted the students' attitude also for what concerns the capability of reasoning with a broad-spectrum thinking (S8). As well, also S11 related results witness that the students' attitude changes towards a higher appreciation of system-thinking. It can be thus inferred that the students have assimilated the importance of considering the technical system as constituted by parts mutually interrelated and cooperating in order to make the system work in a specific environment. S10, in turn, shows that the logic of mentally depicting an ideal solution in order to remove psychological blocks and foster the identification of design

Table 3 Summary of the test of hypothesis for the results of the self-efficacy survey

ID	Statement	Measured $\Delta\mu$ ($\mu_{end} - \mu_{start}$)	μ @ end of course	Probability H_0 is true [$p(\mu_{end} - \mu_{start} = 0)$] (%)	Measured effect on self-efficacy
S1	I am very good at problem-solving	0.42	6.61	17.20	Improved
S2	Problem-solving skills are of vital importance	0.61	7.94	8.13	Improved
S3	I am never intimidated by unknown problems	0.84	6.61	6.49	Improved
S4	I am unable to tackle unfamiliar problems	−0.61	4.87	15.40	Improved
S5	So far, I have resolved every problem I faced	1.19	5.97	0.07	Improved
S6	I am certain that I am able to resolve any problem I will face.	0.97	5.55	0.78	Improved
S7	I always take into account similar problems in different fields of technique	0.39	7.58	31.48	Improved
S8	I always neglect all the elements that are not directly involved in the problem	−1.16	5.13	1.22	Improved
S9	I never follow a predefined strategy	−2.29	4.48	0.00	Improved
S10	I always consider the best desirable solution even if not technically feasible	1.06	6.1	0.52	Improved
S11	I always consider the impact of design choices on all the requirements	0.71	7.29	1.91	Improved
S12	The focus is always on the structure/layout of the technical system	0.03	5.87	92.75	(Slightly worsened)
S13	It is necessary to find the best compromise among system requirements	−3.23	4.94	0.00	Improved
S14	I always try to modify the system as less as possible	−0.03	6.32	91.47	(Slightly worsened)

conflicts and contradictions has become more present in their creative processes during inventive problem solving.

Conclusion

This contribution aims to clarify if a course on inventive design and problem solving embedding TRIZ contents contributes to empowering the students' self-efficacy in problem solving skills. They are one of the key elements through which people stop fearing the unknown and become attracted by challenging situations, such as the ones requiring the building of new knowledge. The chapter clarifies the importance of self-efficacy in inventive design by initially scoping the theme of design creativity and its relationships with inventive problem solving and then presenting the main, even if few, contributions in the specific field of creative self-efficacy.

A group of 30 volunteers from a MS course in Mechanical Engineering participated in the investigation by expressing their different degrees of agreement to six relevant statements, which emerged from the literature analysis. Moreover, the study has been also carried out by including further eight customized statements that have been specifically developed in order to also map the change of students' attitude with respect to the models and instruments presented along the course.

The overall results show that there is a general improvement in self-efficacy about problem solving skills. Good results appear also for what concerns the change of attitude after experiencing design analysis and design synthesis activities with TRIZ and OTSM-TRIZ models and solving instruments. Especially for what concerns the refusal of trade-off solutions and the need of formulating design conflicts as a key point towards a more effective creative idea generation. Important improvements have also emerged for the self-perception of acquired broad-spectrum reasoning and system-thinking. From the perspective of efficiency in design, the content presented along the course on design creativity and inventive problem solving has also fostered the need of pre-defining a design strategy in order to follow a set of systematic steps, capable of supporting the transition from the problem state to the solution/goal state.

A more complete and accurate analysis of statistical significance will be carried out as a further development of the presented activity. With a larger set of data, a pre-post statistical test for ordinal discrete quantities will provide more reliable results, which may corroborate the qualitative discussion here, presented.

Among the weak points of self-efficacy investigations after the delivery of courses, it is worth mentioning that whatever the statistical method to measure it, the ex-ante and ex-post surveys are not currently able to distinguish if the pre-post shift depends on the course contents and/or, for instance, the teachers' ability and charm. In order to overcome this ambiguity, it would be necessary to repeat similar investigation with testers having a similar profile in classes about the same topics, but different teachers. This issue can be tackled by comparing the results with the ones emerged in similar studies. In both this study and the one proposed by Harlim and Belski (2011) TRIZ contents, even if the syllabus of the two courses present some differences, proved to be a significant booster for improving the self-efficacy in tasks requiring problem solving skills. The two studies, indeed, provide significantly convergent results for some of the specific statements of the six questions shared by the surveys, especially for what concerns the perception of past problem solving performances and the expectations people have about their effectiveness in solving future problems.

Nevertheless, it is also worth mentioning that these studies have been carried out with slightly different approaches for what concerns the analysis of data, so that their comparison is not straightforward. The authors would like to continue this study by both deepening their understanding also for what concerns the relationships between the agreement values for different statements, in order to highlight potentially unexpected regularities and involving other scholars willing to work on the same subject. The scholars interested in performing similar tests are, then, welcome to join the research.

Finally, for what concerns the future development of such studies, the authors are also interested in developing further statements and refining the existing ones in order to start capturing some other relevant elements potentially characterizing and impacting the human behaviour in design.

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Creating Bio-inspired Solution Ideas Using Biological Research Articles

Maria Katharina Helms, Helena Hashemi Farzaneh and Udo Lindemann

Introduction

The question how nature can be discovered and used for creating ideas for technical solutions has been driving engineers for centuries. Nowadays, bio-inspired design (BID) has been acknowledged to increase creativity and innovation (Cheong and Shu 2010). To stimulate BID and creative thinking in BID, support has been developed to aid engineers or teams of engineers and biologists either in finding biological inspiration for solving technical problems or in transferring biological principles into technical products.

In the following, it is focused on the finding and the creative use of biological inspiration when BID is performed by engineers alone. For finding biological inspiration, supporting methods and tools have been developed either in the form of—or based on—databases or based on unfiltered and unadapted biological literature. Databases, here, mean databases containing information which is useful for BID. Unfiltered literature means literature that has not been filtered by its usefulness for BID. Unadapted literature means literature that has not been adapted for engineers, e.g. simplified or tagged.

The search support BIOscrabble, which is applied here, addresses the latter. It was designed driven by the question: "How can a mechanical engineer without a biological background be supported in finding biological inspiration for technical problems when performing search term based searches in unfiltered and unadapted text sources representing the past and ongoing natural scientific research, namely

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biological research articles?" (Kaiser et al. 2012, 2013, 2014). The approach focuses on unfiltered, unadapted biological research articles, because they offer a great number of relevant research results. Plenty of different biological information—that is partly scarcely known—is stored in these articles.

This huge variety and novelty is assumed to enhance creative thinking in BID by the authors. It can hardly be reached by BID databases or other biological publications. As biological research articles can be harder to understand and use than the biological information stored in the latter, the assumption of an enhanced creative thinking is approached here by initially answering the basic question: "Is a mechanical engineer without a biological background generally able to create bio-inspired solution ideas for technical problems based on search term based searches in biological research articles stored in PubMed?".

PubMed (see section "BIOscrabble") (http://www.ncbi.nlm.nih.gov/pubmed) is a comprising search source which can be searched for biological research articles. In PubMed, unfiltered and unadapted biological research articles are stored. For these reasons it is proposed by BIOscrabble. Another possible search source for biological research articles is AskNature (see section "Databases in BID") (http://www.asknature.org). As AskNature is well known in BID and is described as "the world's most comprehensive catalog of nature's solutions to human design challenges" (http://www.asknature.org), it is chosen as a comparative search source in this work. In contrast to PubMed, the biological information stored in AskNature is edited which, on the one hand, makes it easier to understand and to use by non-biologists, but, on the other hand, comprises only articles that have been considered inspiring for BID by their developers or users before. Compared to PubMed, AskNature contains far less biological information, although it contains—in addition to biological research articles—all kinds of biological articles or information.

The differences between these two search sources are introduced at this point already, because knowing them is essential to understand the purpose of the comparison of these sources in the second part of this work. The question which is addressed is: "If bio-inspired solution ideas can be created based on PubMed, can the biological inspiration behind the created ideas also be found in AskNature?". If the answer is no, this is an indication that—despite its poorer user-friendliness for non-biologists and BID—there is a benefit in using the search source PubMed for searching for inspiration in BID in addition to or instead of AskNature. The assumption that the large number, the variety and the novelty of unfiltered and unadapted biological research articles enhances creative thinking through giving additional thought-provoking impulses is strengthened in this case.

Section "Related Research" provides an overview over related research on solution search in BID. Searching in unfiltered and unadapted biological literature and BID databases are elucidated. Section "Idea Creation via BIOscrabble" illustrates the search support BIOscrabble which was used for creating the ideas and prototypes introduced in Section "Bio-Inspired Ideas or Prototypes". Section "Benefit of PubMed as a Search Source" analyzes and discusses the benefit of using PubMed as a BID search source. Section "Limitations of the Analysis" provides the analysis' limitations. A summary and an outlook on future work are given in section "Summary and Future Work".

Related Research

This section outlines related research in the field of solution search in BID. It focuses on outlining related research in the field of search sources that have been used for existing BID search supports focusing on unfiltered an unadapted biological literature and BID databases. Related research concerning BIOscrabble in terms of which types of search terms to use is explained in detail in Kaiser et al. (2014).

Unfiltered and Unadapted Search Sources Used in BID

Biology Books

At the University of Toronto, researchers developed a natural language approach to bio-inspired design. It supports an effective discovery of unfiltered and unadapted biological literature based on an introductory biological textbook. Search term based searches were performed in this textbook and analyzed. The textbook was chosen as an initial search source, mainly because of two reasons: it can be understood by a reader without a biological background; it provides biological information ranging from molecular structures to ecosystems (Shu 2010; Cheong and Shu 2012). Advanced sources such as biological research articles are suggested for finding further details on selected biological analogies rather than for initial searching (Shu 2010).

Also Stroble et al. (2009), Nagel et al. (2010) used biological textbooks for compiling an engineering-to-biology thesaurus for BID. The thesaurus was developed to provide engineers with biology related search terms that are correlated to the engineering domain. Biological textbooks were also used by Nagel and Stone (2011) for testing a methodology which aims at facilitating systematic BID—including BID solution search.

World Wide Web

Vattam and Goel (2011) analyzed the World Wide Web as an initial BID search source. They proposed a social citation cataloguing system. In this system, designers can post citations or do model based tagging of biological articles they found useful for biologically inspired design.

The use of the World Wide Web as an initial search source in BID was also examined and supported by Vandevenne et al. (2011, 2012). He developed a scalable webcrawling approach that continuously collects documents containing biological strategies for BID. The collection of the documents is updated automatically.

Both approaches end in a support that provides engineers with biological information which is filtered or adapted for BID, still, they start with exploring the unfiltered and unadapted web.

Though biological research articles are part of the information stored in the World Wide Web, such articles have been underutilized in research on methods and tools supporting solution search in BID. For the purpose of analyzing their benefit for BID they have been explicitly included in BIOscrabble and, in this work, are related to the BID database AskNature.

Databases in BID

The above mentioned webcrawler of Vandevenne et al. (2012) as well as the social citation cataloguing system of Vattam and Goel (2011) can be categorized as databases in a sense that both dynamically evolve in a direction where biological information is filtered or adapted for BID use. However, in contrast to the BID databases illustrated below, these approaches do not face the problems of being initially filled and kept up-to-date by their developers. Whereas the webcrawler collects and keeps up-to-date biological documents for BID automatically, the social citation cataloguing system is filled and extended through its use.

Two paper based databases for BID are provided by Hill (1997) and Gramann (2004). Hill (1997) developed a design catalogue based on five elementary technical functions and three flow types. Combined, they result in 15 classes according to which 200 biological principles are filed. Gramann (2004) developed a list of 117 biological associations corresponding to technical functions.

For supporting BID, Chakrabarti et al. (2005) developed the idea generation software IDEA-INSPIRE. IDEA-INSPIRE is a database containing pairs of technical and biological systems represented by the SAPPhIRE model of causality. Searching for biological analogies for a technical problem can be performed either directly by describing the technical problem in terms of the constructs of the SAPPhIRE model (verb-noun-adjective set) or by browsing the database for inspiration.

Löffler (2008) developed another computer aided catalogue providing biomimetic effects for BID. The catalogue is hierarchically organized by technical and biological solution categories (e.g. evolution and optimization or materials) and their corresponding principles (e.g. adaptive growth or fiber material, respectively). For each principle several biological phenomena are stored and linked by cross references. Search term based searching leads to the description of the phenomenon and associated references or links.

AskNature (http://www.asknature.org), a database for solution search in BID is provided by The Biomimicry 3.8 Institute. AskNature is a database containing biological phenomena and bio-inspired applications or products. The AskNature user is offered two functions for searching for biological analogies. First, with the help of the explore function, strategies of biological systems as well as bio-inspired applications or products can be browsed. A strategy, here, is defined as "the means by which organisms overcome or meet a particular challenge" (http://www.asknature.org). The strategies as well as applications or products are organized by the Biomimicry Taxonomy. In this hierarchically structured Biomimicry Taxonomy, biology is organized by functions. Second, the user can perform a search term based search via a Search box. The search can be filtered by categories such as strategies, organisms or products.

A general disadvantage of the described databases is that the data contained has to be initially fed in and kept up-to-date over time. As this is very work-intensive, the amount of data that can be newly identified and stored is limited. Moreover, data selection as well as data editing such as the setting up of data classifications can—through this additional layer of interpretation—bias the user when searching for biological inspiration in BID.

To meet the underutilization of research articles in methods and tools supporting solution search in BID and bypass the disadvantages of BID databases, BIOscrabble was developed. It is illustrated in section "BIOscrabble".

Idea Creation via BIOscrabble

In the following, the BID solution search support BIOscrabble and its application by students of mechanical engineering to develop BID ideas or prototypes (cross-sectional study) is illustrated. Depicted with an example, a more detailed description of BIOscrabble and its application is illustrated in Kaiser et al. (2014).

BIOscrabble

Figure 1 shows BIOscrabble as applicated in this work.

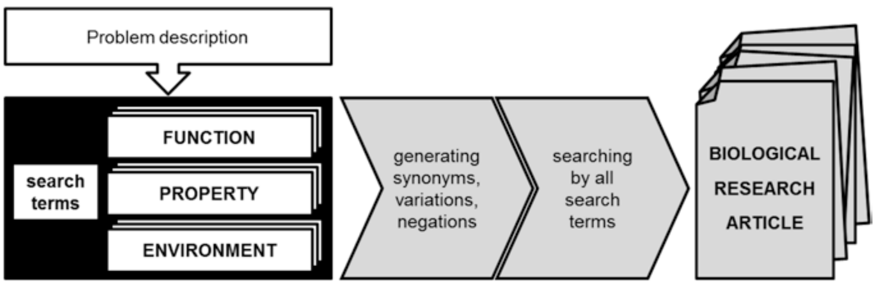

Fig. 1 BIOscrabble as applicated in this work to create bio-inspired solution ideas for technical problems (Kaiser 2014)

BIOscrabble comprises the following steps:

1. A technical problem is described in terms of the technical functions the desired technical system shall fulfill, the properties it shall possess and the environment it shall cope with. The terms for searching for biological inspiration are derived from that description and assigned to the search term categories “function”, “property” and “environment” which are defined as follows:
   - Function: “the intended input/output relationship of a system whose purpose is to perform a task” (Pahl et al. 2007).
   - Property: “A property is anything that is possessed (owned) by an object (a TS)” (Eder and Hosnedl 2008) where TS is the abbreviation of technical system; Eder and Hosnedl defined several classes of properties. In BIOscrabble it is focused on the classes “Internal Properties” and “Purpose Properties”. Within the latter “functions properties, effects properties” are excluded as technical functions are regarded separately.
   - Environment: all environmental effects on a technical system as well as the interplay between a system and its environment.
2. The search terms’ synonyms, variations (noun, verb, adjective forms), and negations can be derived in order to broaden the solution space and at the same time to enhance the differentiation of the terms. The latter accounts for the possible differences between the terminologies designers and biologists use to describe their work. Synonyms and variations can be partly generated by using the lexical database WordNet (http://wordnet.princeton.edu).
3. Using the original search terms as well as their variations, the metadatabase PubMed is searched for biological research articles. PubMed provides over 23 million citations for biomedical literature. It is a free search source developed and maintained by the National Center for Biotechnology Information (http://www.ncbi.nlm.nih.gov/pubmed). Single search terms can be connected by Boolean Operators.
4. The search results are research articles which match the search terms or phrases it was searched by.

BIOscrabble was and is further developed to a software tool to additionally support the managing of a large number of search results (Kaiser et al. 2013).

BIOscrabble Application in a Cross-Sectional Study

For solving different technical problems, students of mechanical engineering searched for biological inspiration via BIOscrabble. All students had been studying mechanical engineering for at least two years. They performed the BID solution search in the context of their bachelor theses or term papers.

BIOscrabble was applied as follows:

1. Each student chose a technical problem based on interest. To search for biological inspiration for their chosen technical problem, the students applied the search support BIOscrabble.
2. For the selection of inspiring biological research articles, the titles and abstracts of the search results were scanned. Articles which each student considered to contain biological information that is inspiring for creating solution ideas for the chosen technical problem were selected by different selection criteria.
3. The selected articles were further examined by the students with the help of sources like books or internet contributions.
4. Each student incorporated or combined one or more of the selected articles' contents in a bio-inspired idea or prototype which aimed at solving the chosen problem.

Bio-inspired Ideas or Prototypes

Section "Bio-inspired Ideas or Prototypes" illustrates the bio-inspired ideas or prototypes the students created by applying BIOscrabble and using biological research articles in the cross-sectional study described above. These ideas or prototypes are illustrated to show that a mechanical engineer without a biological background is able to create bio-inspired solution ideas for technical problems based on search term based searches in biological research articles stored in PubMed. They further show that creative thinking can be stimulated by unfiltered and unadapted biological research articles.

Device for Purifying Water

The intention to design a device for purifying water was to provide an easy and cost-effective way for individuals to produce drinking water out of polluted water—which is especially relevant for areas lacking access to clean water.

The technical solution idea with the highest innovation capacity was to use the selection mechanism of aquaporins as it is based on latest research results. Aquaporins are also the biological system which promises the highest functionality in terms of eliminating any kind of water contamination. They are channel proteins in cells through which only water molecules are able to pass whereas all other ions or molecules are hindered from passing (Rutkovskiy et al. 2012). The advantage of this mechanism is that the desired molecules are specifically selected. A complex filter system for filtering out all possible undesired ions or molecules is not necessary here. This mechanism has not been technically implemented so far.

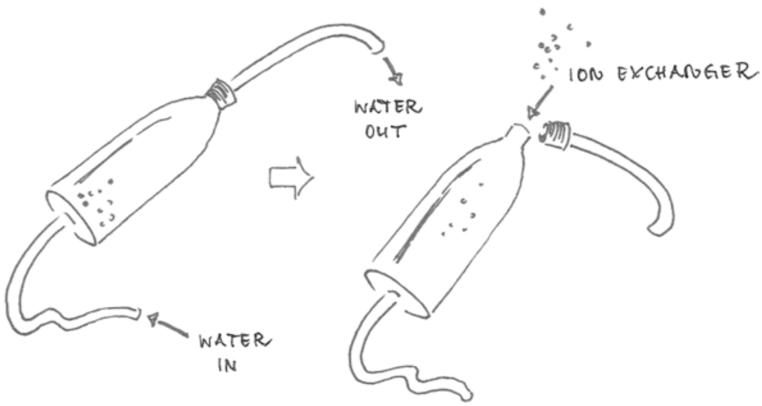

Fig. 2 Sketch of the prototype of the device for purifying water

Further solution ideas promising a good functionality in terms of filtering out as much pollution as possible were inspired by the green alga Spirogyra (Lei and Ma 2009), Phillipsite-rich tuffs (García Hernández et al. 1992), photosensitizers (Jemli et al. 2002) and ion exchangers in damp biotopes' soils (Yang et al. 2006). Though the latter were not rated to have a high innovation capacity by Flämig (2013), the principle was incorporated in a prototype for two reasons: first, there are ion exchangers which are already technically implemented and commercially available; second, the filtering capacity of these ion exchangers can easily be adapted to different kinds of pollution. Both factors support an easy and cost-effective use of the device for purifying water in areas lacking access to clean water.

A sketch of the prototype is shown in Fig. 2. It can easily be built from PET-bottles and—according to the kind of pollution—filled with commercially available ion exchangers. To protect the purified water from the ion exchangers a layer of fleece is attached to the inside of the screw-cab (Flämig 2013).

Cooking Pot with Adaptable Heat Conductivity

Here, the intention was to design a cooking pot which shows good heat conductivity when used for cooking, but keeps the cooked food warm after taking the pot from the cooker. The bird Brünnich's guillemot inspired the technical solution idea for such a cooking pot. During diving, Brünnich's guillemots show decreased peripheral temperatures, but increased body core temperatures. The maintenance of heat within the body seems—inter alia—to result from a peripheral narrowing of the blood vessels (Niizuma et al. 2007). The resulting change in the blood flow rate and the blood's passage surface area inspired the design of the cooking pot described below.

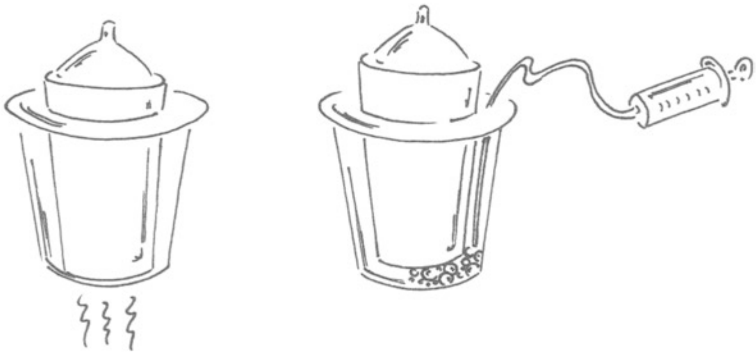

Fig. 3 Sketch of the prototype of the cooking pot with adaptable heat conductivity in conducting (*left*) and insulating (*right*) mode

The base of the cooking pot consists of two metal surfaces. The surfaces can be separated for heat insulation, whereas for heat conduction they are in contact. During insulation, a fluid is frothed between the surfaces. A sketch of the corresponding prototype for the cooking pot with adaptable heat conductivity is shown in Fig. 3. Further details on the prototype as well as its testing are illustrated in Macnish (2013).

Further biological systems or phenomena which inspired technical solution ideas were: the increased heat conductivity of spider silk under stretching (Huang et al. 2012) and thermoregulation in bats (Reichard et al. 2010), in tuna fish muscles (Carey and Teal 1966), in Florida manatees also known as sea cows (Rommel and Caplan 2003), in rabbits (Stitt 1976) and in the starling Sturnus vulgaris during flight (Torre-Bueno 1976) (Macnish 2013).

Aquaplaning Reducing Car Tire

The capillary effect as used by different biological systems for surface adhesion inspired the design of a car tire which aims at reducing aquaplaning during car driving in wet conditions. The biological systems which have been inspiring are spider capture threads, snails and the leaf beetle *Gastrophysa viridula*. Spider capture threads containing noded fibrils increase their stickiness under high humidity. It is assumed that under high humidity these fibrils adsorb water from the atmosphere and thereby realize hygroscopic or capillary adhesion (Hawthorn and Opell 2003). Within the context of the adhesive locomotion of snails, hairs on the shell of the snail *Isognomostoma isognomostomos* have been found to reveal further adhesion properties. In wet conditions, these hairs allow an enhanced adhesion on host plants through capillary forces (Beckmann and Kobialka 2007). Though capillary forces do not enhance adhesion under water in general, the terrestrial leaf

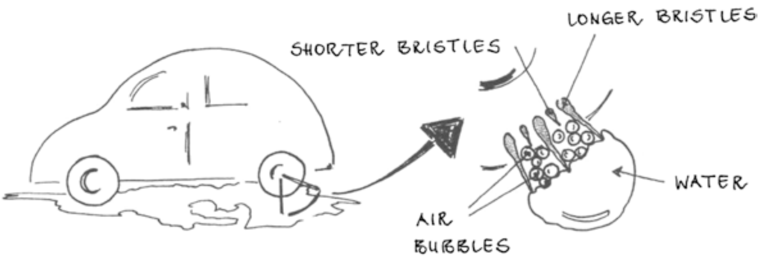

Fig. 4 Sketch of the prototype of the aquaplaning reducing car tire

beetle *Gastrophysa viridula* is able to walk on solid substrates under water through capillary adhesion. In air, the beetle uses capillary forces between the fluid covered setae ("bristles") on its feet and the substrate for adhesion. For capillary adhesion in wet conditions, the beetle traps air bubbles between the setae (Hosoda and Gorb 2012).

The idea of trapping air bubbles for improved adhesion on substrates covered with water was implemented in a prototype, a sketch of which is shown in Fig. 4. To reduce aquaplaning caused by a water film between car tires and road, a layer of hydrophobic bristles is attached to the tires. Between the hydrophobic bristles, an air gap is maintained which enables capillary adhesion between tires and road. The design of the bristle layer was inspired by the water repelling dual layer hair array on the wings of the brown lacewing (Watson et al. 2011; Henze 2013).

Tension Adaptable Mechanism for Luggage

The design of a tension adaptable mechanism for luggage primarily aimed at supporting a luggage's closure if being under tension. In case the closure fails, it further aims at protecting the luggage's content against getting lost and being damaged. Several technical solution concepts were inspired by different biological systems.

Fibers in the spinal disc nucleus inspired one solution. It is proposed that the fibers contained in the disc nucleus show an increasing level of convolution from the periphery to the center. Therefore, the fibers are progressively loaded under tension and the inner fibers fail after the outer fibers (Wade et al. 2011). In Fig. 5 the technical solution idea which was derived from that finding is depicted. Fibrous material is attached to the inner surface of the closure of the luggage to relieve or replace it in case of increasing tension due to overloading. Short, rigid fibers support the basic stability. In case the closure and those fibers break, long, flexible fibers prevent the luggage from opening. As the breaking of the fibers is not reversible here, the solution was further developed to a reversible version inspired by self-repairing elastomers (http://www.asknature.org, 2013). Instead of

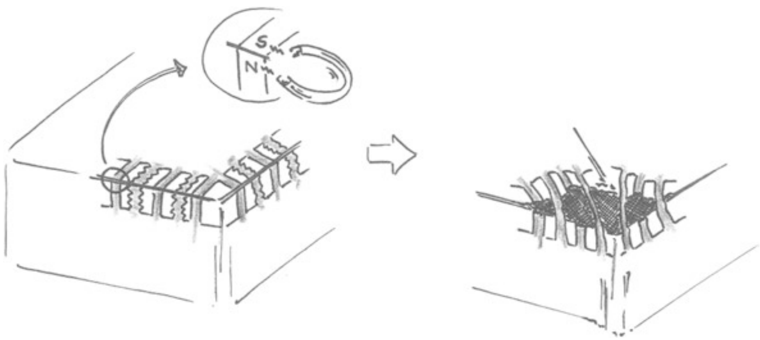

Fig. 5 Sketch of the prototype of the tension adaptable mechanism for luggage; intact (*left*) and prevented from opening through long, flexible fibers (*right*)

uncharged fibers, magnetic fibers are proposed. On the one hand, the support of the luggage's basic stability can be increased by the magnetic attraction between the poles of the short, rigid fibers. On the other hand, after "breaking", the magnetic fibers can be reattached.

A similar solution idea was inspired by proteins acting as soft biological adhesives (Dastjerdi et al. 2012), the spinal discs' annulus fibrosus (Pezowicz et al. 2005), tight junction networks (Hull and Staehelin 1976) and biological bulk and surface nanostructures (Gao et al. 2004). The idea was to make the piece of luggage out of cross-linked material showing an adaptable level of cross-linkage. Under tension the level of cross-linkage decreases resulting in an increasing elasticity of the material.

The idea of increasing the surface area of the piece of luggage also arose from bacterial mechanosensitive channels preventing bacteria from lysis (Topp 2013).

Cable Tie for Water Pumping Systems

The idea of designing a cable tie for a water pumping system arose from a technical problem appearing in a specific water pumping system in Italy. Using commercially available cable ties it is not possible to securely connect the water pumping system's components (cables, rope and water pipe) of different diameters when pumping water. Biological inspiration was searched for the following problems: clamping the pumping system's components together, closing the cable tie and preventing slippage of the components.

Clamping was, e.g., inspired by prey fixation in insect claws which can be found in praying mantis species. Here, the prey is fixed between the upper and the lower arm of the claw which is able to close over the entire length. Straight, spiny claws as well as smooth, curved claws can be found (Petie and Muller 2007). The corresponding technical solution idea is shown in Fig. 6. The resulting prototype

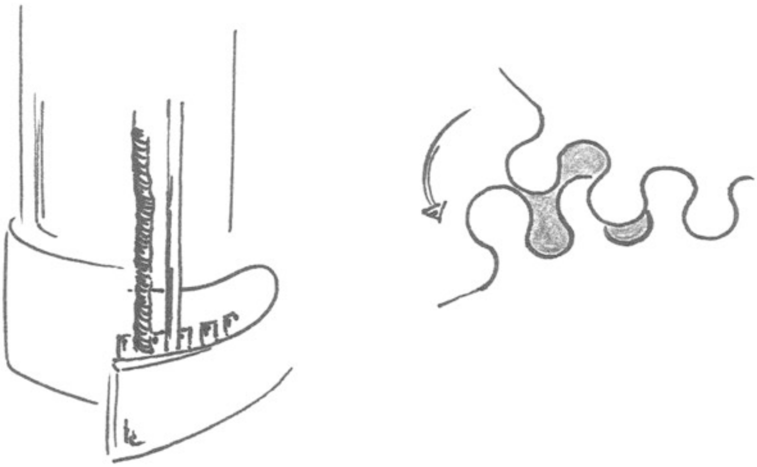

Fig. 6 Sketches of the prototypes of the clamping mechanism (*left*) and the closing mechanism (*right*) of the cable tie for water pumping systems

is composed of a curved aluminum component and a microcellular rubber component. The aluminum component secures the force transmission from the closing mechanism of the cable tie to the pumping system components. The microcellular rubber mimics spiny praying mantis claws. It adaptable to the clamping of components of different diameters and distributes the clamping forces.

For closing the cable tie different technical solution ideas were created inspired, e.g., by the walking leg muscle of the stick insect (Guschlbauer et al. 2007), releasable attachment devices in insects, such as wing-locking devices, and magnetic nanoparticles (Zheng et al. 2011). A promising solution was inspired by insects' wing-locking devices. Here, locking is realized through co-opted fields of cuticular outgrowths. The outgrowths cover five surfaces on the insects' body and eight on the wings. The surfaces' location as well as the outgrowths' directionality stabilize locking and prevent movements in any direction (Gorb et al. 2002). The corresponding technical solution idea takes up the principle of interlocking layers (Fig. 6).

To prevent slippage, solution ideas were inspired, e.g., by carnivorous plants and a northern clingfish. The surface of the glandular digestive zone in the trapping mechanism of the pitcher of the pitcher plant *Nepenthes ventrata* has been found to be microscopically rough (Gorb et al. 2004). This inspired the idea to use rubber material for the clamping surfaces of the cable tie. The northern clingfish *Gobiesox maeandricus* inspired the idea of producing a vacuum between the cable tie and the water pumping system components to prevent component slippage. As—in contrary to man-made suction cups—the clingfish adheres to slippery, fouled and irregular substrate, the technical solution idea was further inspired by microvilli around the fish's adhesive disc (Wainwright et al. 2013). With the help of microvilli-like technical structures like rubber extensions attached to suction cups suction can be achieved even on the irregular surface of the arranged pumping system components (Spiegel 2013).

Benefit of PubMed as a Search Source

Based on the biological systems that inspired the technical solution ideas or prototypes shown in section "Bio-inspired Ideas or Prototypes", the benefit of PubMed as a BID search source is examined. It is compared to the BID database AskNature

Table 1 List of biological systems (introduced in Sect. 4) along with their presence in AskNature and the AskNature search date

Biological system	Present in AskNature	Search date
Device for Purifying Water		
Aquaporins	✓	*1.5.14*
Green alga Spirogyra	–	1.5.14
Phillipsite-rich tuffs	–	3.5.14
Photosensitizers	–	3.5.14
Ion exchangers	✓	*3.5.14*
Cooking Pot with Adaptable Heat Conductivity		
Brünnich's guillemots	–	3.5.14
Heat conductivity spider silk	–	3.5.14
Thermoregulation flight starling	–	3.5.14
Thermoregulation bats	✓	*9.5.14*
Thermoregulation tuna fish muscle	✓	*9.5.14*
Thermoregulation Florida manatee	–	9.5.14
Thermoregulation rabbit	–	9.5.14
Aquaplaning Reducing Car Tire		
Capillary adhesion spider threads	–	9.5.14
Adhesion snails	–	9.5.14
Adhesion leaf beetle Gastrophysa viridula	✓	*9.5.14*
Water repellant wings lacewing	–	9.5.14
Tension Adaptable Mechanism for Luggage		
Fibers in spinal disc nucleus	–	9.5.14
Self-repairing elastomers	✓	*9.5.14*
Annulus fibrosus in spinal disc	–	9.5.14
Proteins as adhesives	✓	*9.5.14*
Tight junction networks	–	9.5.14
Bulk and surface nanostructures	–	9.5.14
Bacterial mechanosensitive channels	✓	*9.5.14*
Cable Tie for Water Pumping Systems		
Claws praying mantis	–	29.5.14
Stick insect walking leg muscle	–	29.5.14
Insect wing-locking	✓	*29.5.14*
Magnetic nanoparticles	✓	*29.5.14*
Pitcher Nepenthes ventrata	✓	*29.5.14*
Adhesive disc northern clingfish	–	29.5.14

to work out if PubMed can complement AskNature in terms of adding new biological inspiration and, thus, can enhance creative thinking.

Table 1 shows the biological systems introduced in section "Bio-inspired Ideas or Prototypes" along with their presence in AskNature and the date at which AskNature has been search for them. It has to be noted that only those systems have been categorized as present for which also the inspiring phenomenon is described. For example, there are articles about spider silk contained in AskNature, but none of them mentions its heat conductivity.

From the 29 PubMed systems or phenomena which inspired one of the technical solution ideas or prototypes illustrated in section "Bio-inspired Ideas or Prototypes", only 11 are contained in the BID database AskNature.

This result strongly indicates that PubMed is a beneficial complementation of AskNature as a BID search source in terms of additional stimulation for creativity. If it is also beneficial to replace AskNature with PubMed remains to be proven. To approach this question, PubMed and AskNature were applied in parallel in another BID student project. In this student project, the design of a self-sharpening knife was addressed. It was found that it can be easier to find inspiring biological systems in AskNature than in PubMed. For the design of the self-sharpening knife, there were inspiring biological systems or phenomena that—in the first place—were found via AskNature only. These systems or phenomena were mainly also contained in PubMed, but were missed when performing the initial BIOscrabble solution search. This can be due to the huge amount of potential biological inspiration stored in PubMed. PubMed comprises more than 23 million citations for biomedical literature compared to about only 1673 biological strategies and bio-inspired applications or products contained in AskNature. To support exploiting PubMed's maximum potential, the authors are working on a BIOscrabble software prototype, which, in BID, supports the engineer in structuring and discovering the PubMed search results (Kaiser et al. 2013).

Limitations of the Analysis

One limitation is caused by the nature of the design projects. Every technical problem was addressed by only one student. Hence, the selection of biological inspiration from PubMed is influenced by the students' personalities as well as their environments and is, therefore, subject to a certain degree of subjectivity. Analyzing a different selection of biological inspiration can result in a different proportion of PubMed inspiration which is contained in AskNature. This can also be true for a different selection of technical problems.

Another limitation is caused by a possible difference between the terms by which AskNature was searched for biological inspiration which was found in PubMed before and those terms which are contained in the biological or bio-inspired system descriptions stored in AskNature. Although a number of different search terms have been used for searching, it cannot be completely excluded that a biological inspiration has been wrongly labeled as not present.

No statement can be made regarding the quality of neither the biological inspiration solely found in PubMed nor that found in both search sources. It was only examined if the use of PubMed leads to biological inspiration that cannot be found in AskNature and, therefore, is beneficial to solution search and the stimulation of creativity in BID—which proved true. Whether the use of PubMed as a complementary search source leads to additional biological inspiration that, in turn, leads to more creative and innovative bio-inspired solution ideas of high quality remains to be proven.

Summary and Future Work

This work mainly aimed at answering if biological research articles can be used by mechanical engineers to create bio-inspired solution ideas and if using the search source PubMed generates a benefit for creating these ideas by providing additional stimuli for creative thinking when compared to the easier-to-use database AskNature. By looking at different bio-inspired solution ideas for different technical problems and analyzing the corresponding underlying biological inspiration, answers to these questions were provided. It was demonstrated that a mechanical engineer without a biological background is able to create bio-inspired solution ideas for technical problems based on search term based searches in biological research articles stored in PubMed. The search source PubMed was found to be beneficial to BID in terms of providing additional biological inspiration compared to AskNature and, thus, can enhance creative thinking.

To further support BID solution search via BIOscrabble, BIOscrabble is currently implemented in a software prototype to support the engineer in extracting biological inspiration out of a huge search source like PubMed. With the help of the software the user will be able to structure the search results by different criteria, such as the research article's topic. This feature aims at partly compensating for the huge size of the search source PubMed by facilitating the scanning and examining of the search results.

Further potential BID search sources such as Scopus (http://www.elsevier.com/online-tools/scopus) will be examined regarding their usefulness for and benefit to solution search and idea creation in BID.

The students' bio-inspired solution ideas or prototypes will be evaluated regarding their degree of creativity, innovativeness and quality. Thereby, the benefit of BIOscrabble—and the search source PubMed—to BID as a means to enhance creative thinking can be assessed.

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Tele-Board MED: Supporting Creative Problem Solving in Behaviour Psychotherapy

Julia von Thienen and Christoph Meinel

What Does Mental Health Have to Do with Creative Problem Solving?

When people enter psychotherapy, they come with problems. Yet, before seeking professional help most people have already tried to solve their problems by themselves. Obviously they were not successful. Thus, they need new solutions for old problems.

Sometimes patients come with problems that are well defined. For example, someone is afraid of entering an elevator after having been stuck in one. In this case, very often precise treatment strategies are available that are very effective—such as an exposure therapy to reduce anxiety (Marks 1979; Margraf and Schneider 1990). Once the precisely defined problem is treated, the patient needs no further psychotherapeutic support.

Yet, very often patients do not come with a single well defined problem. Rather, there are diffuse problem domains and similar problems recur in the patients' lives. For example, a patient has always had difficulties maintaining close relationships. He enters therapy pondering whether or not to end his current partnership due to several discontents.

Patients with chronic problems tend to invoke ever the same strategies to solve their problems, even when these strategies turn out to be rather unfavourable in practice. Often times, the rigidly followed strategies were useful at some

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point earlier in the patients' lives, but they have become dysfunctional over time (Roediger 2009; Young et al. 2003). In parallel, these patients typically hold rigid views of their problems. More specifically, they diagnose themselves as facing certain problems in all kinds of situations. Thus, they always seek to solve the same problems and always use the same strategies.

For instance, the man who cannot maintain close relationships may have grown up with parents who were alcoholics. When the man was a boy, his parents mistreated him regularly. Thus, he developed a highly sensitive ability to perceive impending threats from important others so that he could react quickly. Also, as a boy he could do little to resolve issues with his parents. He could not talk things over. He could not appease them through pleas for understanding. The only thing that helped a little was to beat a quick retreat. Now that the boy is a man he could choose among many strategies to solve problems with important others. He may even find himself a partner who is very benevolent and reliable. Nonetheless, the man regularly feels that others he is close to endanger his well-being, because his sense of a threatening situation is so acute. And he still resolves issues by withdrawing from them.

When treating patients with repetitive life problems, a central psychotherapeutic aim is to explore both new views of problems and new solution strategies. For instance, when the man with volatile relationships learns his new partner has a very different music taste than himself, how will he perceive this situation? Will he think: "She wants to impose her taste on me; we can never lead a harmonious life together—so I'm back to square one again"? Then retreat may seem the only sensible reaction. Or can the man tap into other interpretations of the situation which open up gates to new, alternative solutions? Differing music tastes could be a chance to broaden the personal horizon. They could inspire interesting evening activities—a tango day with Argentinean food and a heavy metal day with American fast food, for instance. In any case, the more approaches the man can come up with to address his issues, the less he has to depend on his former strategy of retreat.

More generally speaking, creative problem solving skills are an important endowment of mentally healthy people. These skills help in handling all kinds of life challenges. If you lack creativity in solving life problems, chances are you will get stuck in the first dead end you encounter since you fail to develop alternative routes. If you are very good at developing new routes, on the other hand, even severe life events will hardly paralyze you forever (cf. American Psychological Association 2014).

How to Achieve Creative Problem Solutions?

Psychologists have developed process models to help people understand and solve personal life problems (Fiedler 1996; Kämmerer 1983). These models are not only used in psychotherapy sessions. They are also taught explicitly to patients to equip them with problem solving competencies for all kinds of future life problems. In the following, we will focus on behaviour psychotherapy where models of (creative) problem solving have long played a particularly important role.

> “Typically behaviour therapy” was and is, that behaviour therapists work according to the pattern of a structured problem solving process. [.…]
> Even though several models exist, which invoke a varying number of phases in the problem solving process, their content is typically very similar. Over the years, a unified model emerged. Since the early 1980ies proceeding according to a process with six phases is regarded as necessary and sufficient for therapeutic problem solving.
>
> (Fiedler 1996, p. 48, our translation)

The problem solving process common in behaviour psychotherapy encompasses the following six phases: (1) explore problem, (2) name problem (3) generate ideas, (4) select idea, (5) implement and test, (6) evaluate and refine.

Creativity plays an important role in all stages of the process, but we would like to highlight three moments in particular when creativity is sparked.

The first moment is when you “name the problem”. Here you pinpoint your personal interpretation of a problematic situation. That interpretation makes all the difference in the world for possible solution pathways. For instance, is a different taste in music a chance to broaden one’s horizon or rather a warning sign that two people don’t fit together? You pick the interpretation and it sets you on one or the other track of likely solutions.

The second—and very obvious—moment when creativity plays a crucial role in the process of problem solving is when you “generate ideas”. Typically, this is done via brainstorming.

A third moment of creativity that may seem less obvious is when you “implement” your idea. Typically, you can come up with an infinite number of concrete realizations. For example, when your idea is to integrate new music styles in your life—will you have tango versus heavy metal days with differing food? Will you attend diverse concerts? Will you create new music mixes for the car? Again, creativity plays an important role in tapping various attractive options.

Interestingly, the psychotherapeutic model of solving life problems is very similar to models of problem solving used in other domains. In particular, we would like to highlight parallels to a process known under the label of “design thinking” (d.school 2010/2014; Plattner et al. 2011), which is used to tackle engineering design problems.

In the engineering domain, design thinking has been introduced to promote technical developments that are not only incremental—providing more of something that already exists like a USB stick with more memory. Instead, true innovation shall result. The community strives to identify unmet human needs that can be met with new, more human-centred products or services.

Far-reaching parallels of the two models on problem solving in behaviour psychotherapy and design thinking (Fig. 1) suggest rich opportunities for mutual learning that we will discuss in more detail below.

In both models you start by exploring a somewhat diffuse problem from different angles (**explore problem** or **empathize**):

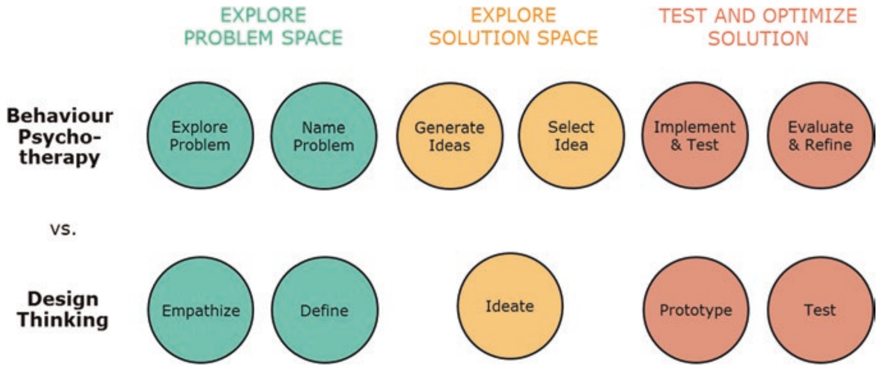

Fig. 1 A model of problem solving common in behaviour psychotherapy compared to a model of problem solving used in design thinking

- In the psychotherapeutic context, the man with alcoholic parents can be asked to retell how certain conflicts developed with his parents, friends and later on with romantic partners.
- In a model design thinking project, an interdisciplinary team observes and interviews nurses who provide wound care in a hospital (Aquino Shluzas et al. 2014).

In the next phase, the team chooses one particular point of view and formulates a problem statement to work with (**name problem** or **define**):

- In the psychotherapeutic context, patient and therapist can decide to work on the issue of differing music tastes. In doing so, they want to pay special attention to one particular aspect of the challenge: anxiety. Different tastes among the patient and his girlfriend scare him.
- In the design thinking project on wound care, the team chooses to focus on the aspect of wound care documentation. Here, they observed striking disadvantages. For instance, the nurses have to write down long patient numbers to identify the person whose wound they document. This does not only take a considerable amount of time; it is also error-prone.

Afterwards, the participants **generate ideas** and **select** one or more options for implementation. In the vocabulary of design thinking, people **ideate**:

- In psychotherapy, patient and therapist generate a couple of ideas how the patient could handle his worries aroused by differing music tastes. The therapist asks the patient which option he would like to try out. The patient decides to try telling his girlfriend about his fears.
- Design thinkers generate a couple of product or service ideas regarding wound care. They decide to design a device which takes pictures and recognizes patient codes. Thus, nurses can simply photograph patient codes instead of copying them manually. This is a lot quicker and, hopefully, less error-prone.

In the next phase, participants **implement and test** their selected approach. Design thinkers speak of building **prototypes** to elicit feedback in a **test**:

- Therapist and patient stage a role-play with the therapist acting as the patient's girlfriend. The patient starts a conversation about how he feels threatened when he notices their conflicting music tastes.
- The design thinking team builds a prototype of the new documentation device. A study is launched where nurses try it out. Afterwards, they give feedback on what they liked and disliked.

Finally, participants **evaluate and refine** their approach based on what they have learned. In the design thinking process model, all this is part of the test phase. Refinement may mean that you go back to any earlier stage of the process:

- The patient may sum up that he spoke long introductory words in the role-play, which didn't seem necessary in the end. It would suffice to say "Dear, I would like you to know that our different music tastes are no small matter to me. Whenever you say you don't like my songs, I really have no idea how the two of us can ever live happily together."
- From the nurses' feedback, the design thinking team learns that using their device over time became unpleasant because of its tendency to overheat. The team redesigns their battery storage since this turns out to be an effective way of countering the temperature issue.

In summary, there are striking parallels between the psychotherapeutic model of solving life problems and the design thinking model of satisfying unmet user needs.

Tele-Board MED Supports Collaborative Problem Solving in Psychotherapy

Behaviour psychotherapists and design thinkers share many concerns that encourage collaborative learning: Both communities want to advance creative problem solving competencies and self-efficacy (of patients or students). They use and teach highly similar process models to arrive at compelling solutions. Several auspicious paths of knowledge transfer from behaviour psychotherapy to design thinking have been discussed elsewhere (von Thienen et al. 2012). Here, we would like to explore the other direction: How to advance behaviour psychotherapy by building on design thinking knowledge and practices?

One initial issue is the use of documentation. In standard psychotherapy settings, only the therapist takes notes. The patient has no access to the information about his or her problems that is being collected over time (Fig. 2a). This signals a role hierarchy where the therapist is the problem solving expert and the patient is the therapeutic-following adherent. Quite obviously, such a setting does not

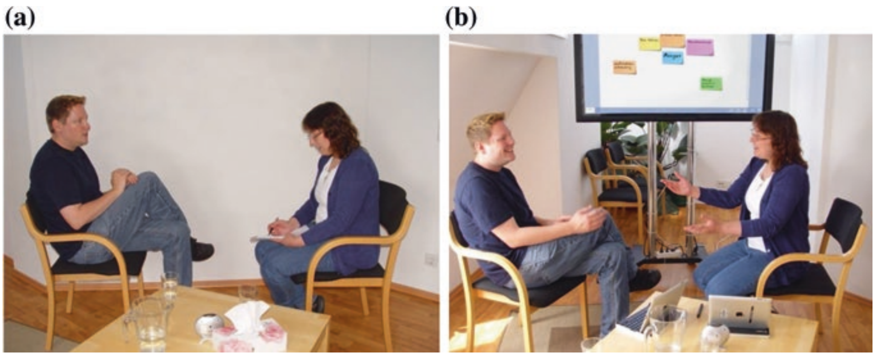

Fig. 2 **a** In a standard psychotherapy setting, the therapist takes handwritten notes. Thus, the patient cannot access the information about his problems that is being collected over time. **b** Tele-Board MED supports teamwork in psychotherapy. Patient and therapist can collect and use information jointly

directly empower patients. However, over time therapy should enable patients to solve new problems more or less independently. That is one of the reasons why we created Tele-Board MED as a tool to support joint documentation and teamwork at eye level in psychotherapy (Fig. 2b). It is based on the design thinking Tele-Board tool for collaborative problem solving (Gumienny et al. 2011).

Tele-Board MED is designed to be a means of patient empowerment. Therapists can help empower patients by inviting them to take an increasingly active role in the gathering and handling of information. To achieve that, therapists can even rely on simple gestures such as handing over a digital pen.

Practicing Creative Problem Solving in Behaviour Psychotherapy, Design Thinking Style

The design thinking community does not only use collaboration tools that can be of interest to psychotherapists. Design thinkers are also aware of the experiences they create in a quite unique way. This awareness can be particularly interesting for therapists when it comes to the issue of learning experiences. Design thinkers create and refine the trainings they offer much like they design and refine cars or medical devices.

One good example of design thinking education is the *Stanford Virtual Crash Course* (d.school 2012/2014a). The course duration is only two hours. In these two hours, design thinking novices try out a full cycle of the problem solving process from empathizing to testing.

The training has been designed and refined to elicit particular experiences. These are some of them:

- **Self-Efficacy**: Students develop a reasonable sense of optimism or even enthusiasm about their ability to personally solve difficult problems.
- **Process Efficiency**: Students experience design thinking as a highly rewarding and helpful means to understand and solve problems. After taking a course, participants are usually eager to practice design thinking more thoroughly and to work on more problems using the design thinking approach.
- **Uplifted Feeling**: Taking the course proves to be a great experience. Predictably, students have fun. They feel inspired, illuminated and energized.

All of this might be nice to have in psychotherapies as well. While behaviour psychotherapy and design thinking share a highly similar process model and the aim of promoting problem solving skills, therapy sessions are typically less carefully designed regarding the immediate experiences they elicit. Problem solving tends to come across as a more laborious or even strenuous activity in traditional therapeutic settings. When worksheets are used, they often resemble assignment sheets from high school courses. To view some examples, interested readers can consult the treatment manual for Problem-Solving Therapy by Nezu et al. (2013), where the authors share a considerable number of worksheets. Design thinking "worksheets" often address similar issues, but in a more playful and light-hearted manner.

Of course, there can be cases when it makes sense to present problem solving as an austere undertaking in psychotherapy. For instance, some patients expect their therapists to tell them precisely how they should solve their problems. These patients seeking authoritative instructions may not be ready for a fully-fledged design thinking based problem solving crash course at the beginning of their treatment. However, psychotherapies could profit from more diverse treatment options. Sometimes it makes sense to introduce problem solving as an activity which is not only helpful and relieving, but also energizing and fun. In design thinking education, students typically become passionate and insistent problem solvers quickly. They become flexible in their problem views and solution attempts, eager to learn from experiences. We believe, these are nice-to-have effects for psychotherapies as well. That is why we re-designed the *Stanford Design Thinking Virtual Crash Course* to help people tackle personal life problems in psychotherapy, design thinking style (von Thienen and Meinel 2014).

The remaining part of this chapter will serve to introduce the problem solving crash course for psychotherapy in more detail. For that purpose, we will share an example of patient and therapist following the crash course by outlining their therapeutic conversation. However, there is one aspect of the crash course that could cause confusion and it will therefore be discussed in advance.

The *Stanford Virtual Crash Course* is 120 min long. Our adapted version takes less than 50 min to fit in single therapy sessions. That is quite short given the numerous tasks which are included. However, rigorous time constraints and a fast-pace working style have been found highly beneficial in design thinking education—particularly in training novices. Thus, the short time is absolutely not a necessary evil but rather a benefit. There are several reasons for this.

- **Anti-Perfectionism**: Many people are perfectionists. They want close to perfect solutions right from the start. When no nearly perfect solution is in sight, people keep ruminating and nothing changes at all (d.school 2012/2014a). In design thinking training, people immediately recognize that their working time is much too short to solve each task thoroughly and as well as they might wish. Therefore, they have an excuse for imperfect answers. Thus, they get going. In sum: Perfectionism can inhibit divergent, creative thinking and time shortage has been found to be an effective antidote.
- **Permitting Failure**: The shortness of time does not only provide an excuse for imperfect answers, but also for clear-cut errors. Design thinkers embrace action, failure and learning in line with their mottos: "bias towards action" and "fail early and often" (d.school 2010/2014). Iterating the process several times is a means to ensure that errors don't remain unfortunate mistakes. They lead to valuable insights and learnings which can finally culminate in all the better solutions.
- **Rough Sketches**: When time is short, people have just enough time to create rough drafts of everything they work on. Design thinking research found that rough drafts are ideal to stimulate discussions of fundamental ideas (Edelman and Currano 2011). This is exactly what we want in the beginning of design thinking project work. By way of contrast, fine-grained and polished drafts (which many people create when they have enough time) tend to stimulate discussions of details only.
- **Forestalling Unconstructive Discussions**: Time shortage is often an effective means to avoid unconstructive, long discussions of general doubts, or blocking. People just keep going, instead of getting caught up in the details.
- **Energy**: Finally, the short completion time is a "productive stressor" that energizes people.

Few people like rigorous time constraints at the start of their design thinking training. Initially, many participants express their discontent with time shortage in projects. However, within some weeks most participants become convinced advocates of strict time limits, since they observe many positive effects. In therapy settings it seems to be the same. At first, patients dislike rigorous time constraints, but later on they find them helpful.

This much said, we would like to share an application of the new crash course.

The course has been set up on Tele-Board MED. In fact, psychotherapists could also introduce the course without Tele-Board MED, but the system helps them to concentrate on content work only. The program can take over the task of timekeeping and provide worksheets when they are needed. It can also modify the working atmosphere by fading in or out differing types of music in the course of events, which has been found very effective in design thinking education (d.school 2012/2014a, 2012/2014b, 2014a, b).

Readers who are interested in empirical tests of Tele-Board MED we kindly refer to von Thienen et al. (2014). A description of the concrete methods or techniques used in design thinking and their empirically evaluated or (in some cases) assumed effects can be found in von Thienen and Meinel (2015). Videos showing Tele-Board MED in action, including a demo of the design thinking based problem solving crash course, are available online at https://med.tele-board.de.

In the following, we will try to introduce the crash course in a way that helps readers replicate the process or build on it. Readers are welcome to download empty templates ("worksheets") for their own creative work at http://ecdtr.hpi-web.de/report/2014/002.

In the next section, a model therapy session is outlined in which therapist and patient walk through the design thinking-based crash course. We provide their therapeutic dialogue not only to illustrate a typical procedure, but also to share instructions on behalf of the therapist that have proven helpful.

A Sample Therapy Session of Practicing Creative Problem Solving with Tele-Board MED

In the following dialogue, *T* is the therapist. The patient, Mr. Miller, is called *M*. His parents were alcoholics. He is 47 years old, a passionate motorcyclist and has difficulty maintaining close relationships. *P* signals actions of the program Tele-Board MED.

The dialogue printed here takes place after several anamnesis sessions. In the meeting prior to this one, the therapist introduced the process model of problem solving and explained each stage. Therapist and patient agreed to try out a first iteration of the process.

The therapist makes sure to prepare his patient for a process that is *fast-pace* and needs to be *iterated* to yield real-good solutions.

EMPATHIZE: Understanding the Patient's Needs and Worldview

T In the last session we talked about a process that helps to find a new outlook on problems and explore possible solutions—until we finally hit on something that really works for you. For today we have planned a first quick-and-rough iteration of the process. Are you ready to jump in, or is there some pressing subject that we should address instead?

M Let's try the process.

T Okay, great. First we need to state our mission (Fig. 3). In the anamnesis session you talked about how your partnerships end sooner rather than later. There always seem to be some insurmountable conflicts. How about tackling the issue of partnership conflicts?

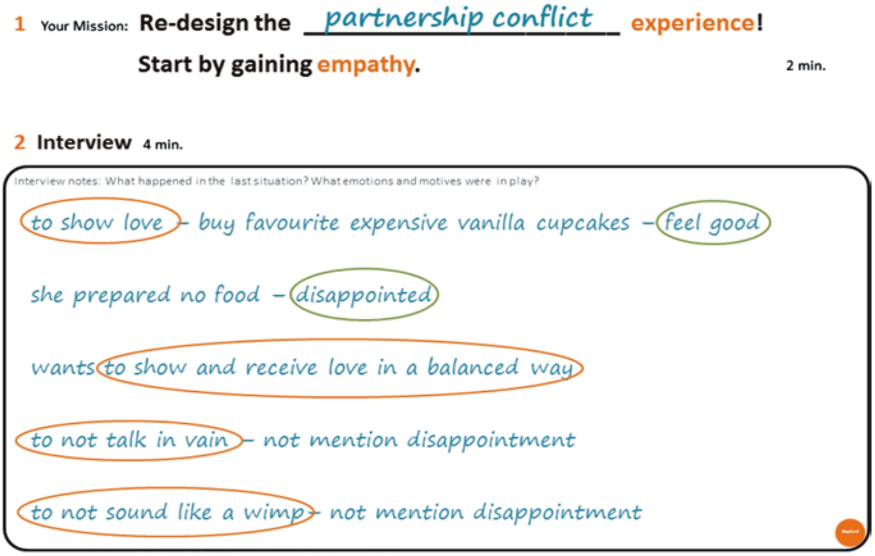

Fig. 3 A template to begin the process of joint creative problem solving

M That sounds good. Last week I was so frustrated again.

T Let's see how there could be different experiences for you in connection with partnership conflicts. I'm really curious what different possibilities we will tap today. [*writes with a digital pen on Tele-Board MED*: *partnership conflict*]

P [*Gong!*]

T In the next step I will interview you about your experiences with partnership conflicts. We only have 4 min for that, so let me ask you straightforwardly: When did you experience a clear partnership conflict the last time? What happened in that situation?

M The last time I had a severe conflict with Miranda [*his girlfriend*] was last Monday. Even though it was the end of the month and I was short on money I bought her these expensive vanilla cupcakes she loves. I came home and found her watching TV. She knew that I would be hungry, but she had prepared nothing for dinner. Nevertheless, I gave her the cupcakes. She just put them aside and started talking about how stressful her day was. I was so disappointed, but I said nothing. The whole evening I thought about the situation, getting angrier and angrier. Sometime later, Miranda spilled some red wine on my shirt and I lost it. She started crying and I felt even more awful than before.

T Let me return to the beginning of that story. You said you bought your girlfriend's favourite expensive vanilla cupcakes even though you were short on money. Why did you do that?

M I wanted to show her my love.

T [*writes: to show love—buy favourite expensive vanilla cupcakes*]
How did you feel when buying the cupcakes?

M I felt good. I was looking forward to seeing her smile.

T [*writes: feel good*]
And then you came home. Miranda was just sitting in front of the TV. No food was prepared for you. How did you feel at that moment?

M I was disappointed.

T [*writes: she prepared no food—disappointed*]
If I recall correctly, in an earlier session you mentioned that there is no clear agreement between you and your girlfriend about who cooks and when, even though she cooks more often than not. I'm sure last Monday there was a reason why you were disappointed when you learned that she had cooked nothing…

M Of course. I pampered Miranda with her favourite cupcakes which I could barely afford. In return, she did not even bother to prepare some precooked fast-food for me. I think, in a partnership there should be some balance in the way people show and receive love. In reality, though, I always seem to end up making more efforts than she does.

T [*writes: wants to show and receive love in a balanced way*]
You also said you kept your disappointment to yourself that Monday afternoon. Why didn't you tell your girlfriend how disappointed you were?

M Why should I have told her? It wouldn't have changed anything. In addition, it would have sounded awfully strange, don't you think?

T [*writes: to not talk in vain—not mention disappointment*]
What do you mean by "it would have sounded awfully strange"…?

M I don't want to sound like a wimp.

T [*writes: to not sound like a wimp—not mention disappointment*]

P [*Gong!*]

T Oh, time is already up. I would have liked to ask many more questions. Fortunately, we can always go back to the exploration phase later on in the process if that makes sense for us. Yet, for now, let's move on.
To prepare the next step in the process, let's circle motives and emotions in the notes. We talked about how you want "to show love", "to show and receive love in a balanced way", "to not talk in vain" and "to not sound like a wimp". In terms of emotions we have been speaking of "feeling good" and "feeling disappointed" [*circles notes while reading*].

T In the next step, let's sum up some findings that we can build on.
Here we can collect needs and insights [*points to the next template on Tele-Board MED*, see Fig. 4]. Needs are things that the protagonist (you) wants to achieve. Insights are new pieces of knowledge about the protagonist's feelings or world view that might help us in our challenge.
To collect needs, we can just copy the motives that we have hit on in the interview.
[*copies circled motives*]

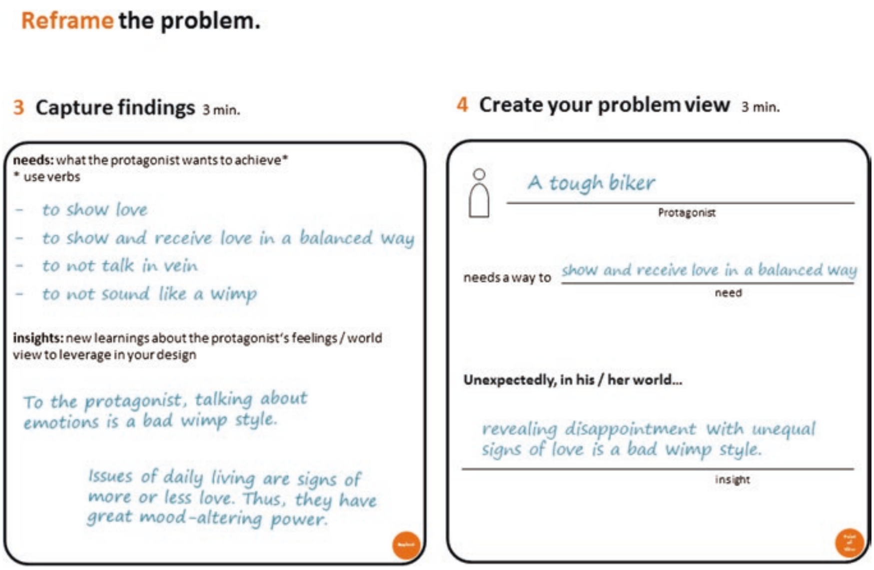

Fig. 4 Findings from the interview and a unique problem statement

To find insights, let's start by asking ourselves whether maybe there was a moment of surprise in the interview. To me, for instance, I found striking how you actually started the afternoon with good expectations. You bought these expensive vanilla cupcakes for your girlfriend and felt good about that. Later on, the dinner issue came into play and turned everything around. The contrast seems drastic: You showed love by buying cupcakes. She showed no love by not preparing dinner. Does that make sense?

M That's the way it is. I guess she just doesn't love me that much.

T How about some insight like:
"Issues of daily living are signs of more or less love. Thus, they have great mood-altering power."

M Well, that's true, yes.

T [*Writes: Issues of daily living are signs of more or less love. Thus, they have great mood-altering power.*]
You also said talking about emotions might seem wimpy. How about an insight like this: "To the protagonist, talking about emotions is a bad "wimp style"? That would tell us something interesting about the protagonist's world view. After all, there may be wimps who see things differently… [*smiles jokingly*]

M [*smiles too*] Sure.

T [*Writes: To the protagonist, talking about emotions is a bad wimp style.*]

P [*Gong!*]

DEFINE: Creating an Actionable Problem Statement

T Our next job is to come up with today's problem statement. So, let's focus on one need.
Often, it pays to choose a rather fundamental need… maybe a need that one has not explicitly thought much about before. Also, our problem statement will be most helpful when it's short and catchy.
Do you have a feeling where you would like to start?

M The most fundamental need to me is that I want to show and receive love in a balanced way. But I have thought about that issue before—many times.

T Oh, we don't need to be perfect. Our goal is to learn more and iterate. We can just try it out. How about a statement like this: "A tough biker needs a way to show and receive love in a balanced way. At the same time, interestingly, in his world revealing disappointment with unequal signs of love is a bad "wimp style".

M Yeah, that's pretty much me.

T [*Writes: …A tough biker… to show and receive love in a balanced way… revealing disappointment with unequal signs of love is a bad wimp style.*]

P [*Gong!*]

IDEATE and PROTOTYPE: Coming up with Diverse Solution Ideas and Sketching Them Graphically

P [*shows the "brainstorming template" and prints out two paper copies*]

T Okay. Our next job is to brainstorm as many different solutions as we can. If one page doesn't suffice, just flip it over and continue sketching ideas—the more, the better. Here, really there is no limit whatsoever to the solutions we may consider. Magic is welcome, time-travel is welcome; overall wild ideas are welcome. Our sketches can be as rough or hard to interpret as they happen to end up. Later on, we will have time to explain what we mean. We are just to come up with as many different options as we can in 5 min. Are you ready?

M Yes.

T [*starts timer on Tele-Board MED*]

P [*timer runs, lively instrumental music fades in*]

T&M [*They sketch ideas on the brainstorming template.*]

P [*after* 5 min*: Gong! Music softens.*]

TEST: Gathering Feedback and Learning from It

T [*The therapist looks over to Mr. Miller.*]
Would you like to share your ideas?

M Okay (Fig. 5). My first solution is that Miranda, magically, is turned into a super-woman. She shows me her love all the time.

T [*nods smiling*]

M My second idea is that I have an iron heart and don't need anybody's love.

T [*nods smiling again*]

M Then I have the idea that Miranda and I are on holidays. Everything is relaxed. Miranda has time and is very positive about everything I do.

T [*smiles*]

M The next idea is pretty crazy. You know, I like these video jump-and-run games: You shoot a target, a bonus icon appears in the air and your bonus counter goes up. My idea is to have such features for Miranda and me. Whenever I show her a sign of my love, a heart icon appears in the air and a bonus counter adds some credit points to my profile. So, I don't have to say anything and she still realizes how often I show her my love. What's more, she also sees how much she falls behind. Conversely, I also recognize when she does something for me that I might have otherwise overlooked. I hear the sound that comes when you get a bonus and her credit points go up. As things stand now, I think she sometimes does me good and I don't even notice it.

T [*grins*] Wow.

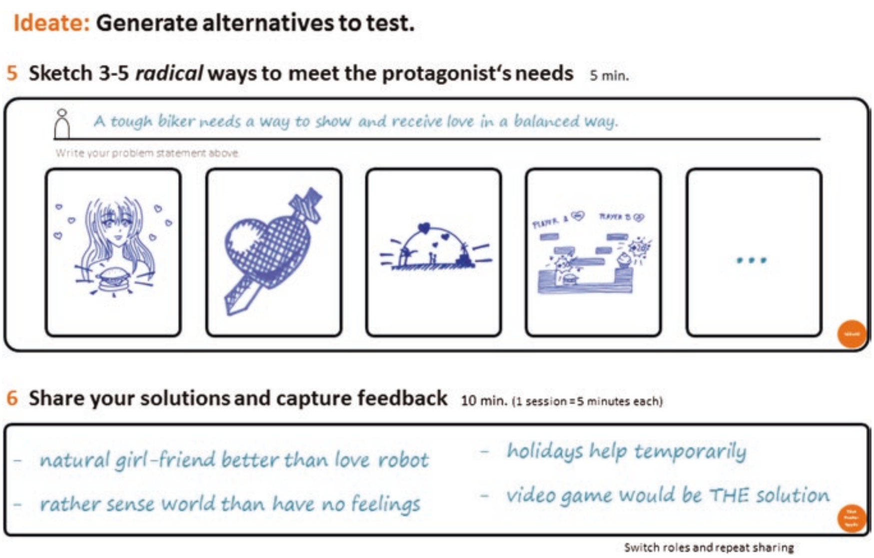

Fig. 5 Mr. Miller's brainstorming ideas

M [*He reports several more ideas.*]

P [*Gong! Music dims.*]

T Wow. You came up with so many ideas; you actually filled two pages! Also, I really like how you included many wild ideas next to the ones that are more down to earth. And your ideas explore many different directions. That's great! There are so many options now. …I'd be curious to learn what you think of each option (?)…

M Miranda as super women does not seem very appealing to me. I like her naturalness; I don't want a love robot. Myself with an iron heart—that might be practical. But I don't want that either. What joy is there in life if you lack the heart to sense it? The holiday solution works pretty well, I know that. But you can't be on holidays all the time. The video game I like best. It is impossible, I know. But if it worked, it would be THE solution. [*He continues to discuss the remaining ideas.*]

T [*writes: natural girlfriend better than love robot; rather sense world than have no feelings; holidays help temporarily; video game would be THE solution*] Great!

P [*Gong!*]

T Would you like to hear my ideas as well? (Fig. 6)

M Sure!

T Please tell me what you think about each option. And you have every permission to be critical. After all, we are here to learn.

So, this is my first idea: You have such a good time at your job that you come home in the best mood. Whether or not your girlfriend waits for you with signs of love doesn't matter much—you feel good anyway.

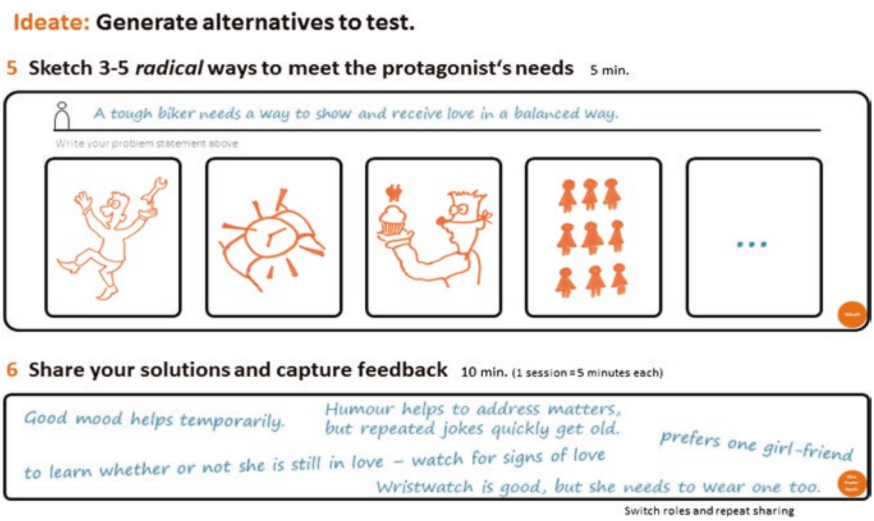

Fig. 6 Brainstorming ideas of the therapist and Mr. Miller's feedback

M That works, I know. When I have a good day I don't mind her just taking care of her own issues. Yet, in the long run, I want to learn whether or not she is still in love with me. So I do want her to show me how much she cares.

T [*Writes: Good mood helps temporarily; to learn whether or not she is still in love—watch for signs of love*]
The next idea is: It might happen that your girlfriend shows her love for you while you are absent, so you miss some signs of love. For instance, even though she's short on time she might decide to wash clothes only because she knows you need them desperately. So, in the sketch you are wearing a watch that glows green whenever she does something for you. This mechanism works even over long distances.

M Yes, I like that watch. But I want her to wear that kind of a watch too. She should see how much I do for her as well.

T [*Writes: Wristwatch is good, but she needs to wear one too.*]
The next idea: You talk with humour. For instance, you give her the expensive vanilla cupcake saying "Here, I bought you this precious vanilla cupcake as a sign of my love. Now, in return, I'm really curious what signs of your love you might want to show me?!"

M Yes, I like that. Humour is good. I guess I could say that. But a joke doesn't get better if you tell it again and again in different situations.

T [*Writes: Humour helps to address matters, but repeated jokes quickly get old.*]
The next idea: You have many different girlfriends at one time. If each girlfriend shows you only 10 % of the love that she should be showing, then you need ten times as many girlfriends. [*grins*]

M [*smiles back*] No. I want a normal relationship with Miranda. Many girlfriends at one time don't make me happy. Believe me, I know what I'm talking about.

P [*Gong!*] [*shows template "iterate based on feedback"*] (Fig. 7)

T Now, let's sum up our most important findings. In terms of ideas that tanked, I found quite striking how you seem to be happy with Miranda in general. You seem to prefer the woman that she is over a Miranda love robot. And you didn't like the idea of a big girlfriend collection either. Does that make sense?

M Absolutely. Um-hum.

T [*Writes: The existing partnership is generally appreciated, no change wanted.*]
For me, another important lesson from ideas that tanked concerns the reason why signs of love are important. At the beginning, I thought it was just a matter of equality: You engage this much, so she should engage herself to a similar degree. But then, you disliked the idea of being in a good mood all the time based on things going well at work; you said you also want to find out whether or not Miranda is still in love with you. So, as I understand it now, in addition there is a need for knowledge. You watch out quite vigilantly for signs of love because that's your strategy to estimate how much she is in love with you. Would you agree?

M Of course I agree. I might have chosen other words, but it's true. Both issues are important, equality and knowledge… or certainty, I might say instead.

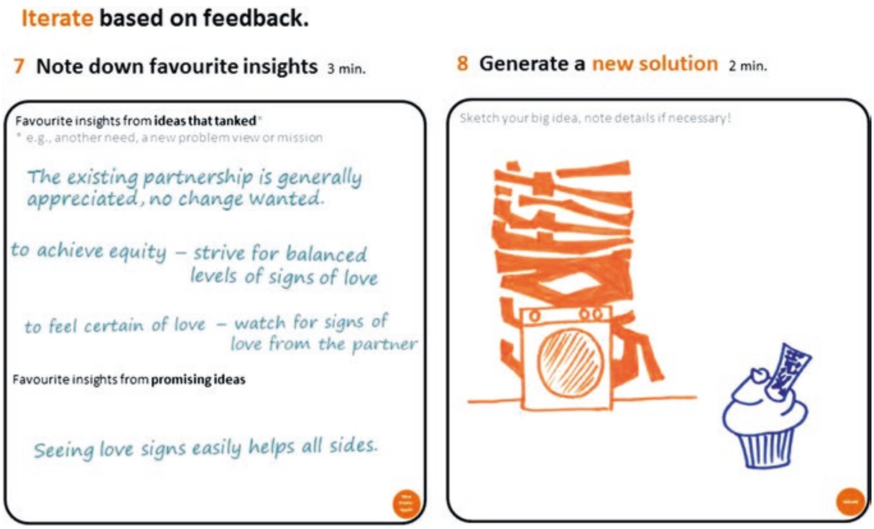

Fig. 7 Insights from brainstorming feedback and a new idea

I want to be certain that she loves me. After all, our partnership might be just a habit for her. In a corner of her mind she might already be considering leaving me.

T [*writes: to achieve equity—strive for balanced levels of signs of love; to feel certain of love—watch for signs of love from the partner*]
[*points to the "promising ideas" headline on the template*] In terms of promising ideas I also liked your video-game approach a lot. Generally speaking, making both your and her engagement more visible seems to me a very promising idea. I like how balanced that approach is; the two of you could profit in so many ways. Even when her bonus counter goes up because she has done something for you, it's not negative for you in the sense that you fall behind. Rather, it can help you feel certain that she really loves you because you see signs of love that otherwise might have escaped you.

M Yeah, maybe that's actually a flaw in my video game idea. In a video game the person with the most bonus points wins. But if Miranda shows me her love and her account gets credit for that, I win, because I know she really loves me.

T Interesting. That also seems to imply: The better you sharpen your view for her engagement, which may not always be obvious, the more signs of love you will discover. And the more signs of love, the more certain you feel about her love. So the sharper your view, the more you win.

M Yeah. And when I see more, Miranda wins too. I guess, as long as I trust she loves me I'm much more of a charming fellow.
Maybe we can write: Seeing signs of love helps all sides.

T Sure, please… [*hands over pen and points at "favourite insights from promising ideas"*]
M [*Writes: Seeing love signs easily helps all sides.*]
P [*Gong!*]

IDEATE, Second Iteration: Creating a New Idea Jointly Based on the Latest Learnings

P [*Barely noticeable, the music becomes a little louder and livelier.*]
T Now we are to generate a new solution jointly based on what we've learned. We only have 2 min for that, so let's start right away.
M I liked the video game idea best. But how could we get these virtual hearts in the air?
T I recall a prep school teacher who highlighted good jobs with colourful stickers: hearts, stars, animal, whatever. She would have put two stickers on your expensive vanilla cupcakes—one sticker for the intent to please your girlfriend and an extra sticker for the extra investment in view of the tight financial situation.
M [*frowns*] So I come home with vanilla cupcakes that have flower and heart stickers on them? What a wimp I am after all!
T Last time when we met on the street you showed me a new image on your motorcycle from a talented graffiti artist… Wasn't that a sticker as well?
M It was… The guy who did that sticker, Danny, he makes real cool stuff. I wished I had more space on my bike for his pieces.
T Since time is running out, let's just start sketching an idea. Never mind if it's bad. We can learn and return. So, let me sketch your washing machine with a cool piece from Danny on the wall behind it because your girlfriend has invested much time to wash your clothes there. [*draws*]
M Man, I don't know if we're on a good track. But anyway. Let me add a cupcake with a somewhat smaller Danny-piece. In the long run, Miranda has made a greater effort by washing all our clothes than I have by buying cupcakes once. [*draws*]
P [*Gong!*]

PROTOTYPE and TEST, Second Iteration: Trying Out the New Solution

P [*shows next template, music becomes a little louder and livelier*] (Fig. 8)
T Okay. Now we have 2 min to build something tangible to interact with. Shall we try our hand at creating Danny-pieces? We also need something to put the stickers on. Here, this cup could be a cupcake…

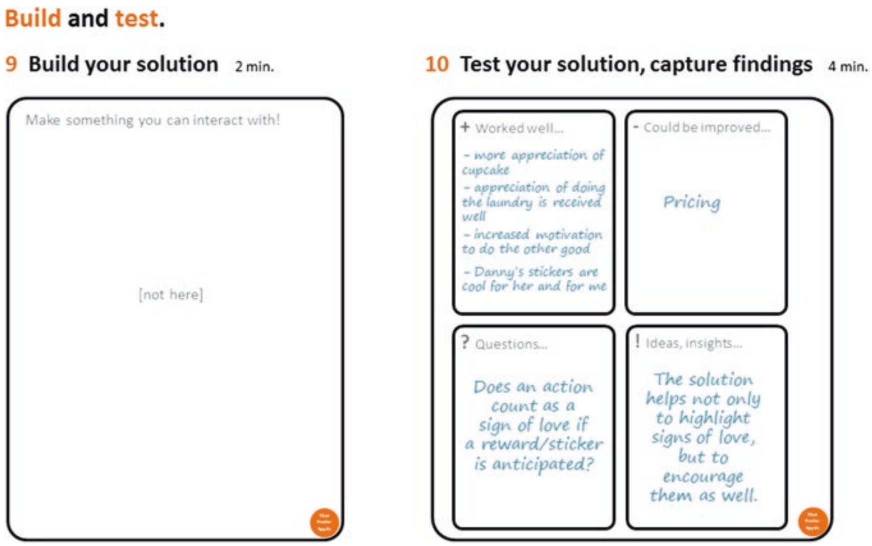

Fig. 8 Test of a solution prototype

M [*frowns and grins*] Okay.

M&T [*They create graffiti sketches, cut them out, tape one piece on a cup* (=*cupcake*) *and one on a printer in the corner of the room* (=*washing machine*).]

P [*Gong! Music dims.*]

T Okay, now let's try our solution. Maybe you can bring me the cupcake and we see how things go? That would mean, for the moment I would be Miranda, if that's okay with you?

M Hm. Okay. [*hands over cup with sticker*] Here, I bought you your favourite vanilla cupcake.

T Oh, that's nice! …It has a cool sticker on it!

M Yeah, that's from Danny… you know, the guy who made a sticker for my bike as well. [*waits a moment*] You know, it's the end of the month and my wallet is suffering from anorexia, so I thought this cupcake is really worth a Danny sticker… kind of like a bow on a gift box… only, I know you don't like knickknacks…

T Oh, that's so sweet! I'll really take my time to enjoy this cupcake! [*hesitates for a moment*] Hm… I have nothing to give you in return! …Let me bring you a beer that I bought for you yesterday… [*goes to fetch a bear… in passing sees printer/washing machine with the big sticker on it*]. There's another Danny sticker over the washing machine?!

M Yeah… Danny gave me a whole bag of some samples he made. I know you like that style so I thought we could decorate the apartment a little. … When I walked around I thought it would look kind of cool over the washing machine… [*hesitates*] …and I thought, given how much time you spend there, it's actually worth quite a big Danny sticker… bigger than the cupcake one, I mean…

T [*nods somewhat puzzled but appreciative*] Yeah, looks cool anyways. [*hesitates*] Have you thought about other places where you would like to put stickers? I could imagine one on the kitchen unit… that looks pretty aseptic at the moment…

M Yeah, sure. [*hesitates*] We could put a big sticker on it for your cooking and a smaller sticker for my cooking.

T [*hesitates a moment*] Cool. Can I see your bag?

M [*hands over bag*]

T [*sifts through the bag*] This sticker is pretty cool. Can I have this one for the kitchen—for my cooking, I mean?

M [*alarmed*] That sticker is my favourite! I wanted to put it on my engine hood! Hm… I think you need a better argument to make me release that sticker. …You can have this one though [*offers a big but rather boring piece*]

T Okay, wow! Shall we take a break here to quickly discuss our test?

M Sure.

T When you gave me the cupcake with the sticker and explained what it meant, it really boosted my feeling of being appreciated. That was lovely. I also liked to hear you appreciate my work on the dirty clothes. For a moment, then, I kind of drifted away from your original intent. I thought you had this big bag of stickers and we could just decorate the apartment—regardless of signs of love. But then you got your act together by pointing out my efforts spent in the kitchen. I really got the point then and could join in easily. At the end, the stickers even became a motivating factor for me to see the good things I could do you. I really wanted to have that cool sticker you hung onto … How did you feel?

M At times, I was a little unsure. But overall, things went better than I thought. In the end, bargaining about what my girlfriend would have to do to get the cool sticker promised to be a lot of fun. In my mind some suggestions formed that YOU probably don't want to hear.

T [*grins*] I see our process fuels your inspiration, that's great.

Turning back to the feedback grid in our remaining time, let me write [*writes: more appreciation of cupcake; appreciation of doing the laundry is received well; increased motivation to do the other good*]. The latter is actually an insight, I think. We came up with the stickers to highlight existing signs of love, but really cool stickers might actually be a motivation to do good things for the other person more often. [*Writes: The solution helps not only to highlight signs of love, but to encourage them as well.*]

Yet, wait a minute. Here I have a question. If your girlfriend likes the stickers too, and does something good for you so that you'll cough up your favourite sticker—does her action still count as a true sign of love? Or is she materialistically motivated in this case? [*Writes: Does an action count as a sign of love if a reward/sticker is anticipated?*]

M Hm. I don't think the sticker reward is that detrimental. I mean, it's more of a game if the story takes this turn. In the end, Miranda could easily drive by Danny's herself and buy whatever stickers she wanted. But I'm sure she really likes this style and she would like to have those stickers in the apartment. So, that's another positive point. [*Writes: Danny's stickers are cool for her and for me*.]

T Would you like to improve something?

M Yeah! The pricing! These stickers are really expensive. I have to talk to Danny to see how much of that stuff I can afford… [*writes: pricing*]

P [*Gong! Music fades out.*]

BRING HOME: Recapitulating Benefits from the Session and Stimulating Further Engagement

P [*shows "benefit template"*] (Fig. 9)

T Okay. Time is almost over. We have moved forwards with our process very quickly. Let's take a short moment to step back and reflect.
Maybe you recall that I told you last time the overall aim of these sessions is not primarily to find a wonderful solution straight away. The main point is to look at strategies that you might use any time, any place to solve whatever

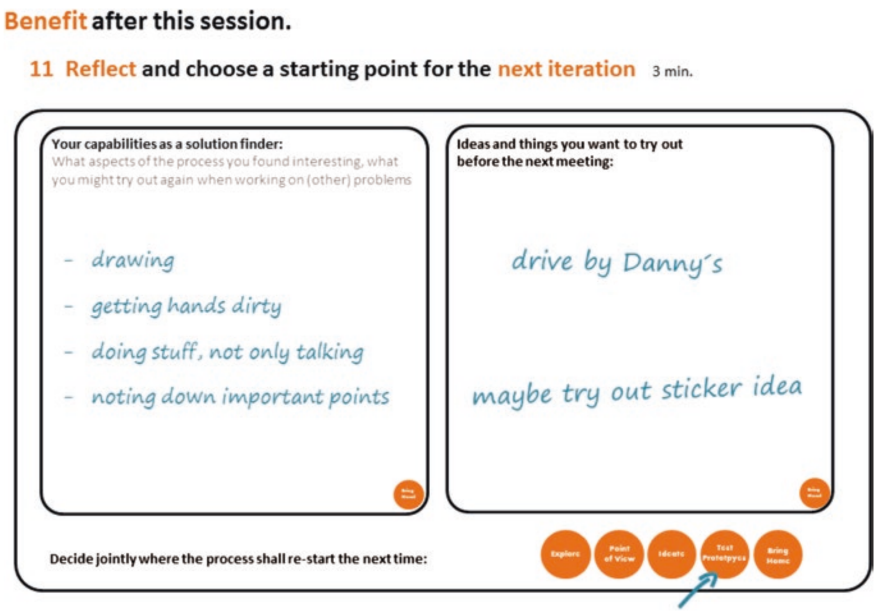

Fig. 9 The patient sums up benefits

life problems you encounter. I can imagine the process we used today may be somewhat different from what you ordinarily do when you tackle problems. Typically, in our culture, we learn to hesitate when there is something problematic and think our way through the problem until we finally have a close-to perfect solution ready in our mind. In this process, however, we had a strong bias to action. We moved forwards without readily imagining a close-to-perfect solution. We started with a very short and barely finished interview; we built on a problem statement that was good but not perfect. In any case, we moved forwards quickly in order to learn quickly. Then, after learning, it is always possible to iterate the process and return to any earlier stage—but better informed than before. How did you feel in that process? Was there maybe something about the process you found interesting? Something you could imagine trying out again?

M Yeah, today was different. I liked it. The first thing I can tell you: It was fun. You know, normally digging into one's problems is pretty exhausting. But today, for the first time I had the feeling that I kind of liked working on my problems, if you know what I mean. It was interesting. I never thought about the process while we were talking. I had no idea where we were heading but I trusted you'd know what you were doing. And then we really did have a couple of insights that were cool. I feel I understand the situation better now. And our solution is… neat. So, yes I can well imagine trying out the process again. I'd like to. But I don't know how much I'd do all by myself already. I'd like to try it again here next week.

T Is there something about the process you liked in particular?

M I liked drawing. I also liked how we got our hands dirty before testing the solution. I liked doing, not only talking.

T [*hands over pen*]

M [*writes: drawing; getting hands dirty; doing stuff, not only talking*]
I also like to have stuff written down. Normally, in therapy, we talk a lot. Often I have the impression that we hit on an important point but it's too elusive. Later on, I can barely remember what exactly we said. [*writes: noting down important points*]

T Yeah, I like that too about this process. We can also print out our notes. Would you like to take a copy home?

M Absolutely! [*smiles*] I'll hide it in the garage. Miranda never goes there.

P [*prints out copies of all templates with notes*]

T [*hands over copies*]
Are there things that you would like to do before we meet again next week?

M I'll drive by Danny's and see how much a whole bag of stickers costs. Maybe I'll actually try that out with Miranda. I have to think about it. It would take some courage … It's just an experiment at this point.

T [*points to the template and looks at the pen in Mr. Miller's hand*]

M [*writes: drive by Danny's; maybe try out sticker idea*]

T Yeah, you're right, it's really an experiment. The whole process is very much based on experimentation. That's the path of rapid learning. Even if an idea tanks and you have to start from scratch, you know more, so you are in a better position. It often helps much more to try, fail, learn and improve instead of to just lean back and think forever. Indeed, that culture of thinking forever often gets us stuck and nothing changes at all. So, if I can encourage you to dare some action—to try and learn—then I surely deserve a shiny "well done"-sticker too for the supporting effect. [*smiles*]

M [*smiles back*] I'll see what I can do.

T Now, to finish up we just have to decide where in the process we want to start our next iteration. Do you have a suggestion? Where would you like to pick up our challenge next time?

M Maybe I can tell you how things went with Danny. Maybe I will have tried out our idea, maybe not. In any case, I guess we'll have stuff to discuss.

T Oh, that sounds good. And maybe we can use today's feedback grid once more to see what went well, what didn't go so well and what might be improved (?)…

M Sounds good.

T [*draws an arrow to the "test prototypes" bubble in the process model*]

P [*Gong!*]

Résumé and Outlook: Using Design Thinking Tools in Behaviour Psychotherapy to Promote Mental Health

To sum it up, let's return to a thought that started this chapter. The confidence and competence to solve life problems creatively is an important attribute of mentally healthy people. Persons who tend to be rigid in dealing with problems get stuck rather easily once the preferred solutions do not work.

Behaviour psychotherapy seeks to help people step beyond rigid problem views and solution attempts by teaching an approved problem solving process. To support that practice, we have adapted design thinking tools for psychotherapeutic settings. In particular, we have developed Tele-Board MED and implemented a design thinking based crash course for psychotherapy patients. It helps patients practice creative problem solving by splitting the long process of creative problem solving into manageable steps. Patients are guided towards process mastery in a way that can be fun and that does not prescribe any concrete goals or solutions.

To conclude, we would like to embrace a definition of mental health by the World Health Organization (WHO) and share a model of therapeutic change to communicate our notion of how design thinking tools can contribute to mental health in behaviour psychotherapy.

> Mental health is defined as a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community.
>
> (World Health Organization 2013/2014)

Rigidity in attempted solutions is a frequent reason why people fail in coping with life problems, why they fail to engage fruitfully and remain far from realizing their potential. Broadening the spectrum of possibilities that people can tap is exactly the way to help them explore their potential. Strategies of creative problem solving—as taught by behaviour therapists or design thinkers—are powerful means of enhancing mental health. They allow people to react in a flexible and beneficial way to stressful life situations. By using an approved process of creative problem solving, people can create and re-design their problem views and solutions iteratively, until they reach a unique solution which really does make life better—their own and often that of others.

Let us finish with a sketch of the learning path we envision for users of Tele-Board MED (Fig. 10), building on common design thinking education models (Jobst et al. 2012; Rauth et al. 2010; Royalty et al. 2012, 2014). Firstly, patients become acquainted with the process of creative problem solving. That process can certainly be taught in many ways. We provide a lot of design thinking based training material since it is fun to use and seems to support rapid learning particularly well. Upon finding the process helpful, people tap new mindsets and values; they acquire both the necessary flexibility and the skills to handle all kinds of personal life problems. Thus, Tele-Board MED helps to strengthen the patients' disposition to mental health by supporting creative problem solving, design thinking style.

As patients learn to apply the process of problem solving, over time they acquire a new mindset that helps to tackle future life problems. Thus, they are more disposed to maintain mentally healthy even under stress or when confronted with severe life events.

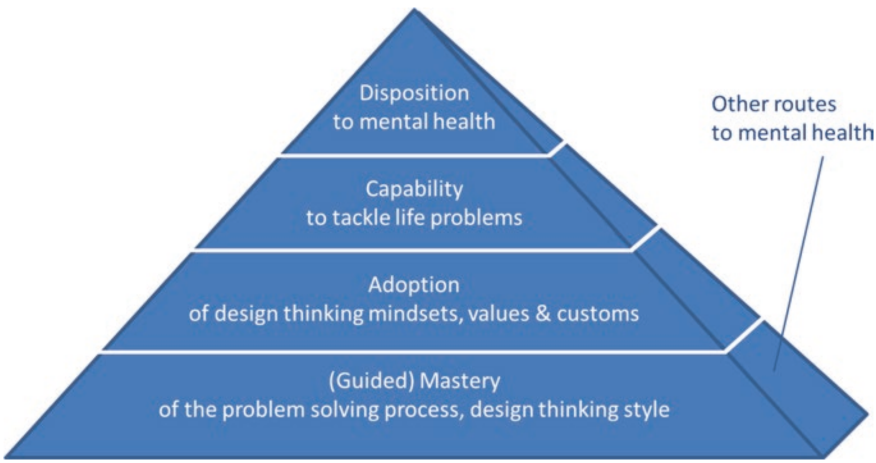

Fig. 10 A model of therapeutic change supported by Tele-Board MED

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Part IV
Creativity in the Arts

Neurocognitive Aspects of Musical Improvisation and Performance

Shama Rahman and Joydeep Bhattacharya

Musical Creativity: Its Elusive Nature

What does musical creativity entail? What are the cognitive processes involved? Does it have distinct neurobiological correlates? Many people, hearkening to 19th century Romantic views, believe that artistic creativity is a mystery forever beyond the reach of empirical science. There is a strong belief that musicianship is a special faculty, confined to a tiny elite, and in fact the very word *music* is derived from the Greek word *mousikē* i.e. of the muses, a divine source. In Plato's view, musicians are not creative per se, but rather they merely imitate the muses as the latter are the original sources of creative inspiration. This view is no longer accepted as tremendous progress in the field of neuroimaging has convincingly demonstrated that all mental functions, from very mundane to highly complex ones, are represented by specific neural correlates (Gazzaniga 2004). Yet musical creativity still remains a very difficult problem to shed light on for neuroscientists as it is seen to be enormously complex (too many attributes of musical creativity), unpredictable (difficult to predict the onset/offset of musically creative ideas), undefinable (no one single definition exists), and lacking introspection (musicians often cannot explain the process of being creative). Nevertheless, neuroscientific research on musical creativity offers an immense promise to reveal the hidden spatio-temporal intricacies of neuronal dynamics of the creative brain in action, which complement traditional behavioural research methods. In this Chapter, we

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provide an overview of the current research, albeit at its infancy, on the neurocognitive aspects of musical creativity. First, we provide a brief description of the available neuroimaging techniques to study musical creativity. Next we explain various facets (i.e. stage, type, model) of general creativity. The topic of flow experience, an optimal experience of an intense reward during pursuit of an activity such as music performance, is discussed next. Subsequently, we present the principal findings of neuroimaging research of musical creativity, mainly of musical improvisation. Finally we provide some concluding remarks and introduce a few open questions for future research.

Neuroimaging Techniques

Before we detail various types, models of creativity, we briefly describe the available neuroimaging techniques to study (musical) creativity. Currently two techniques are used most often in neuroscience, namely functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG). fMRI has high spatial resolution useful for localising brain functions, but it has a low temporal resolution in the range of a few seconds. On the other hand, EEG has limited spatial resolution but offers excellent temporal resolution in the order of milliseconds. The decision to use either fMRI or EEG reflects the capacities of these techniques with respect to how they measure the way that the brain functions.

fMRI is an indirect indicator of neural activity. It detects differences in magnetism in deoxygenated and oxygenated blood i.e. BOLD (Blood Oxygen Level-Dependent). Blood flow through the brain is closely linked to neural activity but oxygen-rich blood displaces deoxygenated blood 2 s later than activity and rises to a peak over 4–6 s before returning to the original level, thus having a limited temporal resolution and explains why fMRI is poor at detecting communication between brain areas in real-time (Logothetis 2008). Nevertheless, fMRI offers the best results, among the techniques available for noninvasive neuroimaging, in terms of localising brain areas.

EEG, on the other hand, is a direct indicator of neuronal activity. It primarily reflects the summation of a large number (in the order of thousands to millions) of post-synaptic potentials recorded on the surface of the scalp (Nunez 1995). One scalp electrode can integrate activity from neurons across 10 cm^2 of cortical surface (Nunez et al. 1997); equally any electrical activity that is detectable at the scalp necessitates approximately synchronous activity of a large number of neurons as a certain number of random fluctuations will effectively cancel each other out.

EEG activity measured at the scalp is a mixture of spectral components that have historically been divided into various frequency bands: delta (<4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–30 Hz), and gamma (>30 Hz) (Donner and Siegel 2011). There exists a rich body of literature on the functional roles of these oscillations in diverse cognitive tasks [see for review (Ward 2003)].

Creative moments are often spontaneous and dynamic in time and therefore EEG may be better suited to capture it. Additionally, there is widespread evidence that brain areas do not work in isolation for processing a cognitive task, instead they form a functional (as well as structural) network by exchange of information on a dynamical basis (Varela et al. 2001), and one could investigate this underlying network by using EEG (note that fMRI also allows a reveal of brain networks but its temporal sluggishness prohibits tracking the fast changes in network configurations). Yet as discussed earlier, a major drawback of EEG is that it is a measurement of electrical brain activity at the neocortex level and does not provide much indication of deeper cortical brain structure activity such as that of the limbic system. Equally, the problem of volume conduction of the scalp means that activity detected in neighbouring electrodes could be from the same or overlapping cortical sources and is travelling and spreading through the bone of the skull which is conductive, giving rise to spurious synchrony.

For both techniques there are some serious practical issues that have impeded the progress of neuroscientific research on musical creativity. For example, during brain imaging, participants are usually instructed to stay in a relatively fixed position during the entire recording, either lying on a bed inside a fMRI scanner or sitting on a chair for EEG. Strict requirement on immobility is imposed to minimise movement related artefacts as both techniques (more so for fMRI) are quite sensitive to minute head (and body) movements. This is ecologically an inappropriate (and unusual) situation for a musician to perform. Furthermore, there are other restrictions on the type of instruments to be used, e.g., any metallic instrument is not possible to use inside a fMRI scanner. Therefore, the neural correlates of musical creativity, in its true colour, are indeed quite difficult to capture. Nevertheless, there are some recent pioneering efforts, thanks to new innovations in fMRI compatible instruments and clever experimental designs, investigating the musical brain in creative action, and these will be discussed in the later section.

Stages and Neuroscience of Problem-Solving Creativity

Most of the neuroscientific research on musical creativity, or on creativity in general, is about revealing the underlying processes. Before we begin probing the creative Process [as per Mel Rhodes well-established 4P model (Rhodes 1961)], it would be useful to outline broad stages of creativity in order to understand the basis of subsequent neurobiological investigations. There is almost a century of qualitative explorations into the realm of creativity that could be related to artistic performance and these are, therefore, important shoulders to stand on. In 1926, Wallas put forward a qualitative model of creativity focusing on problem-solving, with four distinct stages as follows (Wallas 1926).

Preparation: This is the first stage where the problem under consideration is formulated and attempts are made to solve it.

Incubation: This refers to the stage where the problem is left aside to work on other unrelated tasks; it is the process of internalising the problem into unconscious mind.
Illumination: This refers to the moment of inspiration or the moment of insight (Aha!) where the solution is arrived without any conscious forewarning.
Verification: This is the final stage when the solution is consciously confirmed and applied.

Some recent neuroscientific research have explored these various stages of creative problem solving. For example, Sandkühler and Bhattacharya have studied different stages of problem-solving by focussing on the insightful nature of the solution rather than the nature of the problem (Sankuhler and Bhattacharya 2008). They have found that functional fixedness or a mental impasse (a state when the problem solver gets mentally stuck on an inappropriate construct of the problem and any further progress is therefore prohibited) at the preparation stage is associated with a higher gamma band response over parieto-occipital and occipital areas, which might be related to excessive attentional focus on an inappropriate representation of the problem. Interestingly, they also investigated the role of 'hint processing' for insight, which could shed new light into how we process new information to solve creative problems. Higher alpha (10–12 Hz) power over the right temporal and lower gamma power over the parieto-occipital areas were predictive of successful utilisation of hints. This suggests that a diffuse attentional focus, as opposed to a focused attentive state, may be more beneficial for processing and integrating new incoming information to produce a creative solution (Martindale 2004). Furthermore, the reported right hemispheric dominance is also aligned with many previous studies on creativity (Parncutt 1994). Interestingly, gamma power at the temporal region is again associated with subjective moments of insight and the verification stage is associated with a higher gamma power at the parieto-occipital region. Altogether it seems that brain oscillations at alpha and gamma frequencies over many brain areas (e.g., temporal, parieto-occipital) are associated with various stages of creative problem-solving.

On reaching a mental impasse leading to incubation, a solver may be forced to remove the problem from their conscious awareness. It is widely accepted that conscious thought has limited processing capacity, yet unconscious thought could process a vast amount of information (Dijkterhuis and Nordgren 2006). Previous research has demonstrated that spontaneous unconscious thought is beneficial for making an optimal choice in a complex decision that requires consideration of multiple attributes (Dijkterhuis et al. 2006). Interestingly, this beneficial effect of unconscious spontaneous thought holds only for complex decisions, whilst conscious or deliberate thought outperforms unconscious thought for simple decisions that involve only a few attributes. Unconscious thought is also associated with better performance on a creativity task (Dijkterhuis and Meurs 2006). This suggests that spontaneous thought may facilitate access to unconventional or non-dominant information in long term memory, thereby, potentially removing any mental impasse by promoting remote creative associations (Zhong et al. 2008).

Neuroanatomically, cognitive spontaneous insights may have its origin in the posterior association cortex, and basal ganglia, given its role in operating outside conscious awareness. During the period of down-regulation of the frontal attentional network, information from the unconscious processing enters into the working memory network.

Additionally, research has shown that working memory, temporal integration and sustained and directed attention are key cognitive functions that provide the underlying framework to compute even higher cognitive functions because they act as buffers, simultaneously maintaining *in-the-moment* information in consciousness and ordering it in space-time as associations proceed (Damasio 1990). Damasio suggests that a working memory buffer is critical for creative thinking because it allows for the retention of relevant knowledge while problem solving; it allows us not only to retrieve and create internal representations but also to actively hold, rearrange and restructure these representations. A crucial signature of creativity is the ability to manipulate concepts and parts of concepts to create new and surprising combinations from active representations held in working memory. A recent study indeed suggests that across trials musicians with higher working memory capacity perform significantly better creative improvisations than musicians with lower working memory capacity (De Dreu et al. 2012).

It is hypothesised that through long-distance phase synchronisation of electrical brain activity and neuronal clusters, the transient formation of a coherent macro-assembly that selects and binds multi-modal networks is possible. Such assemblies can be between different lobes or across hemispheres which are separated by dozens of milliseconds in transmission time (Thompson et al. 2004). Synchrony appears to allow the binding of sensory attributes and the overall integration of multiple dimensions of a cognitive act including associative memory, affective tone, emotional appraisal and motor planning (Damasio 1990; Varela 1995; Varela et al. 2001). All of these cognitive acts contribute to a musician's creativity and thus synchrony could be a possible mechanism to be analysed in order to find a signature for musical creativity (see section "Neural Correlates of Musical Improvisation").

Neuroscience of Types of Creative Processes

There are two commonly known types of creative processes: convergent and divergent thinking. Convergent thinking refers to finding the single best, or most often correct answer to a problem, leaving no room for ambiguity, i.e. answers are either right or wrong such as in riddles. It emphasises speed, accuracy, and logic, and focuses on recognising the familiar, reapplying techniques, and accumulating stored information. It is most effective in situations where an answer readily exists and simply needs to be either recalled or worked out through decision-making strategies. These strategies are often useful after an initial bout of divergent thinking which generates creative ideas by exploring many possible solutions in a spontaneous, free-flowing and emergent cognitive manner. With divergent thinking, many possible solutions are explored in a short amount of time, and unexpected connections are drawn.

Beeman et al. (2004) have found that participants working on a convergent problem showed burst of high frequency gamma oscillations (~40 Hz) over the right temporal brain areas, 300 ms prior to the moment of insight.

Well-explored functions of the frontal lobes include working memory, personality, mood, executive function and dynamic filtering; in short it is said to be the seat of thought. There is also evidence that frontal lobes might possibly play a role in divergent thinking, as the area plays a role in the ability to disengage and shift to new strategies as revealed by the Wisconsin Card sorting test (Weinberger et al. 1986) and the uses of bricks stated by creative subjects in the Guilford's Alternative Uses test (Carlsson et al. 2000). The frontal lobes also have strong connections with the poly-modal and supra-modal regions of the temporal and parietal lobes where concepts and knowledge are stored (Pandya and Kuypers 1969). These connections can therefore inhibit or activate portions of the posterior neocortex selectively and contribute to the divergent thinking required for creative innovation (Heilman et al. 2003) and allows domain-specific knowledge overlap (Gardner 1983).

Models of (Musical) Creativity

Of course, not all creative activities are of a problem-solving kind and can also make use of mental and thought models. There are two main kinds of performed musical creativity, *Interpretation* in Western Classical music and *Improvisation* which is most commonly found in Jazz and Indian Classical music.

Interpretation refers to the ability of the performer to interpret the composer's markings of dynamics, tempo and emotionality without changing the written score in their performance. *Improvisation* refers to the ability of the performer to change the structure of a musical phrase by modifying its key, melodic contour, the very notes, rhythm and time signature. The improviser may seem to have an unlimited set of choices but they are not necessarily unconstrained. Musical improvisation does implicitly depend on a specific musical style, and therefore, is constrained by the rules and constraints of that musical style e.g. orthodox modern jazz (Johnson-Laird 2002). It is conceptually similar to language as a speaker can produce an infinite number of possible sentences with a finite number of words and finite set of syntactical rules.

Improvisation also involves a wide range of complex cognitive processes along with strong emotional components as "the improvisers must effect real-time sensory and perceptual coding, optimal attention allocation, event-interpretation, decision making, prediction, memory storage and recall, error correction, and movement control, and further, must integrate these processes into an optimally seamless set of musical statements that reflect both a personal perspective on musical organisation and a capacity to affect listeners" (Pressing 1998). In fact, improvisation can be likened to real-time composition where a musical phrase is entirely generated from the mind perhaps with a theme or visual imagery which is a form of mental model, thus simulating processes in the real-world.

The Geneplore model (Finke et al. 1992) is one such mental model that divides creativity into a generative and exploratory phase. Within the generative phase, the construction of mental representations, called pre-inventive structures, occur with certain specific properties. In the exploratory phase, these properties are used to elucidate a better sense of the pre-inventive structures. Johnson-Laird elaborates on this further, proposing a mixture of multi-stage neo-Darwinian and neo-Lamarckian algorithms as a model for jazz improvisation, where the former uses *some* criteria to guide the generative process and the latter uses *all* the criteria acquired from experience to govern the generative stage. His theory proposes that these strategies are split between the generation of chord sequences requiring working memory for intermediate results (multi-stage neo-Darwinian algorithm) whereas the improvisation of melodies would have to fit the chord sequences and can be generated as rapidly as the musicians fingers would allow (Neo-Lamarckian algorithm).

Another model is Boden's *Improbabilistic* and *Impossibilistic* forms of creativity (Boden 1990), where the former involves novel combinations of the familiar, that is, associative or analogical thinking and the latter refers to when the fundamental rules of a conceptual or problem space have been violated, the space itself must change hence ideas that could not have been generated before and are radical, can emerge. For the purposes of musical creativity, *Interpretation* could be likened to the *Improbabilistic* model and *Improvisation* could be likened to the *Impossibilistic* model.

Flow Experience in Music

Most of us, musicians or naïve listeners, have experienced a period of focused concentration associated with an intense positive experience whilst performing or listening to music (Diaz 2013). This type of psychological state is termed *Flow* (popularly known as "being in the zone") by positive psychologist Csikszentmihalyi (1990); it describes an optimal experience associated with an intensely positive emotion of being fully engaged in the successful pursuit of an activity. Flow experience is assumed to be closely related to creativity (Csikszentmihalyi 1996). Furthermore, due to its intrinsically rewarding nature, flow is often considered to be the primary motivating factor for a training musician to invest a disproportionate amount of time in learning musical skill and meeting greater challenges.

Flow is characterised by nine dimensions as follows (Csikszentmihalyi 1990): a balance of challenge and skill, merging of action and awareness, clear goals, unambiguous feedback, full concentration on the task, sense of control, loss of self-consciousness, transformation of time, and extremely rewarding.

Flow has been positively related with high achievement of music performance (O'Neill 1999), quality of group compositions (Sawyer 2006), meaningfulness of songs created during therapeutic songwriting (MacDonald et al. 2006), reduction of performance anxiety (Fullagar et al. 2013), and emotional (more than cognitive) aspects of subjective well-being (Fritz and Avsec 2007).

As the flow state is highly emotionally rewarding, and music is an effective medium of communicating emotions, achieving a flow state during creative music performance may be related to the intrinsic ability to effectively deal with (musical) emotions. Recently we (Marin and Bhattacharya 2013) have explored this issue by investigating whether there is something inherent in the emotional personality of the professional musicians that could explain why some musicians experience flow states more easily and often compared to others. We studied 76 professional pianists and evaluated their flow experience in piano performance and measured their trait emotional intelligence, a personality trait defining the ability to effectively process and manage emotional information (Petrides and Furnham 2001). We have found that flow experience can be significantly predicted by the amount of daily practice and trait emotional intelligence (Marin and Bhattacharya 2013). This is in line with some recent evidence that individual proneness to flow experience is associated with personality traits that are under dopaminergic control and be represented in low impulsiveness, more openness, stable emotion and positive affect (Ullen et al. 2012).

The neuronal correlates of flow experience during musical performance is not yet properly investigated but Dietrich (2004) has suggested a theoretical framework of flow experience based on explicit-implicit distinction. At the initial stages of acquisition of a skill (i.e. musical in this context) explicit processes are involved with associated activities at the medial temporal lobe and frontal attentional network, promoting cognitive flexibility. Once the skill is learned, implicit processes are more involved with associated activities of the subcortical structures like basal ganglia. The optimal flow experience is achieved when the practiced skill that is represented by the implicit system is exercised without any interference from the explicit processes that are temporarily suppressed; therefore, a necessary condition for flow is suggested to be the transient deactivation of the prefrontal network exerting attentional and cognitive control (Ulrich et al. 2014).

Neural Correlates of Musical Improvisation

Neuroimaging studies on musical creativity have predominantly focused on aspects of jazz improvisation, as jazz is a contemporary Western musical form in which improvisation plays a paramount role, and being tonal in nature is easier to analyze for its music content.

Limb and Braun (2008) performed a seminal fMRI study in which jazz musicians are asked to memorise a piece of music (whether low or high in complexity) that they would either play with a pre-recorded jazz quartet or allowed to play freely during improvisation but using the same chord structure of the original composition and the same auditory accompaniment as the basis for improvisation. The principal finding was that improvisation, as compared to the production of over-learned musical sequences, was consistently characterised by a dissociated pattern of activity in the prefrontal cortex, specifically the deactivation of the dorsolateral prefrontal cortex and lateral orbital frontal cortex with focal activation of the medial prefrontal cortex. Interestingly the transient deactivation of DLPFC, the center of executive functioning and control, during spontaneous musical improvisation is aligned with the earlier neurocognitive framework of flow experience (section "Flow Experience in Music"). Note that as the study used accompaniment as a basis for improvisation, the feel is more towards interpretative goal-oriented creativity. Furthermore, the significant role of memory cannot be ruled out either.

In another fMRI study, Bengtsson and colleagues (2007) investigated musical creativity, especially piano improvisation, by employing three experimental conditions. In *improvise* condition, pianists (all males) were instructed to improvise on 8 bars of a visually presented piece of music; in *reproduce* condition, the pianists had reproduced their earlier improvisation from memory, and in *free improvisation* condition, they were asked to simply improvise but without committing to memory. To isolate the neural correlates of musical creativity, the authors first compared the brain activations during improvise with those during reproduction, and identified those differences in the comparison above that are common to activations during free improvisation. A broad network of brain regions, including sensorimotor cortex (presupplementary motor area, the rostral part of the dorsal premotor cortex), superior temporal gyrus, and the prefrontal cortex, specifically the right DLPFC were found to be associated with the piano improvisation. Other fMRI studies on the generation of musical structures have identified similar (and even a broader range of) brain regions including the language areas (Parncutt 1994).

Although pioneering in nature, these fMRI studies may suffer from one principal limitation, i.e. poor ecological validity. Inside a fMRI scanner, the pianists are asked to play whilst lying down, which might have involved different motor skills and cause different perceptions and reactions than usual, as pianists usually perform sitting upright. Interestingly, EEG does not pose such limitations, and here, we briefly describe some of our own experimental findings on musical creativity in pianists.

In a pilot study, we recruited 5 pianists (1 female) from a classical background with at least Grade 8 level (minimum requirement for a university degree in music) with four of them at early stage careers (age range of 20–30 years) and one highly skilled professional (age of 45 years). They were presented with 20 classical musical excerpts (Fig. 1) and given a variety of instructions which included to *play* the excerpts exactly as presented and to *improvise* freely on some element of this excerpt. All musical excerpts were unfamiliar and varied in terms of tonality, rhythm and melodic contours so as to avoid the effect of memory and related bias; this was ensured by including classical excerpts that were not used in any

Fig. 1 **A** range of musical excerpts that were used as stimuli in the pilot study. Note the variety of time signatures, rhythms, tempi, tonalities, keys, dynamics and melodic contours

degree syllabus (after consultation with Richard Dickins, conductor of Imperial's Symphony Orchestra and member of the Royal College of Music and Associated Boards of Music).

We recorded continuous EEG from 64 electrodes and analysed the functional co-operation between different electrode regions by a measure of phase synchrony, PS (Varela et al. 1999). PS values between all possible electrode-pairs were calculated, and averaged across pairs. Subsequently, the mean PS values were thresholded to examine the periods of higher synchrony in the top quartile (25 %). These periods could be termed as 'perseverance', and their duration was measured for the improvisation and play conditions (Fig. 2). These specific higher synchronised events spanned two orders of magnitude in timescales suggesting a degree of scale invariance through a possible observed power-law. Note that due to the limited sampling frequency of 512 Hz (though it is a standard sampling rate for EEG recording), there were not enough sample points in smaller time periods to investigate over a broader range of time scale. Nevertheless this tendency towards scale invariance in pair-wise synchrony could be a putative characterisation for musical improvisation.

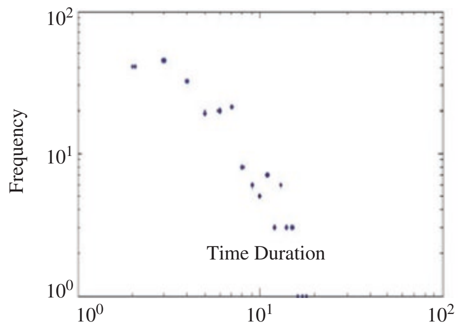

Fig. 2 Two log scaled plots with the *y*-axis signifying 'frequency' and the *x* axis the time duration 'persevered' above the threshold. *Left panel* This is the plot for the condition of 'play'. *Right panel* For the condition of 'Improvisation' which shows a slight tendency toward a heavy tailed distribution

In our next study, we recruited 8 pianists (4 female) and presented them with 20 musical excerpts (10 classical and 10 jazz) and instructed them to *improvise* freely, *interpret* as per the composer's markings and *play* just the notes written without any affect. Like earlier, all excerpts were unfamiliar and this was ensured by including classical excerpts that were not used in any degree syllabus and jazz excerpts that were freshly composed for this study. All excerpts were standardised to accommodate both jazz and classical backgrounds of which there was an equal split. Participants were given a fixed amount of time to mentally think about the instruction to either improvise or interpret the excerpt and their actual performance was not constrained by any time limit. Continuous EEG signals were recorded by 64 electrodes and analysed by the source localisation software, sLORETA (Pascual-Marqui et al. 1994) to identify the brain areas associated with improvisation or interpretation.

sLORETA allows an accurate linear inverse mapping of the electrical activity recorded at the scalp surface onto deeper cortical structures as the source of the recorded activity. It uses a quantitative neuroanatomical digitised Talaraich atlas of the cortical structures in the brain provided by the Brain Imaging Centre, Montreal Neurological Institute. The cortex can be modeled as a collection of volume elements (voxels) in this digitized Talairach atlas similar to the units found in fMRI. It stands for standardized low resolution brain electromagnetic tomography and according to creators, Pascual-Marqui et al. (1994), sLORETA yields images of standardized current density with zero localization error.

EEG/MEG surface scalp measurements do not contain sufficient information on the three-dimensional (3D) distribution of electric neuronal activity for deeper cortical structures as the implication is that the measurements could be due to many different distributions of cortical electrical generators. However, further research suggests that extracranial measurements of EEG and MEG are generated by cortical pyramidal neurons undergoing post-synaptic potentials (PSPs) (Pfurtscheller and Lopes Da Silva 1999). The magnitude of experimentally recorded extracranial signals, at any given time instant, is due to the spatial summation of the impressed current density induced by highly synchronized PSPs occurring in large clusters of neurons oriented perpendicular to the cortical surface.

Ideally, it would be optimum to utilise both the temporal resolution afforded by experimentally recorded extracranial signals and localise the brain activity source of these signals by solving the inverse problem (computation of images of electric neuronal activity based on extracranial measurements). Given that brain activity occurs in the form of a finite number of distributed “hot spots”, using the principles of linearity and superposition would allow the calculation of an instantaneous, distributed, discrete, linear solution capable of exact localization of point sources.

There are N_E instantaneous extracranial measurements and N_V voxels in the brain. The voxels are determined by subdividing the solution space uniformly, which is taken as the cortical grey matter volume or surface. At each voxel there is a point source, which may be a vector with three unknown components (i.e., three dipole moments), or a scalar (unknown dipole amplitude, known orientation). These EEG-based experiments considered here correspond to $N_V \gg N_E$.

If the orientation of the three dipoles is not known, the LORETA inverse solution corresponds to the 3D distribution of electric neuronal activity that has maximum similarity (i.e., maximum synchronization), in terms of orientation and strength, between neighboring neuronal populations (represented by adjacent voxels). If the orientation is known but with an unknown dipole amplitude, the cortical surface can be modelled as a collection of surface elements with known orientation. LORETA can accommodate this neuroanatomical constraint, and find the inverse solution that maximizes only the synchronization of strength between neighboring neuronal populations. It does this using the current density estimate given by the Minimum Norm Inverse Solution (Hämäläinen and Ilmoniemi 1994) but to solve the systematic non-zero error that this has traditionally been associated with, sLORETA infers localization based on images of standardized current density with a method that is unique to it.

We use sLORETA as a tool on the EEG data as a detector of activity difference between different conditions and participants. More technical details can be found in the creator’s paper (Pasqual-Marqui et al. 1994).

Figure 3 shows the improvisation-interpretation contrast during thinking and displays an increased activation of left inferior parietal lobule, supramarginal gyrus (Brodmann area, BA40) which has previously been related to an insightful strategy in verbal creativity (Betchereva 2005). This area has been linked to phonological and semantic processing of words (Stoeckel et al. 2009), thus this finding may support the findings of Brown et al. (2006) who found an overlap of areas for melody and sentence generation.

One of these areas of overlap of music and language is BA6 and is found in our study for both improvisation-interpretation and improvisation-play contrasts during the actual performance (Fig. 4). Brown’s study found a bilateral activation

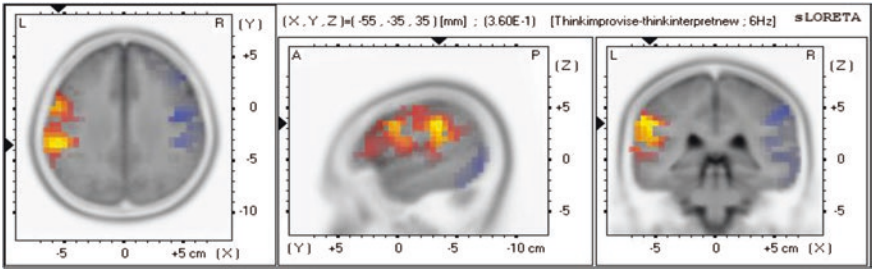

Fig. 3 Comparing the tasks of thinking about improvisation to thinking about interpretation shows a positive modulation in the left BA40. This may imply phonological and semantic processing for improvisation and point to a different mental imagery required, in the form of an 'insightful' strategy

which includes the left hemispheric language areas, whereas in our study, a hemisphere-specific positive/negative modulation activity pattern of BA6 and BA9 presents itself dependent on the time evolution of the task such that in the middle 4 s and last 7 s segments of the improvisation and interpretation tasks, there is a right hemispheric positive modulation concurrent to a left hemispheric negative modulation. This was also accompanied by a negative modulation of the left hemispheric BA42/45/46 in both the last 4 s and 7 s (see Fig. 4).

There is in fact a temporal evolution in improvisation (Sawyer 1992) and interpretation (Dean and Bailes 2010), and the particular global structure of the music that the performer may create or phrase (Cooper and Meyer 1960), which is thus reflected in these findings of large-scale brain activity.

Interestingly, the negative modulation in the left dorsolateral prefrontal cortex (BA9/45/46) for the improvisation-interpretation contrast was hemispherically opposite to that found by Liu et al. (2012) in their recent study of lyrical improvisation. This could be due to the non-verbal nature of our improvisation task and the fact that we were comparing this to a second creative task of interpretation. This latter task may be similar to their lyrical improvised task as they are both goal-oriented.

The positive modulation of BA 6 for the improvisation-interpretation contrast has further implications as this area, which corresponds to the preSMA and dorsal premotor cortex, was recently found in the positive association of improvisation training to functional connectivity during improvisation compared to rest (Limb et al. 2014). Limb corrected for classical training whereas our study involved both jazz and classical musicians performing both the improvisation and interpretation tasks. This implies the association of this brain area to the nature of the improvisation task itself despite other training, however the more experience the performer has of improvisation, the association is further strengthened. Additionally, our pilot study investigated the perseverance of higher global phase synchrony which underlies functional connectivity and this was found to be greater and more scale invariant within a range of timescales, for improvisation compared to play tasks, which is further supported by Limb's study.

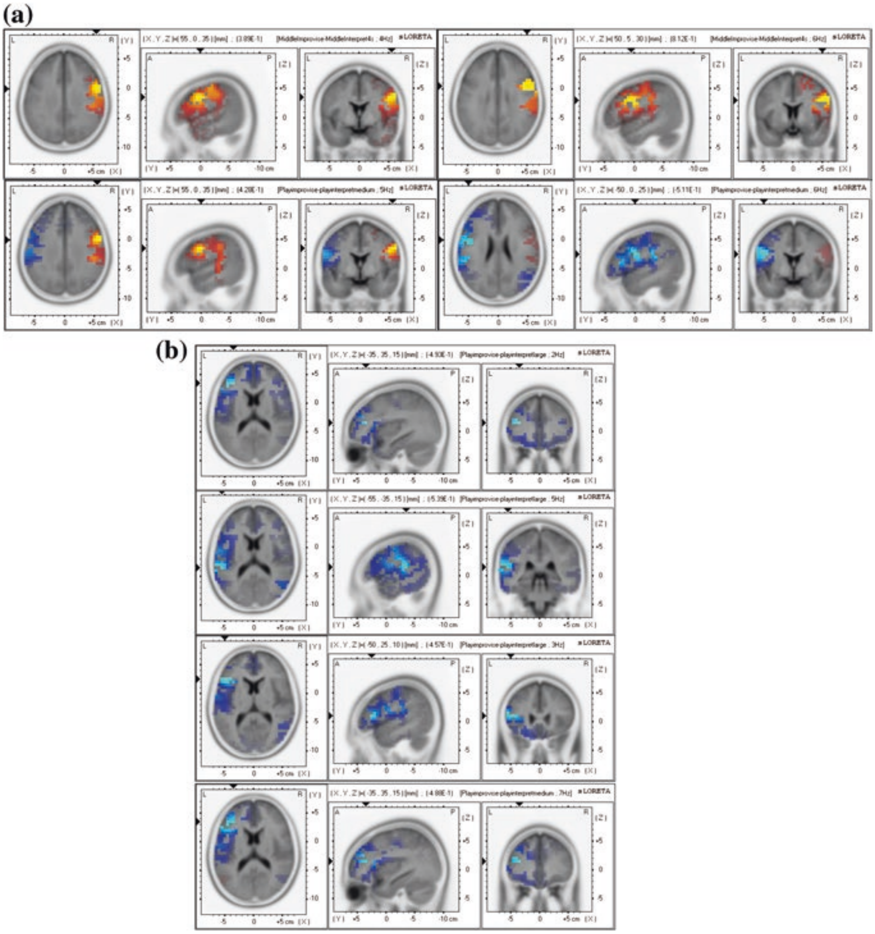

Fig. 4 Source profile for improvisation versus interpretation contrast. **a** The *first row* depicts the positive modulation of the right BA6 and BA9 during the middle 4 s segment. The *second row* depicts the last 7 s segment where the pattern of concurrent negative modulation in the left BA 6 and 9 start to emerge. **b** In order of rows are the negative modulation of BA42, 45 and 46 in the last 4 s segment and finally a maintenance of negative modulation in the BA46 in the last 7 s segment. This indicates a consistent pattern of positive/negative modulations in the pre-SMA and DLPFC during the middle and last sections of our 'Improvisation' task which is less goal-oriented than our 'Interpretation' task

A recent study investigating the interactive improvisation of 'trading fours' in jazz (Ullen et al. 2014), also identified the bilateral activation of the SMA supporting Brown's study. The study also showed an activation of the Broca's and Wernicke's language processing areas in the left hemisphere as well as a comparative increase in their right homologues. This presented differently in our results, of a left hemispheric negative modulation in BA 42/45/46 (which corresponds to these language areas), though they also found a bilateral anti-correlated connectivity in these areas. The main focus of Ullen's study was the bilateral deactivation of the angular gyrus leading them to propose that there was no overlap in the semantic processing of music and language and only a syntactic one. If the word 'semantic' is examined closely, the role of the angular gyrus is linked to metaphor processing (Ramachandran and Hubbard 2003) and corresponds to BA 39 whereas our findings presented a positive modulation within BA 40 which is linked to the direct semantic relation between two simultaneously presented words (Stoeckel et al. 2009), though the implication of its involvement is thought to be due to an automatic phonological processing of a word even if the task does not require it. In fact, Ullen's study also reports a bilateral activation of the supramarginal gyrus (BA 40). Furthermore, our findings presented in participants during an improvisation-interpretation contrast rather than differing complexity of improvisation tasks and also during the mental imagery stage when participants were asked to 'think' about performing rather than actual performance. Our improvisation task was also more 'free' as there were no tempo constraints without a rhythmic accompaniment. This could have led to or allowed participants to create more of a stand-alone semantic structure, developed as a presentation within their improvisations that required no shared syntactic musical rules and even allowed individual rule-making. Importantly, Ullen's study examined *interactive* generative behaviour in the improvisation task through the 'trading fours' technique, giving it a more conversational and communicative framework with shared syntactic rules. Finally, their study looked at a pure jazz musician cohort whereas our participants were not only an equal mix of classical and jazz, but also of male and female; the gender differences in the neuroscientific basis of musical processing remains unexamined.

Subsequently in our analyses, participants were divided into two groups (4 in each group), Jazz or Classical, based on their academic training and performance experience and preferences.

For both the tasks of improvisation and interpretation, there was a negative modulation of BA 18 between the jazz—classical contrasts of participants (see Fig. 5). This area has been attributed to visual saccades (Darby et al. 1996) and also to mental imagery during music perception of pitches (Platel et al. 1997).

The activity pattern of concurrent right hemispheric positive modulation and left negative modulation in BA6/9 and 45/46 is found only during improvisation-interpretation contrasts in the middle and last 4 s in Jazz background participants. This suggests that other instances of this activity patterns are due to participants' Jazz pedagogical training which is in keeping with both the Limb and Ullen research.

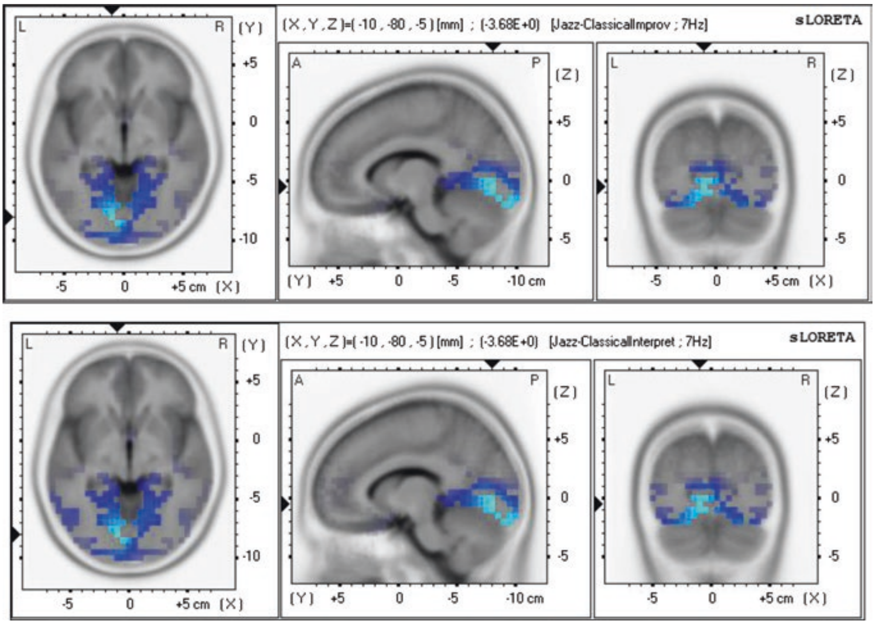

Fig. 5 Negative modulation patterns in BA18 for both tasks of improvisation and interpretation between participants of jazz and classical backgrounds. This indicates that musicians with a classical background adhere more to the visual musical score (visual saccades) and use a different form of mental imagery as compared to musicians with a jazz background

Conclusion

In this chapter we have provided a brief overview of our current understanding of the neurocognitive architecture of musical creativity with a special emphasis on musical improvisation. Music-making is predominantly human, at least at this level of complexity and aesthetical experience. So a proper understanding of musical creativity leads to a novel and critical insight of a core component of human cognition. Empirical neuroimaging research on musical creativity is at its infancy and the limited number of available findings does clearly suggest that musical creativity cannot be localised to a single brain region nor confined to a single cognitive process. This is not unexpected considering the omnipresence of brain networks across tasks and the multifaceted nature of musical creativity itself.

Although this chapter focusses mainly on the performative aspects of musical creativity such as improvisation, another aspect of creativity is planned musical composition which due to the limitations of neuroimaging techniques available, is not adequately researched in the neuroscientific field.

Future research and advances in technology will hopefully further reveal and refine the characteristics of the structure and dynamics of the network underlying both performed and planned musical creativity and also its possible modulations with training, personality, gender, musical style (e.g. non-Western repertoire), collaborative interaction and aesthetical experience.

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Creativity and Art Education Gaps Between Theories and Practices

Jill Journeaux and Judith Mottram

Creativity and the Education of Artists

This chapter reports on a study within the fine art field on whether models of creativity as described in other fields are reflected within university studio art teaching. As this discussion is located within a multi-disciplinary collection of essays on creativity we first highlight two points reflecting assumptions about artistic creativity held beyond the field and based on historically located perspectives no longer operational within the field. The first is the idea that art might have a concern with beauty, and the second that creative capabilities are a special gift. Both would be contested to varying degrees within the world of art in the university or contemporary gallery. We also note a range of different perspectives on creativity within the fine arts, drawing on assumptions not necessarily framed by an understanding of contemporary thinking about creativity.

In the 1990s, coming into art education with some familiarity with current thinking on organizational behavior, Mottram was surprised that theories of creativity were unfamiliar to colleagues. As artists were then being seen as key players in the "creative industries" so vital to city regeneration (Landry 1995), it was anticipated their education might be informed by contemporaneous thinking on creativity.

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There has however, been a pronounced hermetic tendency in university art education in the UK, with regards to theory from other fields. Perhaps because of the unwritten valourisation of the role of the artist within society, with the right to pass comment on and to eschew convention, how we teach has been left to us with no sense of any obligation to look at other theory. The result is that scrutiny of creativity is little known to the field which generates the creative practitioners of the future. Thus we have a circumstance in which clarification might be of use to all parties interested in the field of creative practice in the fine arts and the understanding of creativity from a multidisciplinary perspective.

Interrogation of this topic could provide a platform for review of the investment in creative education, given claims made for the centrality of creativity to innovation, prosperity and well-being. Towards this end, we first give a brief account of how art education reached the current position and the extent to which this relates to models of creativity. In essence, the accounts of past practice are some of the key documents that indicate how the field views creativity. We then describe how we have explored practices, perceptions, values and beliefs in the fine arts field and report on recurring themes. Our conclusions note the specific aspects of practice and values that accord or otherwise with models of creativity from psychology.

The Historical Context of Art Education

We focus on the education of fine artists in the UK because the establishment of publicly funded schools of art and design in the 19th century moved fine art education in this country away from the atelier system that had been dominant for four centuries. This shift, prompted by our early industrial revolution, reflected a change in purpose, from the development of skilled artists and artisans to serve the needs of wealthy patrons, the state and the church, towards serving the larger industrial and economic requirements of the nation (Quinn 2012). There have been pockets of pedagogic innovation elsewhere in the 20th century, such as at Black Mountain College, Nova Scotia College of Art and Design and CalArts. Black Mountain's emphasis on the student as at the centre of the curriculum presaged current student-centered curricula, as did the CalArts emphasis on independent artistic work. While the libertarian basis of these innovations is an important topic in relation to conceptions of artistic identity and world view, we constrain our focus to methods which have remained in use through such innovations.

The training of artists has been based on a model of learning through doing for centuries. While the focus on the depiction of the human form has changed over time, the supremacy of experiential over theoretical learning has remained central. The Carracci, who opened their Accademia degli Incamminati in Bologna in 1582 (Robertson 2008), established life drawing as the key discipline for all aspiring artists. Working in the life room remained central to the training of artists in Western Europe and the USA until the end of 20th century when it was challenged by less need for the skillset, and by feminist art historians such as Nochlin (1971) and Pollock (1996).

Central to learning through doing is the practical project which involves the student responding to a ‘brief’ or specification set by staff, which mirrors the tasks of the professional marketplace in working to commission or order. The place of projects was re-enforced in the UK in the 20th century by the establishment of a centrally examined national curriculum, the National Diploma in Design (NDD 1946–1961), with project briefs set nationally. During the post-war period (1945–1960), there were debates in the UK about the purpose of art and design in society and the best way to construct an educational experience. The art critic Sir Herbert Read and the painter Sir William Coldstream lobbied for changes to the art school curriculum. In 1960 the *Coldstream Report* (Her Majesty’s Stationary Office 1960) enabled schools to design their own curriculum for the new Diploma in Art and Design (Dip AD) for the first time. The use of project briefs generated by individual studio staff has continued as a core component of first year undergraduate fine art education until the present.

The activities prescribed by project briefs were influenced by the carefully constructed and challenging curriculum of the Bauhaus (Itten 1975), which stressed the combination of expression with intellectual framing. This was partly a response to Richardson’s (1948) emphasis on the individual creative child rather than upon the work they made. Beth Williamson’s review of recent developments in British art education (Williamson 2013) quotes Maurice de Sausmarez’s observation that:

> there is in art theory today a thinly disguised conspiracy against the intelligence, resulting from an arbitrary splitting of consciousness into intuition and intellect… no one can estimate how intuition and intellect are disposed in creating a work of art.

Ascott (1964) recounted of a set of projects from a Dip AD course, that

> in the first–year course, the student is bombarded at every point with problems demanding total involvement for their solution. Ideas are developed within material limitations and then in the abstract. For teachers, the formulation of problems is in itself a creative activity.

Projects have been described as “an established and universal vehicle used by tutors to teach and for students to explore studio curriculum agendas in art, design, media and communication” (Blair 2008). In the period in which our interview respondents practiced as teachers in UK art schools, 1970–1995, projects were structured and developed by staff in order to present a range of challenges to students. The subjects of projects included working from observation, generative strategies, or practical skills, like color mixing. Our understanding was that one of the main purposes of project-led curricula was to introduce students to the field, establish that the discipline was more important than the individual studying it, and to clarify the need for the student to understand a discipline before being able to make any contribution to it.

Since 1970 the centrality of the core elements of drawing from life and the project has been eroded. Various factors have impacted upon art practice and education: the emergence of conceptual art, the development of digital technologies, the internationalization of the art market, and the introduction of "institutional" theories of art (Dickie 1971) to encompass anything that was labeled art as art. Together they appear to be producing shifts in art practice and education, effectively dislocating 400 years of traditional practices. *The Second Coldstream Report* of 1970 set up one of the key conditions for this change by stating that it did not believe fine art study should be defined in terms of media, but that "studies in fine art derive from an attitude which may be expressed in many ways" (Her Majesty's Stationary Office 1970). This led to the gradual decline in courses that focused on a particular media, like painting, in favor of more all-encompassing courses covering all fine art media. The core change here perhaps pre-figures what seems to have taken place: the move from creative engagement with a discipline, to being a creative producer, which has been re-enforced by the recognition in the UK in 1997 of the contribution of the newly named creative industries to the national economy. A similar shift is now happening in other countries, most notably in China.

Identifying Common Ground

Over the past 50 years creativity has become a topic of interest to disciplines from psychology to artificial intelligence. Amabile (1996) gave a succinct summary of studies within psychology as having been focused on the characteristics of people known to be creative and the variables of personality and intelligence. She noted the absence of scrutiny of "creative situations," drawing a distinction between a notion of "circumstances conducive to creativity" and Simonton's work on the sociocultural influences on creativity (1975, 1977). Work on the conditions or resources for creativity, such as covered by Lubart and Sternberg's "investment theory" (1995), does touch on this notion of circumstances. From artificial intelligence, the distinction between normal or "personal" creativity and that which leads to paradigmatic shift, or "historic" creativity, is made by Boden (1990). She also distinguishes between innovation as requiring critical evaluation and novelty that is "merely intriguingly crazy." What is emerging is a picture of creativity as drawing from normal human psychological resources as opposed to from talent or special giftedness.

When reflecting on the values implicit in the teaching approaches common in European art education over the past 400 years, several models from the study of psychology have particular resonance. Many authors have made the case for subject knowledge as a vital component for creativity: Lubart and Sternberg (1995), Smith et al. (1995), Weisberg (1999), and Csikszentmihalyi (1996). For example, Csikszentmihalyi identifies the requirement for "immersion", and Weisberg (1999) describes this as "internalising what has already been done." This is reflected in generic expectations of degree-level study and in the values the authors experienced themselves as students and have enshrined in their teaching. The 2008 UK

Quality Assurance Agency Benchmarking exercise (QAA 2008) notes the importance for art students to "study the works of other practitioners past and present to locate their practice in an evolving historical context".

The emphasis on drawing from life accords closely with the idea of "deliberate practice" identified by Ericcson et al. (1993) and discussed in conjunction to knowledge by Weisberg (1999). This is distinct from the idea of play, which also emerged in the mid-20th century theorisation of creative expression (Richardson 1948; Milner 1950). In part, the emergence of a more intellectual approach to art education through the use of Bauhaus models was in opposition to the emphasis on playful expression coming from such developmental studies, but as we shall see, playful engagement has become a key strategy for stimulating innovation and progression in art practice.

The recognition of the parallels between the values and practices of art education and several of the theoretical models proposed from studies of creativity stimulated this chapter. Our hypothesis was that some key approaches to art education that were strongly reflected in the literature of creativity were now less prevalent within art teaching at university level. We also anticipated there might be aspects of practice not accounted for in the literatures of creativity that might warrant further scrutiny.

As well as parallels between practice and theoretical models, we noted minimal reflection on creativity in the literature of art education. James Elkins' book *Why Art Cannot Be Taught* (2001) argues that despite the Greek identification of art as a teachable *techne*, what exists in contemporary art education is more like an *emperia*, or a subject that cannot be taught, but has to "be absorbed, or learned by example". He acknowledges that: "Art teachers and students are in a bind. They do not teach or learn art, but they also cannot talk too much about the fact that they do not teach or learn art" (p. 104). This is reflected in volumes such as *Artists in the 1990s*, *their education and values* (Hetherington 1994), which focuses on the importance of artists delivering teaching not on what they were teaching. In *Issues in Art and Education* (Hetherington 1996) the focus was ostensibly on what might be taught, but focused more on the capabilities to be developed through study. Griselda Pollock's paper (Pollock 1996) was an exception, in her call to expose the "sedimented" ideologies of fine art education and to ensure that

> real knowledge of the art made by women and men, lesbians and gays, blacks and whites, Africa and Europe, China and America, Asia and Australia' was used to foster creativity. Otherwise, the curriculum would kill creativity 'by complacent indifference, ignorance and an utterly non-benign neglect. (p. 29)

Pollock's comments reflect appreciation that knowing about other art is vital for creativity. Susan Hiller touched upon another aspect of thinking about creativity shared beyond the field in her discussion about the art school as "the only site where right-brain functions are consistently trained and utilized" (Hiller 1996, p. 47). While she saw scope for art schools to be expanded and transformed into "a highly developed means of education in the conscious use of the visual, perceptual and intuitive modes of the right brain", this perspective has not had widespread traction.

Exploring Common Ground

To make our first incursions into exploring this territory, we identified two possible strands of data collection. The project brief was seen as a potential source of key information about the actual activities and values conveyed through art teaching in the UK university sector. We also decided to undertake interviews with experienced teachers as a second means of exploring how creativity might be embedded in their teaching.

Through purposive sampling we identified nine individuals, known to us, who were understood have used projects as a teaching method in their teaching careers of over thirty years in UK Fine Art degree courses. Three of this group was able to let us have photocopies or digital versions of undated documents they had used during 1980–2010. A total of 12 documents were received, amounting to 49 pages. Of these pages, 19 contained text that was pertinent to this study, with the remainder detailing generic information about course management or being title pages, The material collected ranged from a one-page project brief to a 'handbook' for the contextual studies component of a course. Six of the sample of teachers no longer had any of the project briefs they had used, or said they had never recorded them.

We were disappointed that more material was not available, but a senior colleague noted that it was rare for anything to be written down for project briefs until well into the 1990s, when higher education became more accountable to external agencies. As our search commenced it became apparent that academics had either internalized the activities and never written down briefs, or had jettisoned the material as they moved into managerial roles. The archive records of courses had not included documentation of such specific teaching events. At a later stage in the project, one of the respondents commented on this point that:

> When you compare notes with other people teaching in the same period we were all doing the same thing really. We used to all talk to each other on the train. You knew there was a whole canon of teaching projects that you knew about yourself, you had been taught yourself or you saw other visiting lecturers teach (Respondent 5).

We undertook a qualitative thematic analysis of the project brief material, with two researchers independently marking up the content of the project briefs and handbook, identifying words and phrases that pointed to specific over-arching ideas. We then agreed an exhaustive set of thematic strands that covered all material. The key findings were that the project briefs embodied the following themes: field knowledge, models of how to operate like an artist, practical strategies (including suggestions of how to use stimuli), models of how to think like an artist, and stipulation of what art does. Examples of the sorts of clauses or word strings fitting those categories are given in Table 1.

Practical strategies were the focus of 45 % of the project briefs and 20 % of the active clauses focused on field knowledge. We agreed less on the specification of clauses relating to operating like an artist, and 'thinking like an artist' was <5 % of the identified clauses.

Table 1 Categories and examples of clauses from fine art project briefs

Field knowledge	Staff have chosen these images in order to enable you to contextualise the practice and also gain inspiration from the work of practitioners
How to operate	What areas of specific interest are emerging from your experience—are they formal/material? Are they conceptual? Are they based on context?
Practical strategy	…will be introduced to a number of different approaches to drawing and visual research in order that they can reflect upon the relevance and function of drawing in contemporary art practice
How to think like an artist	The suggestion here is that our experience of an art work … is based around a process of reflection or a series of reflective moments
What art does	What references beyond the immediate experience are encouraged? And how is your subjectivity affected?

The second strand of data collection was a series of interviews with a number of the senior colleagues who had been asked about project briefs. We were able to arrange interviews with five of the nine, all of whom had 30–40 years teaching in the field, with some shared experience, covering in total about twenty UK art education providers. All but one was happy for the interview to be audio recorded. Initial discussion about availability for participation in the project gave a brief outline of the area of our interest. The participant information sheet described the project as looking to see if there are any parallels between the ideas embedded in methods or strategies for studio teaching in paint, sculpture, printmaking or fine art in the mid-late 20th Century with the models of creativity that developed in other disciplines in the late 20th Century. The interview schedule drew upon the initial analysis of the project briefs, literature reviews and our own experience of the field. The following topics were covered: how they became involved in teaching; approach or models used; views on important values or skills; whether they delivered projects, the nature of tutorials; changes as their career progressed; and whether they documented their teaching. We intentionally made no further reference to the topic of ‘creativity’ in the interview questions as we wanted to see if the respondents used the term. Each interview lasted about one hour and audio recordings were transcribed by a research assistant.

The following sections explore the data from the interviews and project briefs. We focus on two themes clearly identified from the analysis of the project briefs: practical strategies and field knowledge. We also discuss a theme that became crystallized as ‘being an artist’ from both sets of data; and a new dimension that arose in the interviews: space.

Practical Strategies

Our analysis of the project briefs revealed that practical strategies were the focus of <45 % of the content of the projects. The intention appears to be to present

Table 2 Phrases indicative of address to practical strategies for studio activity

PS1	The student will be expected to be imaginative in the use of materials
PS2	Using your sketchbook, attempt to find as many potentially interesting things to draw
PS3	You should consider viewpoints of both architectural structures and closely observed details of objects sculptures within each place…consider scale and respond to the physicality of the space. Look at one space in relation to another and consider different surface qualities and textures
PS4	The purpose of this piece of research is to enable you to further develop an analytical approach to the visual interrogation of a two–dimensional image, in this case a figurative painting, which can then be applied to other images which are similarly organised
PS5	You will be expected to actively pursue a programme of drawing activities and generate additional visual reference material that might be of relevance to your ideas and interests

approaches to stimulating powers of invention and breaking stylistic predilections formed through previous study. A selection of phrases indicative of this theme is shown as Table 2.

The assignment to the theme was arrived at through a process of increasing abstraction. For example, for PS5, the initial statement was interpreted as indicating "The need for discipline and input from a range of sources in feeding and sustaining a personal practice," then generalised as being about "how to build a personal practice." This then was grouped with other generalisations such as "how to learn from other art and artists," "how to make an interesting drawing," or "practical technique," as all indicative of practical strategies.

The intended aim of the briefs appeared clear, but there was normally a lack of specific directions, e.g. as in PS1, which expects students "to be imaginative in the use of materials." There is no indication in this brief of how this might be realised, apart from the intention of this being "in order to broaden a mark-making vocabulary." PS3 is an example of where more specific instruction is embedded in the brief: "consider scale… respond to physicality…look at one space in relation to another." In essence, the destination may be stipulated but the map was rarely given. The objectives appear to be to support the development of strategies to generate visual vocabulary, and range of style and visual language, to enable new approaches to realising ideas.

All of the interview respondents talked at length about projects they had delivered and noted the importance of generative strategies, which could deliver a volume of material and develop the appropriate discipline for self-directed working. Volume and hard work were prioritised to support reflective processes of learning through making. Momentum of making and volume were seen as central to establish a sustainable art practice. Respondent 4 recalled a one-week project in which each student was given a single matchstick and asked to generate 50 drawings from that match by the end of the first day. After the tenth drawing, the question became "where do I go now?" introducing "the idea of reflective, reflexive practices." In another project, two marks were made in the drawing room and the participating students were asked to draw what was between those two marks.

The respondent commented that both projects put the onus onto the student to generate thinking through practice as opposed to thinking prior to and separate from practice.

This focus on working through problems and emphasis on volume of production was also noted by Respondent 1, who said

> the volume of work was probably considerably more than today, people did spend hours in the studio… and I think that thing of moving a practice through momentum and setting in because you're doing a lot, that's a difficult thing to get over with people who haven't got grants, who've got part time jobs and all the rest of it,' and that 'students need to be making and doing for their ideas to come through.

Our respondents recalled projects aimed at developing articulation of abstract properties of media, rather than on external stimuli. Some projects were intended to equip students with a practical understanding of how colour operates in art. Respondent 2 recounted setting a project involving each student painting an 8 × 4 ft piece of hardboard with household paint, using just a single colour and "mindfully painting the whole surface taking it from hardboard coloured to colour." She recalled discussing this with a former student some years after who commented that it had taken years to understand what he had learnt from this "experience of colour as stuff." Another project involved asking each student in the group to bring in 20 highly coloured objects. A still life was then built with the objects, giving an arrangement of c.400 coloured objects to work from. Her reflection during the interview was that with hindsight, she was giving the students some parameters to work within but with freedom to improvise. She would now use these terms to talk about her own process. She had not consciously linked her practices as an artist to her teaching delivery, but looking back, she reflected that requests for her to deliver these projects may have recognised that what she did as an artist was felt to be a good model for students. When asked if anyone had told him what he should be doing when he was teaching, Respondent 5 recalled: "nobody said anything at all so I had to invent things."

Field Knowledge

The knowledge of what specific artists did, and the use of that as a building block for creative practice, was reflected in the project briefs reviewed. We classified 20 % of the material in the briefs as about field knowledge. Phrases drew attention to the external stimuli that other artists used, indicated the role of representational drawing or drawing from figure, and raised questions about who had made what, when, and why it might have been made that way. The clear sense here is about looking at other art, stressing there is more to creative expression than only drawing on individual experience. A selection of the phrases indicative of this theme is given in Table 3.

Table 3 Phrases indicative of address to field knowledge for studio activity

FK1	Staff have chosen these images in order to enable you to contextualize the practice and also gain inspiration from the work of practitioners
FK2	…on completion of this module the student should be able to show through the evidence of the work produced that they have increased their understanding of some of the key issues of observational life drawing
FK3	…the aims are to help to place the work that you do in the studio into a relevant context and to open doors about ideas, critical thinking and artists work. Artists and designers have never worked in a vacuum. The best are aware of contemporary as well as historic practice

The process of arriving at the categorisation of field knowledge was again carried out through a process of re-phrasing. In FK3, we identified the stress on knowing what others are doing and their reasons, and of the importance of a shared understanding of innovation in the field as a point of comparison for one's own work. As with the practical strategies, there is much unsaid in the project briefs. We presume that there may have been a discussion at some point about why the staff chose the reproductions referred to in FK1, but this was never made explicit nor was there a statement in the project brief that carried FK2 of what constitutes the key issues in observational life drawing.

From the interviews, the role of projects as promoting an informed, analytic and objective attitude to qualitative judgements of other work was clear. Respondent 3 recounted how one project was devised to require students to transcribe key 19th century paintings into drawings. The project, devised by Respondent 3 (and experienced by Journeaux as an undergraduate) arose because the staff team concluded that students had insufficient knowledge of art history. They built a large still life in the studio and then briefed students to make a drawing from that still life in the style of futurism, cubism, or impressionism. The students had to spend time in the library researching these art historical movements and then use this knowledge in their drawings to explore how those works had been made. Respondent 3 likened the rational for this as establishing the capacity to look at other art "the way the mechanic looks at an engine."

The interviews indicated that the interests and knowledge of the teaching staff informed the construction of the projects and reflected what the artist-educators perceived as being key questions for those wishing to become artists. The values underpinning projects were rarely explicit but seen as secondary to the collective acknowledgement of what students needed to know. Many staff used the project-led approach to address their perceptions of what had been missing in their own education. Respondent 3 described this as "checking out what you were thinking in your own practice with a bunch of students." Respondent 1 recalled "presenting twenty images to the students first thing every morning for a week, and of doing two lectures every week, covering every single 'ism' going." She commented that "actually students needed hooks to find ideas."

Table 4 Phrases indicative of address to being an artist through studio activity

BA1	Tutoring people making art is tutoring people in ways of thinking about art
BA2	The thematic content of the work will be entirely determined by the student
BA3	Processes of informed critical reflection; How are your responses informed by your intentions and ambitions
BA4	To develop an informed, analytic and objective attitude
BA5	Artistic ambitions/intentions > *declaring future ambitions*

Being an Artist

Knowledge of the field was presented as something that it was normal to be curious about, to be used in an everyday way to stimulate practical work in the studio. We saw the theme covering matters that related to the values accorded to practical strategies. There were embedded values of the demanding nature of studio practice needing discipline and self-determination and time spent in the studio, and guidance on how to operate as an artist. A selection of the phrases relating to this theme is given in Table 4.

The process of coding saw BA5, for example, as indicating the imperative for the student to articulate their artistic objectives. Developing clarity about one's creative intention was again seen as embedded in BA3. The briefs do seem to provide a template for the 'rules' of entering into the community of contemporary art practice. The briefs indicate the spiral of preparation, incubation, insight, evaluation, reflection and re-iteration, towards an understanding of informed judgment based on experience and knowledge rather than personal or emotive responses. The material reflects the processes of reflection in action identified by Schön in his 1983 book *The Reflective Practitioner*, which some teachers on fine art courses became familiar with during the 1990s.

The interviews reflected this. Respondent 2 recounts not having had the sense herself as a student of having been taught, but of coming to "recognize the importance of parameters that nevertheless allowed for real improvisation." She noted that "you look at the really good stuff in the past… you read the big books."

The core values of being an artist that we identified do have a degree of crossover with the sorts of activities identified as practical strategies. The most important of these was the notion of artists as having discipline, stamina and persistence, and the expectation that students would learn a working habit which involved them putting in long hours in the studio, to underpin a working pattern for after graduation. Respondent 1 recalled a senior tutor commenting: "you know if you're not painting full steam in your thirties or twenties, imagine what you're gonna be doing in your forties." Respondent 3 noted there were colleges where one might get students saying "you wouldn't be allowed to do that here," indicating quite a bounded sense of what was permissible. Respondent 5 noted that the absence of agreed principles in fine art "leaves them floundering. The paradox is that the less guidance and direction you give student the more support they need."

Space

Although there were indications of some constraints within the permissible, the fourth theme of note within the data we looked at we have labelled ‘space’. This is space in two key dimensions: what is unsaid, the absence of explanatory detail or specification, and also, the freedom given for different perspectives to be held, or for self-determination of focus, direction or activity.

We saw in Table 2 that project briefs lacked exact specification. This poses the question of where and how learning happened. In our experience as students and teachers we recall that the specifics were divulged in response to the particularities of the encounter with practical work. In individual tutorial or end of project critiques there would be identification of what seemed to have worked effectively or not, and through collective experience and peer group recognition, particular procedures rose to the status of strategy.

In our interviews, Respondent 1 recollected a strategy of leaving students to sink or swim, with it feeling “a bit random.” Respondent 3 recalled: “being cast adrift after some intro projects in the first year was really daunting. Some students never recovered.” Similarly, Respondent 1 had recounted “the projects were a coat hanger, by the second year students were making work under their own volition but within the framework.” The model of projects followed by student-initiated activity, was also noted by Respondent 2. He recalled that students were offered “an intense learning experience in the first year then left to their own devices.” And Respondent 4 notes that “nowhere where I worked was there a sense of teaching painting.” It was just: “you got the first year project but after that it was very much well you can make a stretcher, you know, you can get on with it.”

Respondent 5 stated that “fine art, if you are going to do it well is a dangerous occupation because you must be able to make mistakes and go down blind alleys and so on” and that “the teaching I experienced on pre-dip was based loosely on the Bauhaus and basic design principles, but by the time I was teaching I wasn’t thinking in those terms at all.” He describes the model he aspired to as “basically allow the unexpected to happen and go with that.”

The Studio and the Critique as Additional Conditions for Creativity

There are two topics, which hardly appeared within the project briefs and only in passing in the interviews, which have been the focus of some discussion in art education in relation to the conditions for creativity. These are the role of the studio space within the teaching environment and the in- or end-of-project critique.

While our interviewees spoke about the work ethic and the volume of work produced, they did not talk about the physical space in which it is produced. Discussion within the university sector has focused on this in recent years, as universities have explored space-charging models. The argument has been presented that: “if students are to make open ended explorations and tolerate ambiguity they will need to spend time sitting with work in progress” (Rogers and Kilgallon 2009). While this does not necessarily mean that the space is a shared space, Woolley (2013) has explained this further:

> Generations of students in the creative arts have been taught within a very particular learning environment, and largely according to the principles of the atelier system. It is perhaps inevitable therefore that at such a formative period in their development, undergraduates should absorb attitudes to the creative environment that they readily transfer into their professional lives.

What is at issue here is the importance of learning alongside colleagues, of testing and reflecting on values and judgments as they are formed. The working method that was expected within the shared studio environment was to leave aside distractions in order to reach a state of creative production in which the student learnt to forget themselves and the passage of time. Such a state might now be called ‘flow’, after Csikszentmihalyi (1996). He described the “optimal experience” of “painful, risky, difficult activities that stretched the person’s capacity” as flow. The project briefs we considered and the interviews did give a clear sense that hard work and immersion in activity was seen as a desired state, but there was no reasoning given for this. Cornock’s (1985) discussion of a methodology for art students identified the movement between “existential thrall” (the generation of visual ideas through making in the studio) and the emergence from this “to review and ‘discuss’ his work with himself.” The notion of flow would appear to equate with the thrall identified by Cornock. There has, however, been little discussion since this work on what actually happens in the studio. Since the period when Cornock was conducting his studies, the emphasis within the discourses of the studio have taken a more conceptual orientation, with fabrication and digital tools marginalizing the forms of tacit material knowing that characterized the situations that he was observing.

The studio critique is central to project-led teaching and embodies key attitudes of the community of practice. Critiques usually involve at least two staff discussing completed work or work in progress with a group of students. Each student’s work is considered by the whole group, and the extent to which the work meets the terms of the brief is considered. Variations of the model abound, with students or tutors taking the lead. Elkins’ chapter on critiques in *Why Art Cannot Be Taught* gives some examples from the USA, which communicate the nature of the transactions that occur within these encounters. There was a brief mention in one project brief we looked at which noted that the volume of work produced by students would be considered in the final crit. This gives a sense of the critique as a way in which the community will measure progress. Respondent 1 notes the purpose of the critique was “to have more than one voice. To get the students used to talking among themselves." Many accounts (e.g. Blair 2008) suggest that while a daunting process, the critique develops verbal skills associated with the articulation of purpose and evaluation and more general advocacy skills. It requires students to defend their work publicly whilst acknowledging failures and shortcomings. It enables students to observe staff using, and their peers developing, ways of reading art objects and thinking in, through and about art. It also allowed students to experience expert practitioners displaying confidence and dexterity in recognizing defects or successes, and in explaining them. The critique taught students how to think on their feet in front of art objects, to interrogate and deconstruct the object, and to weigh its value. This skill-set has become a core part of the contemporary conception of the artist and has contributed to the notion of artist as entrepreneur.

Mapping the Common Ground

On reflecting upon the project briefs, it is clear that there was little reference to creative thinking or creativity embedded within the specified tasks or narratives presented to students. We suggest that this is indicative of the unspoken status of creativity within fine art pedagogy. This is manifest through the ambiguous nature of some of the instructions given. Austerlitz (2007) notes that while "Students entering higher education often seek 'clarity' … a central, although largely unspoken, tenet of the art and design pedagogy would appear to be the centrality of 'ambiguity' to the creative process."

The small sample size of respondents and project briefs generated enough data from which to appraise the extent to which art education in the period from the 1970s through to the early 2000s reflected the models of creativity generated through studies in other disciplinary fields. In relation to the conditions required for creativity associated with, for example, Lubart and Sternberg's 'investment model' (1995). Although their discussion focuses on the strategies of pursuing ideas with growth potential, it is their articulation of the resources for creativity which was of interest to this study. We considered that the themes evident in the project briefs and interviews mapped quite logically across to some of the resources they identified, as shown in Fig. 1.

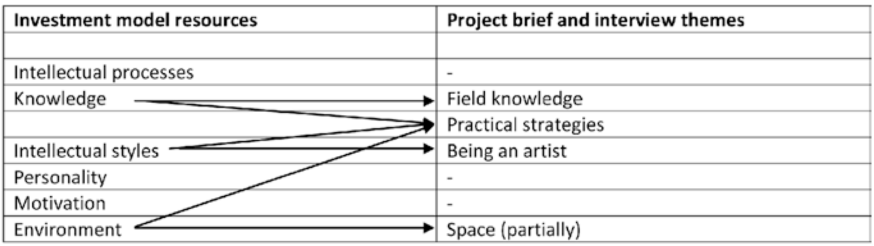

Fig. 1 Matching themes to investment model resources

While our research methods did not initially generate clear findings in relation to the intellectual processes such as problem definition, the nature of the project briefs would seem to set up a context for this. Our methods also did not elicit significant reflection on the personality type, of student or teacher, and only passing comment on topics that might relate to motivation. What was clear however, was the importance of knowledge of the field. This aligns closely to the emphasis given to knowledge in the comments of Pollock and Hiller referenced in Sect. 3, but we reflect how their perspectives have not been utilized in current pedagogical thinking in fine art pedagogy

Knowledge of the field and understanding of the practical strategies for practicing in the field were clearly very important aspects of the project briefs and were intrinsic in many of the responses from the interview respondents. This reflects the notion of immersion or exposure to a domain central to Csikzsentimihalyi's (1996) systems models of creativity. A particular point to note is the construction of identity as a player within the community who together identify when novel contributions are made. This is where the theme of being an artist, and recognition of how to operate as such, reflects the systems model emphasis on the role of various stakeholders in the field or domain.

Our study was working with teachers who also saw themselves as artists, but we were talking to them primarily about their role as teachers. We were deliberate in constraining our focus not to explore themes relating to the personality or motivations of our respondents as artists themselves, or their recollection of the personality attributes or motivations of their students. This decision was taken as we considered that the study of personality and motivation was beyond our subject expertise. Despite this, we can see that some of what we recognize as indicative of acculturation into the community of practice, through the privileging of ideas such as being responsible for your own content, being informed and critical, being disciplined and self-determined, could be viewed as indicative of personality characteristics or motivating values.

The cognitive styles of creative individuals identified by Amabile (1996) were recognized to have a good fit with the objectives of the practical strategies used within project briefs and recounted by our respondents. An indication of how the evidence from our study maps across to the Amabile cognitive style set is given in Table 5. The notion of breaking sets, whether perceptual or cognitive, would appear to be clearly present in the emphasis in project briefs and accounts of projects given by the respondents. There was a clear indication that the intent was to get students to do something that either made them look at some visual stimulus with a fresh perspective, such as the painting of a large board in a single color, or to use the brief to get them to think and act differently. With the 50 drawings of a match project for example, the student had to find ways to think beyond what they knew of ways to draw a very simple object, as well as keeping response options open. Suspension of judgment and use of wide categories can both be seen in the account of the project to make drawings of a presented still life according to a number of different artistic 'isms'. Here we have the requirement to work to

Table 5 Mapping of cognitive style in creative individuals to the practices and values evident through the project briefs and interviews

Amabile's cognitive styles	Practices and values in briefs and interviews
Breaking perceptual set	Looking differently
Breaking cognitive set	Making in other styles
Understanding complexities	Absence of explanation
Keeping response options open as long as possible	Working to 50 drawings brief
Suspending judgement	Working to brief
Using wide categories	Thinking in other styles
Remembering accurately	Recalling methods of other artists
Breaking out of performance scripts	Using practical strategies
Perceiving creatively	Drawing what was between marks

specification with no personal framing of the activity (counter to much of the other emphasis on self-determining practice), and a requirement to work with intellectually conflicting stylistic frameworks.

Our only points of contention would be whether there is any evidence of understanding complexity in the education of artists, or only of getting used to tolerating it. The absence of specification, of only giving the starting point, suggests something not as resolved as understanding. On the suspension of judgment, we note the role of surprise which is associated with the recognition of new artistic achievement, and the surprise which often accompanies assessment of success or failure to work produced by student artists. Cornock (1984) gives a good account of a student being 'stung' by a negative assessment of progress. It may be interesting to explore the relationship of judgment and surprise further. While judgment calls on knowledge, recognition of innovation requires both recall of what has been before with recognition of the new and surprising. The role of memory that is embodied in knowing how something was made was evident in the emphasis of learning through doing in both briefs and the interviews, but this distinct physiological experience may be somewhat different to the accurate memory of theory or fact.

We noted earlier how our interview schedules had purposefully avoiding using the term creativity or creative in any questions. One of the respondents did not use the terms creative or creativity at all in the session. Respondent 4 used it most frequently (seven times in the interview of just over one hour), with Respondent 2 and Respondent 3 using the term 5 and 3 times respectively.

Identifying the Gaps for Further Investigation

Our study has explored the teaching of artists in UK universities in the past 40 years and has shown characteristics which map across to models of creativity from other subjects. We saw how space or absence of specification was seen to give room for individual expression and that this worked in a context of a community of practice. Practical strategies, knowledge and values were all supported by working alongside each other, and those gaps were accommodated through this context.

This study has however, focused on a specific generation of respondents. There have been changes in the art education context since the periods referred to in the interviews. These have included the contraction of the space accorded to studio environments, less use of the project within curricula, and less time on critiques. The rise in digital tools has changed the skills required to generate effective representations and expanded arenas for creative practice. In place of a strong work ethic in the studio what has emerged is the theorization of the 'community of practice' by Wenger (1998). Although his work was originally focused on office workers, the notion of the community of practice has been seized upon by theorists of art and design education as an explanation of how ideas and practices are shared. It is not yet clear to what extent modeling of behaviors through the critique or the project brief can be accommodated by this framework.

There are indications that current thinking about art education at university level in the UK is changing. The 2014 National Association for Fine Art Education Annual Symposium (NAFAE 2014) included a series of presentations on current key issues in fine art education. The concluding discussion identified that the curriculum was becoming empty at its core, with so much attention paid to peripheral generic skills like professional practice, or team-working, there is now little room for anything else. The Paradox Fine Arts European Forum also looked at the contested legacies of practice, research and education in its 2013 meeting, published in a special edition of the Journal of Art, Design and Communication in Higher Education (Fortnum and Pybus 2014).

We conclude by restating there has been a gap in the studies of creativity to date, both by our own field and by the omission of scrutiny of educators of creative professionals such as artists. Our intention is to expand our enquiry to address the current generation of academics teaching fine art on undergraduate courses, both in the UK and beyond. We also hope this foray beyond our own field can stimulate future collaborative work with other disciplines who are also interested in creativity, with their different structures and conventions for progressing knowledge, which might underpin this initial exploration.

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Music Listening, Composition, and Performance: An Experience of Creativity for Education

Chiara Sintoni

Introduction

Overview of the Chapter

This chapter presents six case studies of beginner pianists engaged in processes of listening, analyzing, composing and performing associated with Mozart's Variations "*Ah, vous dirai-je, Maman*", for piano (KV. 300e (265)). The aim of the study was to facilitate the composing and performing of a single set of seven variations comprising the original and each of those of the six students. To that end, listening, discussion, analysis, exploration and knowledge building were the pedagogic competencies applied. The main goal of the study was to integrate those tools to combine logic and imagination for students to gain a comprehension of and a pleasure for the art of traditional 18th century style and genre.

More in details, the goals of the project were the following:

1. To favour the acquisition of listening competencies and capabilities that reinforce and enrich learning;
2. To promote the potentialities of verbal language in order to describe music, analyze it and understand its meaning;
3. To favour the acquisition of basic competencies in the creative use of musical elements and in composition, starting from the concept of *variation*;
4. To contribute to the acquisition of specific competencies in writing music;
5. To contribute to the construction and acquisition of gesture abilities and musical taste in piano performance.

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Background and Theory

The author begins with a scholarly and detailed description of variation technique and form drawing on both past and current literature linked to oratory (variation as rhetoric) and dance (variation as structure, deconstruction of theme). Presented also a recognized analysis of each of the Mozart piano variations.

The Study

The 4-fold activities plan:

1. construct of theme, techniques and devices through discussion;
2. guided listening to stimulus (Mozart 12 variations);
3. preparation for and writing of individual composition;
4. individual performing of composition noting individual gestural expression and interpreting.

The author presents a profile for each of the students' constructed and performed variation noting the use of repetition and alteration through the devices of pitch elaboration, transference and extension, rhythmic alterations, dynamics shifts and structural similarities and differences. In addition the author provides interesting comment on the students' choices of performing linked to gestural patterns in referring to the work of Davidson and Salgado Correira (2002) in the integration of gesture and intention to bring meaning and expression to performance.

Findings

The author presents a case to suggest that creative thought elicited through listening, analysis/discussion, composing and performing is a cognitive, integrative process based on knowledge building and flexible practice.

Background and Theory

The Concept of Variation in the Western Music Tradition Between Terminology, Art of Rhetoric and the Development of the Musical Form

The workshop started with a listening activity on a famous piano variations set by W.A. Mozart, (*12 Variations on* "*Ah, vous dirai-je, Maman*", in C major, KV. 300e (265); composed in Vienna between 1781 and 1782; published 1785) most likely written for one of Mozart's pupils and could be considered both a masterpiece of the art of variation and a series of exercises for mastering the various kind of touch in playing scales (i.e., a short set of subsequent musical notes, in upward or downward order), arpeggios (i.e., the subsequent execution of the single notes of a chord, from lower to higher, or vice versa) and ornaments,[1] which represent the basis of pianistic technique. The aim of the activity was to initiate a discussion with the young students in order to identify, analyze and comprehend the main features of *variation technique* and *variation form*—based on the compositional rules of the 18th century Western music tradition—which could be interesting and useful for the purpose of education. So the activity began by considering some notable features regarding the concept of *variation* under a terminological, historical and musical point of view: all these aspects are intertwined each other and are important to give a wide cultural perspective to the young students, so they are very useful in first step compositional training.

In the Western music tradition, the term *variation* has two meanings, which are related each other:

1. Variation is a *technique* of manipulating and elaborating a music material in many different ways (in this case it refer to the procedures displayed in the Western music tradition, and on Mozart's pianistic writing in particular);
2. Variation is a *music form* based on *repetition*—i.e., one of the most important principles in musical language—and on the *elaboration* of the music material; more exactly, for a larger part of its history, variation is based on a *theme* (or *subject*)—i.e., on a well shaped musical idea that can be manipulated in many different ways, according to the compositional rules developed in the 17th and 18th century in the Western music tradition—which is repeated several or many times with various modifications. A theme for variations, rarely shorter than eight or longer than thirty-two bars, should have musical features which make it *suitable* for a variation treatment—shortness, simplicity, usually a singing mood, well-shaped musical phrases, and so on—and it may be a melody, a bass line, a harmonic progression, or a complex of such elements.

Considered as a musical form, variations set in the Western music tradition from the 18th century on may be based on a *borrowed theme*—a popular, favourite or well-known melody (most commonly an operatic aria) or a harmonic scheme—or on an *original theme* (i.e., written by the composer himself). Mozart's variations set is based on a *borrowed theme*, a popular French air entitled *Les amours de Silvandre*; the theme is known to Americans as the children song (nursery song) *Twinkle, twinkle little star* and to Germans as the Christmas song *Nun kommt der Weihnachtsmann*.

[1]Ornaments are those conventional formulae of embellishment, often indicated by symbols, which proliferated from the Baroque period. The general understanding of SIGNS, symbols, terms and contemporary performing styles of ornamentation has varied greatly across time and place.

In the second part of the 18th century, variation is treated both as a *technique* and as a *musical form*; the term "theme and variations" makes its first appearance in Koch's *Versuch einer Anleitung zur Composition* (1793) and it becomes common in 18th-century musical praxis. In 18th and 19th centuries, sets of variations may be independent pieces, most often for solo keyboards—written for didactic aims and for *virtuoso* pianists—for orchestra and chamber music, or movements in a larger work such as symphony, piano sonata or string quartet (Sisman 2001). From the 18th century, variation is considered the first step in compositional training, according to some important composers, such as Johannes Brahms.

Some variation's musical features come straight from the art of rhetoric: rhetoric and variation share some features common to both, first of all the use of *repetition* and *ornament*. The correlation between rhetoric and variation, probably due to the rhetorical knowledge shared by composers and theorists, is based on the existence of rhetorical models for the structure of variation form, and on the concepts of *figure* and *figuration* as flexible tools for analysing variations; according to G.J. Vogler, «variations are a type of musical rhetoric, where the given meaning appears in different guises, with the distinction the boundary lines are much more rigorously determined in music than in oratory» (Sisman 2001). Models for the structure of theme and variations come from the *ars praedicandi*, the medieval rhetoric of preaching, especially from the widely circulated 16th century treatise by Erasmus von Rotterdam (*De copia* 1512), based on the necessity for developing the ability to say the same thing in different ways and drawing extensively on Quintilian's *Istitutio oratoria* (Sisman 2001). Erasmus provided the means of variety in a list of figures, then he demonstrated his theories by means of 150 variations of the sentence "Your letter pleased me mightly" and 200 variations on the sentence "I will remember you as long as I live".[2] Cicero gives a description of *oratory*, referring to the *pleasure* it gives, the neatness and symmetry of sentences. As means of acquiring and polishing style, variation is considered the first step in compositional training in the Western music tradition, because it offers different ways of manipulating and "reclothing" a given subject (Sisman 2001).

As far as terminology is concerned, the term *variation* finds its roots in the adjective *varius*, originally referred to mixed coloration on plants and animals, but also used in the more negative meaning of "indeterminate" or "fluctuating". During the 17th and 18th centuries, the term acquired many different meanings; considered as a *technique*, it becomes a *figure*, i.e. a *schema* (Quintilian 90–96 d. C.), and a rhythmically plain series of notes, according to musical theorists of the 17th century: *variatio* «occurs when an interval is altered through numerous shorter notes», so that many notes of less rhythmic value follow the longer note through many sorts of runs and leaps (Bernhard 1657). Other theorists, Praetorius and Vogt

[2]A modern example of the same procedure is given in *Exercises de style* by Raymond Queneau (Paris, Gallimard, 1976).

among others, considered *variatio* as a synonymous of *diminution*,[3] *coloratura*[4] and *passaggio*[5]: the terms mean both a *melodic*—to fill in a large interval—and a *rhythmic* treatment—to subdivide a larger note into notes of less rhythmic value. In the 18th century, the term *variatio* is synonymous of the ancient term *mutatio* and refers to each of its changes of mode, of accidentals, of manner, of register as a *Veränderung* (Walther 1732). The varied model was identified as a "simple melody for singing or playing" (Walther 1732).

From the 16th century on, the term *variation* began to refer to specific musical forms and techniques, especially in the instrumental music. The term *double*, first related to the *pas double* of court dance (*ballet de cour*) in the 16th century and quoted in 1589 by Thoinot Arbeau in his treatise *Orchéosographie* (Cervellati 2007), made its first appearance as a varied repetition of a dance in instrumental suites (a Baroque instrumental genre consisting of several movements in the same key, some or all of which were based on the forms and styles of dance music). In the 17th and 18th centuries, many dance forms can take one or more *doubles*: the *allemande*—originally a German moderate double-metre instrumental dance in two or three strains, later a dance form as similar to the prelude based on a succession of changing harmonies in an improvisatory style (Marpurg 1762)—and *sarabande*—a Baroque instrumental dance originated in Latin America and Spain; various types developed in France and Italy: a fast type (Italy, England and Spain) and a slow type (France and Germany) finally emerged. Synonymous of *Double*, even if with some semantic distinctions, are Spanish *Deferencia*, Italian *Partita* and English *Division*, all of them referring to "parts"—i.e. to segments, later called *theme*, that were repeated with alterations—and to *division*—in the sense of subdividing the original note values. The German term *Veränderung* means change or alteration, but also a need of musical unity between the theme and its modifications (*variations*). These musical features, the necessity of the theme—or the bass line on which the variation process is based—to be *recognizable*, and the harmonic unity, including a shift from major to minor mode, usually in the central variation, influenced the ongoing development of the term, which began to be considered both as a *compositional technique* and a *musical form* (Sisman 2001).

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[3]*Diminution* is a term used to describe a melodic figure that replaces a long note with notes of shorter values; it decorates the transition from one note of a melody to the next passage-work, giving scope to *virtuoso* display. The term is close to the English *division*, the Italian *passaggio*, and the French *double*.

[4]The Italian term *coloratura* indicates a florid figuration or ornamentation. The root of the Italian term is that to "colour", and it probably relates to its use of *diminution*.

[5]A vocal or instrumental technique of variation in which the notes of a theme are divided into shorter ones, usually not of the same pitch, moving usually by step, and chosen with regard to the rules of musical composition. In Baroque music the term may also refer to ornamentation in general, such as *diminution*.

The Study

First Step of the Workshop: The French Air Ah, vous dirai-je, Maman[6]

The first step of the workshop was a listening activity on the French air which gives its title to Mozart's variations set. The cognitive activity was based on the listening theory of Giuseppina La Face Bianconi. She writes: «A reading of musical text requires to student an active attitude and contributes to a general process of education, because it develops knowledge, promotes a critical attitude, refines taste and sensibility, favours an emotional participation and the composure of feelings, reinforces the sense of membership to a tradition and the respect to cultures» (La Face Bianconi 2011, p. 13); this kind of structured knowledge is reached step by step by the students under the guide of the teacher, favours other acquisitions, and it adapts both to frontal lessons and to workshop activity (La Face Bianconi 2011). The aim of the listening activity was to discuss with students the structural components of the twenty-four bars popular French air on which the variations set is based, in order to underline and identify the main musical features which make the air particularly *suitable* for a variation treatment: shortness, simplicity, well shaped musical structure, well shaped musical phrases, singing mood. As far as the musical construction is concerned, the melodic linearity is particularly suitable for cognitive and graphic representation by means of spatial and kinetics analogies. Melody may be described as a linear sequence of "pitch-points" in a time succession, or as "moving points" that generate the linear form (Klee 1959): the melodic linearity may be indentified with the concept of "melodic profile", i.e. a graphic representation of the perceptive image of the melody as a continuous line (its contour depends on the space and time relationships among the pitches). The analysis of the French air's melodic profile was particularly useful to a didactic aim. The teacher and the students chose to consider the *fourth type* of variation form, which is the simplest one, according to scholars' standard classification: it is based on melodic outline and it doesn't require a manipulation or modification of the harmonic plan and the formal scheme. Through the listening activity, students concentrated first on the definition of the main structural and musical features of the little theme, then on the elaboration of the melody of the French air, with care to its harmonic melodic rhythmic expressive aspects, in order to create original pieces (*variations*) which come from the musical features of the theme and can be summed up as follows.

The French air (theme) is a short two part composition in C major, based on a regular rhythm (beat) both in left hand and right hand (crotchet), on a simple harmonic plan and on a singing melody. The first part (A) is based on a short phrase (*a*, eight bars), which we could consider as an "arch form"; the middle section (B) is based on

[6]The musical examples are taken from Petrucci Music Library, an *online* free source music catalogue.

Fig. 1 W.A. Mozart, piano variations op. 12, theme, section A.*a* (b. 1-8)

Fig. 2 W.A. Mozart, piano variations op. 12, theme, section B.*a* (b. 9-16)

Fig. 3 W.A. Mozart, piano variations op. 12, theme, section B.*b* (b. 17-24)

a little development of the opening phrase (a short descending scale—B.*a*, eight bars, i.e. a melodic, harmonic and rhythmic pattern of four bars which is repeated twice on the degrees of a scale) and ends on the fifth degree of the tonality, in order to prepare the reprise of the opening phrase (B.*b*, eight bars) (Figs. 1, 2 and 3).

Both parts (A and B) are repeated twice (in the video performances, the theme and the student's variations are performed from the beginning to the end without repetition of the two parts A and B).

Second Step of the Workshop: Mozart's Variations Set

The second step of the workshop was a listening activity aimed at bringing students to comprehend the compositional rules which have aroused musical structures in Mozart's variations set. Learning conditions were created so that students could understand the formal and syntactical unity of the variations and the musical relationships between them and the main subject which they come from. The final aim was to give to students the means and the musical devices to *compose* and *perform* a set of variations of their own composition, starting from the *elaboration* (i.e., the *variation*) of the theme used by Mozart. So, the workshop combines three aspects of music activity—listening, composition (as an aspect of *creativity*), and performance—which lead students to *know* music and to *make* music at the same time, as an experience which *produces knowledge*.

At this step of the workshop, students were first introduced to Mozart's compositional means and techniques to analyse and better understand the single steps of the composer's creative thought. Mozart's compositional method can be divided in four phases. The first one begins before any writing takes place, as a purely mental process which we can only imagine. The direct contact to the instrument in order to trying the first musical idea over at the keyboard represents the second phase of Mozart's compositional method: according to scholars, «the absence of sketches for solo keyboard works may be explained by the composer's close relationship to the instrument» (Eisen 2006). Mozart's thought, writing and performative gesture are strictly connected each other, to the instrument's technical, mechanical and expressive features, and produce the third phase (draft score) and the fourth one (complete score) of Mozart's compositional process: in other words, Mozart's *creativity* is *idiomatic*. Through the listening activity, the students recognized and pointed out some main musical and structural features of Mozart's composition, which could be summed up as follows:

- an equal technical and musical treatment between the two hands, which is an evidence of the didactic aim of the composer: the same pianistic idioms—such as scales, arpeggios, chords (as a combination of two or more musical notes played and sounded at the same time), broken chords (the effect produced by performing the notes of a chord successively, rather than simultaneously)—and some performance modalities, such as *legato* (i.e., playing the notes one by one without interrupting the sound) or *staccato* playing (i.e., detaching the notes)—are played first by the right hand, then by the left hand. That's why the first variation, based on quatrains of semiquavers, can be considered strictly linked to the second one; the third variation, based on arpeggios (triplets of quavers), is linked to the fourth one;
- the original *tactus* of the theme—crotchet—is always preserved and it's recognizable in all the variations: at the left hand, it assumes a role of rhythmic and harmonic support to the musical elaboration of the main theme; at the right hand, it has a melodic aim;
- the phrase- and harmonic structure of the theme is generally preserved intact; at times the students noticed a progressive separation of the twelve variations from their theme, due to a deeper degree of elaboration of it and to a progressive increase of technical and musical difficulty;
- the use of *diminutions*, a compositional process which plays an important role in Mozart's variations, as a dynamic support in the left hand, or as a florid melodic contour in the right hand;

- the use of *imitation* between the two hands (eighth, ninth and eleventh variation);
- the change of mode (the minor-key eighth variation) tempo and metre (the 3/4 Adagio eleventh variation), which are topics in Mozart's variations sets. The Adagio variation displays a wide singing mood and it is rich in embellishments and diminutions (crotchet value is replaced with quaver value). It requires a *legato* performance and subtle nuances of touch and phrasing; it also creates a sort of suspended musical time which prepares the expectation of the final *virtuoso* variation of the set (XII).

The structural form of Mozart's variations maintains the tree-part structure of the theme—A; B.*a*; B.*b* (see above, pp. 8–9). By means of the compositional technique of *diminution*, in the first variation each note of the theme (crotchet) is subdivided in quatrains of notes of less rhythmic value (semiquavers) through passing notes which are played by the right hand. The left hand takes the beat and the regular rhythmic motion (crotchets) and the harmonic plan. The rhythmic pattern is maintained thorough the whole piece (Fig. 4).

In the second variation Mozart applies the same compositional technique in the reversal form, i.e. the process of *diminution* regards the notes of the left hand (quatrains of semiquavers), while the theme (crotchets) remains in the upper voice at the right hand, enriched by a polyphonic construction (Fig. 5).

The third variation is based on *diminution* by means of arpeggios of triplets of quavers at the right hand (Fig. 6).

Fig. 4 W.A. Mozart, Piano Variations op. 12, Var. I, section A.*a*, abstract (b. 1-4)

Fig. 5 W.A. Mozart, Piano Variations op. 12, Var. II, section A.*a*, abstract (b. 1-4)

In the fourth variation arpeggios of triplets of quavers are at the left hand, while the main theme is maintained in the upper voice at the right hand, enriched by a polyphonic construction (Fig. 7).

In the fifth variation, the theme is maintained in the right hand; the whole construction is based on alternations of notes and rests between the two hands; *chromatism*—i.e., semitones movement—enriches the middle part of the piece; the reprise is constructed as a varied repetition (semiquavers) of the opening phrase (Fig. 8).

The sixth variation is based on *moto perpetuo* (rapid figurations pattern persistently maintained throughout the piece) and on the alternation of the same figures between the two hands (quatrains of semiquavers and chords); the theme is in the upper note of the chords (Fig. 9).

Fig. 6 W.A. Mozart, Piano Variations op. 12, Var. III, section A.*a*, abstract (b. 1-4)

Fig. 7 W.A. Mozart, Piano Variations op. 12, Var. IV, section A.*a*, abstract (b. 1-4)

Fig. 8 W.A. Mozart, Piano Variations op. 12, Var. V, section A.*a*, abstract(b. 1-4)

Fig. 9 W.A. Mozart, Piano Variations op. 12, Var. VI, section A.*a*, abstract (b. 1-4)

Fig. 10 W.A. Mozart, Piano Variations op. 12, Var. VII, section A.*a*, abstract (b. 1-5)

Fig. 11 W.A. Mozart, Piano Variations op. 12, Var. VIII, section A.*a* (b. 1-8)

The seventh variation is based on scales and broken chords at the right hand (Fig. 10).

The eighth C-minor variation presents a three-parts polyphonic construction based on the compositional process of *imitation* of the same melodic contour and rhythmic pattern between right hand (b. 1-2) and left hand (b. 3-4); the reprise is a varied repetition of the opening phrase (Fig. 11).

Like in the previous one, the ninth variation presents a three-parts polyphonic construction based on the compositional process of *imitation* between the right hand (b. 1-2) and the left hand (b. 3-4); the theme is in the upper voice; the reprise is a varied repetition of the opening phrase (Fig. 12).

The tenth variation displays a *virtuoso* writing, i.e., exhibited and technically difficult (broken chords and hand-crossing: “L.H.” means “Linke Hand”, i.e. “left hand”, crossing over the right hand); in b. 4-8, the main theme in the upper voice presents a chromatic descendent motion, supported by the octaves in the left hand (Fig. 13).

Fig. 12 W.A. Mozart, Piano Variations op. 12, Var. IX, section A.*a* (b. 1-8)

Fig. 13 W.A. Mozart, Piano Variations op. 12, Var. X, section A.*a* (b. 1-8)

Fig. 14 W.A. Mozart, Piano Variations op. 12, Var. XI, section A.*a* (b. 1-8)

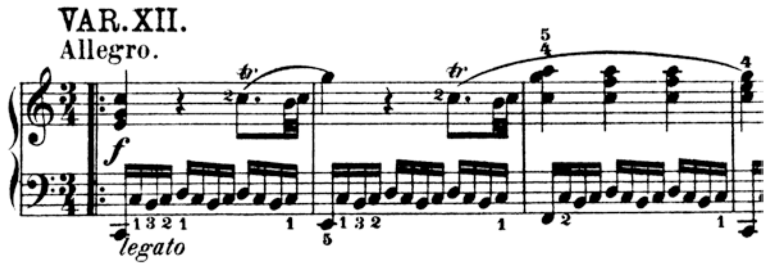

Fig. 15 W.A. Mozart, Piano Variations op. 12, Var. XI, section A.*a*, abstract (b. 1-4)

The eleventh variation (Adagio) presents a singing mood, an imitation writing (b. 1-2) and is based on diminutions and embellishments, more evident in the middle part of the piece (Fig. 14).

The final variation (Allegro) presents a change of the metre (3/4) and it is based on quatrains of semiquavers at the left hand; the theme is in the right hand; in the middle section, the quatrains are extended in both hands. The variation ends with a eight-bars *coda* (conclusion, b. 17-24) (Fig. 15).

Third Step of the Workshop: Preparation for and Writing of Individual Composition

The Concept of Creativity

The third step of the learning activity involved the students in creating a seven variations set of their own composition, starting from the elaboration of the subject (theme). The students defined the strategies useful to compose original and coherent variations: the pedagogical value of the activity lies on the abilities both of maintaining the original scheme of the subject and manipulating it in a *creative* way.

It can be useful now to recall briefly the concept of *creativity,* which has been developed in different fields of knowledge (Pedagogy, Pedagogy of Music, Psychology, Psychology of Music). To this aim, we will recall now three useful definitions. In the perspective of Psychology, *creativity* is a cognitive process which generates both *art* and *science* (Battistelli 2012): it has nothing to do with the concept of *spontaneism* and with some superficial meanings widely referred to the term today, especially in music education, such as *spontaneity*, *ingenuousness*, *disengagement*, *originality* as an end in itself, *oddness*; on the opposite, the creative process «takes place *inside* the mind of a subject who is *conscious* about her/his thoughts, who directs them and decides about their direction and their destiny» (Battistelli 2012). In the same direction, Umberto Eco had underlined that creativity «depends on the ability to select the useful combinations […] according to the criteria of *pertinence*. The selection is made by the rules, and the creative genius uses more rules than others» (Eco 1986). Franco Frabboni and Franca Pinto Minerva summarize this kind of concept in the definition of *creativity* as a process which combines harmoniously rational and fantastic thought (Frabboni and Pinto Minerva 2003). Thus we can conclude that many different voices converge in considering *creativity* as a *cognitive exercise*.

Indeed, also some recent theories in the field of Psychology of music consider creativity as a cognitive process, which generates new ideas starting from acquired informations; according to Irène Deliège, creativity is an innovation process «which is put into action by human spirit through pre-acquired knowledge, which is stored in the long-term memory […]. The studies about creativity pay particular attention to the cognitive strategies which give rise to new ideas and procedures; anyway, new ideas come from familiar and assimilated concepts which are strongly fixed in what the subject already knows» (Deliège 2008).

This statement is crucial to go beyond the definition of creativity as a simple “inspiration”, as an “urge to create” rising abruptly from sudden emotions which are out of control (this is true especially about music, composition and music education, as we will see later). As the authors mentioned above, many recent theories have clearly demonstrated that new ideas can not rise without a solid background of knowledge. The “creative thought”—in science and in music—is a cognitive process which *uses* knowledge. It is *original* and *flexible*, it is suitable to new needs, conditions or acquisitions thanks to paradigmatic thought, not to the detriment of it (Farneti 2012).

We can conclude that creativity is the ability to *use* and *transform* knowledge in different and unexpected ways and to different aims. But it is not only a characteristic of talented or exceptional people (i.e., the genius). On the opposite, it is an intrinsic feature of everyone's cognitive life and a structural element of our mind, which needs to be trained.

Creativity has been operationalized into *Indicazioni Nazionali per il curricolo della scuola dell'infanzia e per il primo ciclo d'istruzione*, i.e. the Italian education guidelines for the first cycle of instruction, age 3–11 (2012). The document recognizes the importance of *creativity* as the ability which *can* and *must* be trained in the educational setting and as one of the most important features of the European cultural tradition. The ability "to express concepts, thoughts, feelings and opinions in a *creative* way" refers in particular to the communication in the mother tongue, to technology and enterprise, to the "cultural awareness and expression" of ideas, experiences and emotions in a wide variety of means of communication (music, visual and performing arts, and literature), and it is generally referred to *practical* music activities (to play an instrument, to sing, to make music together) which seem to be spontaneous, immediate and free, in order to "explore" the musical language. There's no evidence of the concept of *creativity* as the *result* of cognitive abilities and as a *means* to elaborate and to use knowledge, even if one cannot expect an official document to give a clear scientific definition of the concept and an accurate description of the cognitive activities related to it. On the other side, the document recognizes the importance of music educational functions: cognitive-cultural, linguistic-communicative, affective, identity-intercultural, and critical-aesthetic.

Variations Types in Western Music Tradition

The third step of the workshop involved the students in creating a variations set of their own composition, starting from the elaboration of the French air (theme). The *nature* of the theme on which a variations set is based, whether it is a melody (that's the case), i.e., a song or an air, a bass line, a harmonic progression or scheme, or a structural complex of these elements, affects the type, the technical and expressive features of variations that follows. According to standard classification, four types of variation may be distinguished (Sisman 2001; Drees 1998). The first type is the so-called *ostinato variations*, built upon a short pattern of notes, usually in the bass register (i.e., *passacaglia* and *chaconne*, which are dance frameworks). The second type is the *constant-melody* or *cantus firmus variations*, in which a melody, usually widely known, appears intact or with slight embellishments in every variation, moving from voice to voice in the texture (i.e., the *Chorale variations* by Sweelinck, Bach, Pachelbel and others). The third type is the *constant-harmony variations*, which include many compositions of the 16th, 17th and 18th centuries, and based on a harmonic scheme which is predominant on melodic aspects (i.e., many Italian and Spanish dance frameworks, such as *Folia*, *Romanesca*, *Ruggero* and so forth). The *fourth type*: melodic outline, constant harmonic plan and structure (usually a two-part form with *ritornello*, or *refrain*).

The fourth type of variation allows melodic rhythmic dynamic and movement modifications of the subject, without altering the original harmonic plan and the rhythmic pattern of the left hand: for this reason it can be considered the simplest form of thematic development, particularly suitable for beginners.

Students' Variations Set

Each student composed one variation—except in the case of Alice, who wrote two variations strictly related with each other—and has unique musical features as far as melodic profile, movement and mood are concerned. The students chose to maintain the rhythmic scheme and the beat of the left hand, in order to concentrate their creative efforts on the right hand only, i.e. on melodic output, according to the fourth type of variation process. The activity was also an important exercise for students in writing their own music correctly as far as possible, according to their degree of cognitive and music development (some students' original manuscripts are reproduced in the Chapter; some others were written in pencil by the students some years ago, so they are no more readable). On the whole, the variations set composed by the young students is a kind of "work in progress" from a basic level of thematic development (first and second variation) to a deeper one (sixth and seventh variation), and it was performed by its young authors on December, 16th, 2006, in Oratorio di San Rocco, Bologna.

Students chose different performing gestural patterns for each variation; in other words, they set a gestural plan in order to underline best musical features during performance. Movement—i.e., the use of body—is an important element in performance. The body is not only essential to exert a physical control on the instrument as far as mechanical and technical aspects are concerned, to point out some expressive ideas about the performed music and to favour a relationship between the performer and his/her audience: «a motor program is conceived of as a hierarchical structure that translates information input into performed action» ; so, if it may be assumed that «a concrete and practical way of understanding music can be explored through bodily movement» and that «the pianist's movements may be indicators of the mental and physical intentions necessary to generate the expressive performance» (Davidson and Salgado Correira 2002), it's true that through a bodily movement is possible to *understand* music. The first aim of the fourth step of the workshop was to explore all the expressive nuances by gesture during performance; in other words, the students selected some motor patterns to underline the musical technical and expressive features of the variations composed by themselves; they explored how specifically learned gestures can furnish a musical performance with an expressive intention, the wide range of skills involved in performance and the many kinds of information which could be communicated during performance. So it would appear that «those movements used to produce a performance are informative of the *musical meaning*, as well as being generative of the musical intention itself» (Davidson and Salgado Correira 2002). More in details, the discussion was about some important features of piano writing, gesture and performance related to the musical features of each student's composition.

First of all, the discussion pointed out some physics and physiologic properties of the keystroke (touch), which depends on «the kinaesthetic feedback from finger contact with the keys» (Parncutt and Troup 2002). During the third step of the workshop, the students selected different keystroke modalities, based on the analysis of the pianistic writing of their own compositions which required different performance styles. So, they analysed the use of curved or straight fingers and arm's, forearm's and hand's movements, related to some technical and mechanical aspects of piano writing and performance: *staccato* or *legato* playing, slow or fast playing, loudness, leaps technique, tone repetitions, arpeggios, chords, broken chords, melodic contour. Fingering is one of the most attractive but difficult technical aspects of piano learning and performance, especially for beginners; it depends on expertise—usually, the technique, i.e. fingers independence, coordination of finger, arm, and arm movements—matures before interpretative abilities and personal style. Beginners are much more worried about their physical, anatomic and physiological constraints (Parncutt and Troup 2002) so they may not have the experience and knowledge necessary to choose the best fingering to perform a single passage. During the workshop, the choose of an optimal fingering according to students' variations style was the result of a compromise among the students' real cognitive and physical abilities and the musical characteristics of each composition. The students understood that a good fingering is due to physical, anatomic, motor, cognitive constraints interacting with technical, interpretative, mechanical considerations—according to the most important pianists and composers of the 18th and 19th centuries, performance depends on the physical constraints, i.e., if hands and fingers are too small or too big, too thin or too thick. Above all, the students realized that fingering depends on a continuous, deep and sensitive "dialogue" with the instrument and its mechanical features.

Melodic output is an essential feature in students' variations set and it required to students an intensive study to obtain a regular, controlled touch and a singing phrasing, whether in a slow as in a fast tempo: «Successive tones are more likely to hang together as melody if they close in pitch and time and similar in loudness and timbre. Thus a pianist can optimize *cantabile* by holding key velocity relatively constant» (Parncutt and Troup 2002). During the study of gesture related to each variation's musical features and to performance, it was important to students to adjust their touch, according to the acoustic and mechanical characteristics of the instrument and to the physical features of their hands: these are the most fascinating—and difficult!—pianistic problems to solve.

Fourth Step of the Workshop: Individual Performing of Composition Noting Individual Gestural Expression and Interpreting

The structural form of the students' variations maintains the tree-part structure of the theme used by Mozart. Alice (aged 9 years) composed two variations strictly related with each other: the second variation may be considered as a deeper elaboration of the first one. The student chose to respect the original formal structure and the melodic-harmonic plan of the theme, and to modify the rhythmic pattern of the melody, without altering the original theme's succession of pitches. Both variations are based on the compositional technique of *diminution*, which is the first step in compositional training and the easier way—particularly suitable for beginners—to modify a theme.

In the opening variation, the first crotchet in the first beat of each bar is replaced with two quavers, as repetitions played *staccato* (i.e., detached) followed by a silence. The pattern is maintained in the whole composition (Fig. 16).

The second variation (Alice) is a rhythmic elaboration of the first one: the quavers are extended to each crotchet of the melodic line, and they are divided by octave leaps (alternation of low and high register; alternation of the thumb and the little finger). The quavers are played *staccato*, as in the first variation. Like in the first variation, the middle section respects the descending contour of the theme, so the direction of the octave leaps is inverted (alternation of high and low register; alternation of the little finger and the thumb) (Fig. 17).

As far as gesture is concerned, the two compositions are very useful to study some aspects of piano performance; more precisely, gesture was useful to make clear Alice's creative thought and her piano writing during performance. Variations I and II are both based on a specific aspect of piano performance, i.e. the repetition notes. Usually, high-speed repetitions are easier to perform by changing, i.e. alternating, fingers (it is easier to move finger horizontally off the key and drop another finger onto it, rather than to quickly move the same finger up and down); the *repeating action*, the mechanical device which was invented in 1823 by the French piano maker Sébastien Erard allows a better control of the mechanic of the instrument through the keystroke, so repetitions may be best played *under the surface*,

Fig. 16 Students' first variation, sections A.*a* (b. 1-8)

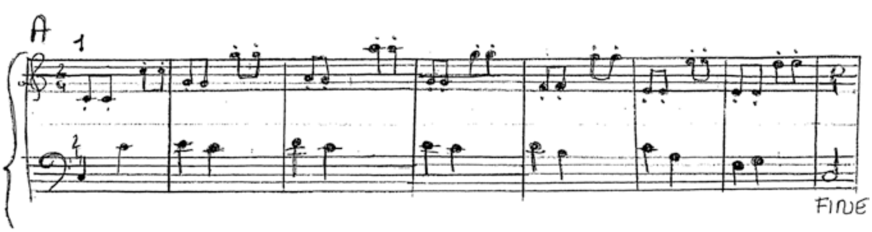

Fig. 17 Students' second variation, sections A (b. 1-8)

that is, depressing the key to the keybed, and depressing it again, without waiting for a complete lift of the key. The discussion with the student pointed out some elements about physics and physiology of the keystroke which play a very important role in piano performance: the position of fingers (curved or straight) and the use of the arm, the forearm and the wrist, according to some elements of piano technique (chords, scales, arpeggios or melodic lines in relation to soft, slower, or loud and fast performance). Alice chose to play the short notes very softly, *staccato*, her curved fingers very close to the keys to better control the loudness and the quality of sound. The second variation may be considered a little study about repetitions combined to *staccato* playing and to octave leaps at high-speed of performance. During a leap, the hand and arm must accelerate from stationary to a maximum velocity and decelerate again before reaching the target. In other words, the leaps force the hand to change its position quickly on the keyboard, and the likelihood of missing a target increases as the trajectory becomes longer (i.e., when the notes are very distant) and the time available become shorter (at a high speed of performance): the anxiety of missing the target increases psychological and muscular tensions which may compromise a good performance. So, students must learn to avoid unnecessary tension; it's important to practice leaps in many ways, because their optimal performance relies on a combined tactile-auditory-visual memory of the keyboard.

The third variation (Giulia, aged 9 years), maintained the original subject's rhythmic profile (i.e., a succession of crotchets) in both hands, creating a rhythmic pattern—broken chords—in which the musical elements seem to reflect each other. The student chose to modify the melodic succession of pitches of the original theme, without altering the whole formal structure of the subject. The composition is particularly interesting, because it displays one of the deepest melodic contour's elaboration among all student's variations set. The *carillon*-like melodic contour is due to the distance between the notes of the chords (thirds, usually used in children's songs) and the mechanical rhythmic motion of the piece (Fig. 18).

The middle section (b. 9-16) displays a deep elaboration of the original theme's downward movement; while the other students' variations maintain the descending melodic contour of the original theme, Giulia's composition shows a motion towards the high register and underlines the closing aspect of the phrasing (b. 15-16) which favours the reprise of the opening part. The composition is not completely successful as far as the accordance of harmonic plan and melodic contour is concerned; anyway, it can be considered as a little study to acquire a good coordination between the hands and a different keystroke (touch) for melodic line *versus* accompaniment. Giulia performed her own variation in a *legato*, singing style, the kind of performance which usually requires straight fingers (Parncutt and Troup 2002): flatter fingers allow a bigger skin area to touch the surface of the key; they can also move through a larger horizontal arc than curved fingers and are appropriate when stretches are required at a low to moderate dynamic level (Parncutt and Troup 2002) and at a quite slow tempo.

The fourth variation (Francesca, aged 11) is perhaps the sweetest and most singing one of the whole variations set composed by the young students. At a first

Fig. 18 Students' third variation, sections A (b. 1-8) and B.*a* (b. 9-16)

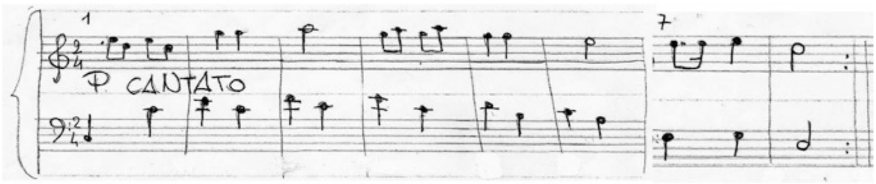

Fig. 19 Students' fourth variation, section A.*a* (b. 1-8)

sight, Francesca's composition shows an extensive use of notes of lesser value (quavers) and passing notes to fill in the distance among the main pitches (crotchets) of the original theme. The result is a singing but dynamic musical fluency. For her composition, Francesca accurately chose both mood and touch nuances: she wrote "*p. cantato*" (i.e., soft and singing touch) at the beginning of the piece. What she had in mind was a good control of the keystroke through fine hands' and fingers' movements, which she put in her pianistic writing and performance in order to play a variety of nuances. Francesca's research of tone quality in piano performance can be developed by concentrated instrumental practice and careful listening: «tone quality depends not only on the physics of individual keystroke but also involves a complex and largely intuitive interaction among body movements, technical finesse, and musical interpretation» (Parncutt and Troup 2002). So, listening and performing can be practised together, to develop step by step the ability to control the touch in order to produce a variety of nuances and to preview them in creating music (Fig. 19).

In the middle the descending contour of the original theme gains ornaments of added singing passing notes. The young author suggests to perform the middle section "*piano, crescendo*", i.e. softly and increasing the loudness step by step; the final bar moves directly and fluently towards the reprise (B.*b*).

The fifth variation (Valerio, aged 11 years) is another, successful example of *diminution* as a compositional device for the variation process (Valerio preferred to write his own composition through the computer's writing system "Finale"). The first part of Valerio's composition is written in arpeggios (quaver quatrains pattern from lower to higher), the middle section displays a broken-chords pattern: both compositional features represent important elements in piano technique and performance. According to different musical contexts, a sequence of arpeggios can be performed in a slow, soft and singing way, or in a fast, loud and *virtuoso* way (Valerio loved so much arpeggios and broken-chord patterns because of the wide span of his hands!) (Fig. 20).

The sixth composition of the whole students' variations set was written by Valeria (aged 12 years) and it is more complex than the previous five. In Valeria's variation, the melodic and the rhythmic elaboration refers to the variation in its whole, so the melodic distance from the original melodic contour is much more evident. Valeria's compositional technique made a pervasive use of notes of lesser values (quavers), of passing notes and a variety of rhythmic solutions (dotted notes and quavers triplets). The student did not maintain the descendant melodic motion of the middle section, which sounds like a further development of the first part. As she chose not to adhere strictly to the harmonic pattern, the restless melodic contour was less predictable, but fascinating (in the video performance the teacher performed Valeria's composition: she was sick so she couldn't perform) (Fig. 21).

Fig. 20 Students' fifth variation, section A.*a*, arpeggios (b. 1-8)

Fig. 21 Students' sixth variation, sections A (b. 1-8) and B.*a* (b. 9-16)

Fig. 22 Students' seventh variation, sections A.*a* (b. 1-8) and B.*a* (b. 9-12)

Valeria's pianistic gestures underlines the single phrasing of her composition: e.g., she choose to lift a bit her right hand at the end of the second, the fifth and the sixth bar, in order to play the little notes and the triplets in a more expressive way; a controlled use of touch underlines the middle section's two little phrasings (bars 9-12 and 13-16) and allows subtle nuances.

The seventh and last variation (Lucia, aged 11 years)—the most elaborated of the whole set—was the most successful both under a harmonic and melodic point of view. The young composer chose two different rhythmic pattern for her variation, which are important features of piano technique and performance. The opening part is written in singing broken chords in the higher register of the instrument—a type of *arabesque*; the wide extension of the quaver quatrains requires fingers' and hands' change of position and subtle touch nuances. The middle section is an elaboration of the melodic contour of the original subject. It may be divided into two parts, the second part as a variation of the first one; Lucia chose scale downward figurations in the central octave, followed by quiet figurations (broken chords) in the treble (Fig. 22).

Conclusions and Future Work

The described teaching activity has aimed to suggest that it is possible to create a circularity between musical listening, composition and performance by means of *creativity*. The case presented by the author demonstrated that creative thought elicited through listening, analysis/discussion, composing and performing is a cognitive, integrative and circular process based on knowledge building and flexible practice, and that music creativity has nothing to do with some superficial meanings widely referred to the term today, such as spontaneity, ingenuousness, disengagement, originality as an end in itself, oddness; on the contrary, the creative process takes place *inside* the human mind and it is a conscious use of human thought and knowledge in order to create something new. The knowledge and the students' assimilation of the compositional and structural rules in Mozart's variations set has favoured the students' *creative*—i.e., analytic and cognitive—thought, the creation of new musical ideas and performance styles and abilities. The study has also demonstrated that it is possible to establish a relation with our cultural tradition in order to understand—and to love—music, by means of *creativity*.

The case presented by the author allows further developments of the activity conducted with the students, i.e. an application of the same cognitive process to specific improvisation techniques and a deeper application of the assimilated technical devices to different Western music themes and more complex music structures, such as the sonata form.

Score

Mozart, W. A. (1973).“*Ah, vous dirai-je, Maman*!”. *12 Variationen für Klavier KV. 300e* (*265*). Schott: Wiener Urtext Edition.

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Creating Music and Texts with Flow Machines

Fiammetta Ghedini, François Pachet and Pierre Roy

Introduction

The word "creativity" has become so popular that virtually every noun, when coupled with the adjective "creative", becomes hype: creative writing, creative thinking, creative problem-solving, creative accounting, creative finance. Creativity has become a modern myth (Bartezzaghi 2013) and the nucleus of Western working life (Florida 2002). Accordingly, research on creativity is developing rapidly. The "science of creativity" focuses on topics such as creative behaviour, motivation, evaluation, correlations with other aspects of personality, social influences and other themes that we briefly review here.

Concepts and Definitions of Creativity

Creativity is a relatively recent target of scientific attention and social praise. In Ancient Greek, the ability to create was often related to divine inspiration (Albert and Runco 1999); for instance, in the dialogue that Plato devotes to the sources of artistic creation, the Ion, Socrates argues that art cannot be defined as a set of skills but as the outcome of the *enthousiasmos*, a sacred inspiration whom the poet has to obey. In the 20th century debate this mystic notion has disappeared from the Western concept of creativity, passing through a phase of transition: the study of "Genius", conceived as an exceptional and superhuman quality, during

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Romanticism (Duff 1767/1964). In the course of time, focus shifted from external, imponderable forces to the active processes taking place inside the creator's mind. Examples of this perspective shift are given by James (1880), who describes for the first time a process that today we would label as divergent thinking,[1] or Francis Galton, who, observing his own chain of thoughts during a whole day, tried to understand which mental associations lead to new ideas. Nevertheless, creation is sometimes described as a supernatural activity by artists accounting for their experience: "This is the doom of the Makers — their Daemon lives in their pen […]. When your Daemon is in charge, do not try to think consciously. Drift, wait, and obey." (Richard Kipling, from *Something of Myself for My Friends Known and Unknown*, 8 (1937), quoted in Lubart et al. (2003).

This appropriation process led to a democratisation of the subject itself: today, creativity is considered a resource that everybody can apply to every context, and not a prerogative of a few exceptional individuals. While, during the early days, famous artists and inventors were the main focus of creativity research (see Rossman 1931; Cox 1926), later on the discrimination between "eminent creators" and laymen has been substituted by the one between "Historical" and "Psychological" creativity (Boden 1990). Psychological creativity generates P-novelty (a novelty "with respect to the individual mind which had the idea") and Historical Creativity generates H-novelty (a novelty "with respect to the whole of human history").

Today, most researchers agree to define creativity as the production of an *original* result *fitting* in a specific context. This is the consensual definition of creativity proposed by Lubart et al. (2003): "creativity is the ability to realise a production at the same time new and adapted to the context to which it is applied."

Creativity Research and the Individual

Although accounts and considerations about creative minds were published before the 1950s (Runco and Pritzker 1999), it is J.P. Guilford, founder of the first Conference on Creativity and advocate of creativity among the American Psychological Association, who can be considered the "father of creativity" (Sternberg and Grigorenko 2001). Thanks to Guilford's research, creativity has begun to be considered as a trait of individual difference. Since then, creativity research has taken the route of the so-called 4P's model: "person" (the

[1]"Instead of thoughts of concrete things patiently following one another in a beaten track of habitual suggestion, we have the most abrupt cross-cuts and transitions from one idea to another, the most rarefied abstractions and discriminations, the most unheard-of combinations of elements, the subtlest associations of analogy; in a word, we seem suddenly introduced into a seething caudron of ideas, where everything is fizzling and bobbing about in a state of bewildering activity, where partnerships can be joined or loosened in an instant, treadmill routine is unknown, and the unexpected seems the only law" (In Horn 2014; Becker 1995).

characteristics of the creative individuals), "processes" of the creative behaviour, "press" (influence of the environment and evaluation) and creativity's outputs, or "products".

Person: Psychological Traits and Emotions

Studies on creative individuals have identified many psychological traits, behavioural characteristics, social and historical features correlating with creative behaviour.

These studies show that creative individuals follow intrinsic motivations (Conti and Amabile1999; Stohs 1992) (an internal need or desire), rather than external motivations (for example: pleasing a professor, receiving a reward, winning a competition). Following Maslow (1943), the intrinsic need to create is so powerful that, if fulfilled, leads to the maximum degree of self-actualisation. Nevertheless, for Eisenberg (2002), receiving a reward is directly proportional to success, and for Gralewski and Karwowski (2013) intrinsic and extrinsic motivations work as a synergy.

Scholars have also extensively investigated the connection between psychological traits and creativity. One of the characteristics correlating with creativity is flexibility: the ability of being ready to change one's point of view, imagining different developments, and not being "fixed" on a solution. Carlier (1973) gave a first definitions of flexibility and Lubart and Georgsdottir (2004) confirmed the correlation. Other traits correlating with creativity are perseverance (Rossman 1931), tolerance to ambiguity (the willingness to accept alternate interpretations, alternate outcomes) (see Tegano (1990) for a first definition, and Cravens et al. (2014) for an application to scientific creativity), openness to new situations (Zenasni et al. 2008), independency of judgement (Barron and Harrington 1981), and risk taking (Lubart and Sternberg 1995).

The correlation of intelligence (measured with IQ tests) and creativity is not unquestionably assessed. This uncertainty produced different models and theories: for an extensive review, see Lubart et al. (2003).

A great amount of research is also devoted to correlations between mental diseases and creativity [see the popular Ludwig (1995), the reframing by Glazer (2009) and a cautionary warning by Schlesinger (2014)]. Studies investigating the link between schizophrenia and creativity (Schuldberg 2001) underline a similarity of "thinking styles", since divergent thinking can have outcomes similar to schizophrenic processes (Rubinstein 2008). The literature on psychological traits also includes insight (Sternberg and Davidson 1995), reviewed from a neuroimaging perspective by Dietrich and Kanso (2010), intuition (Raidl and Lubart 2001), Janusian processes [i.e., the ability to consider two very different perspectives simultaneously, which was examined for scientific creativity by Rothenberg (1996)], and synaesthesia (Dailey et al. 1997).

Regarding the influence of emotions, there is no consensus among scholars. While for Isen et al. (1987), recently supported by Zenasni and Lubart (2011), positive emotions foster creative behaviour, Kauffman and Vosburg (2002) posit that negative emotions stimulate problem resolution whereas positive emotions inhibit cognitive effort. See Baas et al. (2008) for a meta-analysis of 25 years of mood-creativity research. Martin et al. (1993) introduced the "mood as input" theory, stating that opposite emotions have different influences depending on drive. In any case, arousal (versus emotional stability) seems definitively favourable for creativity (Adaman and Blaney 1995). These results have led to the hypothesis, tested by Kohanyi (2009), that creativity is a long-term "mood controller", protecting the individual from emotional excess and mood variability. This thesis resonates with the flow theory by Csikszentmihalyi (1975), stating that creative activities lead to an optimal state of fulfilment (flow) where all external influences are ignored.

Press: Environment and Influences

Murray calls research on "press" (Murray 1938) the study of the environment's influence on the individual. Scholars investigate how "press" inhibits or stimulates creativity, and especially the role of age, society, family, and education.

Developmental research evaluates which periods of life are more favourable to the emergence of creativity (Simonton 1988; Jones and Weinberg 2011). Without reaching a consensus, they agree on the typical shape of the age curve, which varies more over time than across fields of achievement. Early investigations have also identified "slumps" in creative abilities at certain ages (Torrance 1968).

Stemming from the observation that these "slumps" correlate with changes in the educational system, a considerable amount of research investigates the relation between school and creativity. Slumps have been ascribed to the need to conform to conventions, e.g. normative or typical behaviour, peer and teachers' pressure, the value of traditional skills over creative ones in education—but also to an increased capacity of logical thinking, or, lately, brain development (Runco 2007).

Scholars have extended their focus to cultural taboos that, within a culture, can inhibit creative behaviour. For example Adams (1986) identified specific cultural, perceptual and emotional barriers to creativity. Family is another central node for press research; typical objects of study are family internal rules and organisation, number and age of siblings (Sulloway 1996), level of stress (Runco 2004), possible genetic inheritance of creative skills, and parental creativity (Runco and Albert 1986).

The correlation between socioeconomic status (SES) and creativity has been studied too, with the general result that a higher socioeconomic status appears directly proportional to creative thinking (Bruininks and Feldman 1970; Dudek et al. 1994), probably because SES determines the range of available cultural experiences.

Among other topics, we find differences of creativity levels and models across cultures, conceptualized in terms of individualism versus collectivism (Triandis 1995). Empirical studies in this domain usually compare creativity test from individuals from different cultures, (see Niu and Sternberg (2002) for a review on literature and results' analysis).

Finally, authors such as Boring (1971), Feldman (1994), Burke (1995), and Simonton (1984) singled out the impact of role models, war, religion and *zeitgeist* in analysing data concerning historical creative individuals.

Product: Evaluating Creativity

Evaluation is an important part of research on creativity, but also an elusive topic: how is it possible to evaluate how creative a person is, or how creative are the ideas or works s/he produces? One of the first tests proposed to evaluate creativity was the Guilford test (1967) which was intended to measure divergent thinking (DT). In the course of time the test has been modified and expanded, for instance by the famous Torrance test (1974) which evaluates the number of generated ideas, the number of solutions proposed to a problem and the originality of subjects' answers (the frequency on a sample). DT tests are still widely used today (Furnham and Bachtiar 2008).

DT tests, however, were designed within the educational system, in order to identify gifted children and steer their career. Other tests are based on subjective parameters, such as self-evaluation, evaluation from experts and psychological profiling. A more recent trend displaces the focus of attention from the subject to the product of the creative process: in this method, designed and used for the first time by Amabile (1982), the evaluation of creative objects is carried out by peers and/or experts in the field.

The Creative Processes

A certain number of mental skills, thinking habits and psychological skills have been identified as favourable for creativity. Notable among these, is the ability to identify and redefine problems (Csikszentmihalyi 1965), to develop analogies and metaphors supporting the thinking process [especially in scientific creativity, following the several examples given by Holyoak and Thagard (1995) and Hofstadter (1985)], and divergent thinking.

Scholars investigated how these mental procedures are organized, trying to model the process of creative production. The first description of the creative process is probably Wallas (1926), who suggested a four-stage model: preparation, incubation, illumination, and verification. The preparation phase involves problem identification, and the incubation phase is defined as unconscious, or "inactive" processing of information Guilford (1979). The four steps have been widely questioned and challenged, and today the model seems too simplistic to suffice [for a general discussion, see Lubart et al. (2003)].

Computational Creativity

Creative processes play a central role in the recent debate on computational creativity, i.e. "the study and support of behaviour exhibited by artificial systems which would be deemed creative if exhibited by humans" (Wiggins 2006). It is precisely the lack of these processes that was used as counter-argument against artificial creativity: it cannot be denied that machines can create something new and adapted to a context, but the undergoing process of "arriving there" is lacking (Boden 1999). Nevertheless, most recent efforts in computational creativity are headed towards the modelling of such processes (Colton and Wiggins 2012).

Style Development: A Diachronic Model for Creativity

Although most creators are known for singular works, we argue that creative behaviour is primarily a style production process, rather than an artefact production process.

The traditional four-stage model (preparation-incubation-illumination-verification) and its derivatives still lack a diachronic dimension, which could account for the connection between personality, creative outputs, and external influences: style development.

In creative productions, style is so pervasive that it is difficult to circumscribe and transform in an object of observation. The term "style" is used in two different contexts and with slightly different meanings. First, style is an individual trait referring to a personal approach used by each individual to, e.g., carry out a task, learn, solve a problem, or lead a group. For instance, in this stream of research, Runco and Basadur (1993) identified individuals with distinctive problem-solving styles, such as "generator", "conceptualizer", and "optimizer".

Second, "style" refers to "the extent to which an individual's creative output exhibits an identifiable character" (Gabora et al. 2012), independently from the domain in which it is expressed. In this definition, style is an elusive subject and a feature largely neglected by academic literature. To our knowledge, no current theory of creativity accounts for the phenomenon of style development.

Style Development in the Context of Creativity

Style is a feature that emerges clearly after a period of training and in relation with the *zeitgeist,* and thus it is hardly identifiable with classical creativity evaluation methods which, when applied to "P-creativity", investigate exclusively one-time creative outputs. Actually, creative outputs are related to one another and potentially pave the way for one another: style is a quality that makes sense only if applied to quantity.

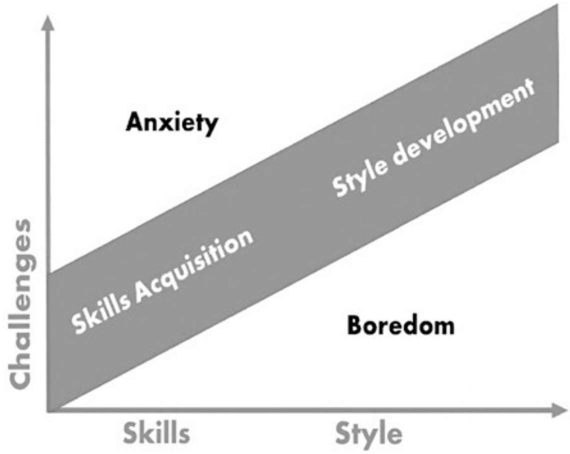

Fig. 1 The diachronic flow diagram: skills lead to style

To include style development in a diachronic model for creativity, we have modified Csikszentmihalyi's Flow diagram and defined style development as an extension of skills acquisition (Fig. 1). When creators have acquired all the needed skills, the next natural step is to create their own, unique style. This is true also for scientific creativity, which can be applied to different domains only starting from the required level of knowledge.

The lithographic series of Picasso's bull (Fig. 2) is a perfect illustration of the process of style development. Picasso created the bull series at the end of 1945: it is a series of eleven lithographs that develops from an academic, realist representation of a bull to a final form purged from any realism and stylised. During this process,[2] Picasso erases one by one all the non-relevant information in different stages, recreating the same image while recombining and rebalancing the elements that compose it. The final abstraction is a concise image consisting in a pure one-line drawing. At the end of this process, we are left not only with the stylised image of a bull, but more importantly with a *style* that can be applied to other objects: the line drawing style of Picasso, which he applied to many productions (see Fig. 3).

[2]"One day…he started work on the famous bull. It was a superb, well-rounded bull. I thought myself that that was that. But not at all. A second state and a third, still well-rounded, followed. And so it went on. But the bull was no longer the same. It began to diminish, to lose weight… Picasso was taking away rather than adding to his composition… He was carving away slices of his bull at the same time. And after each change we pulled a proof. He could see that we were puzzled. He made a joke, he went on working, and then he produced another bull. And each time less and less of the bull remained. He used to look at me and laugh. 'Look,' he would say, 'we ought to give this bit to the butcher. The housewife could say: I want that piece or this one…' In the end, the bull's head was like that of an ant. At the last proof there remained only a few lines. I had watched him at work, reducing, always reducing. I still remembered the first bull and I said to myself: What I don't understand is that he has ended up where really he should have started! But he, Picasso, was seeking his own bull. And to achieve his one line bull he had gone in successive stages through all the other bulls." (An account of Picasso's assistant quoted in "Picasso's Lithograph(s) 'The Bull (s)' and the History of Art in Reverse", Irving Lavin, Art without History, 75th Annual Meeting, College Art Association of America, February 12–14, 1987).

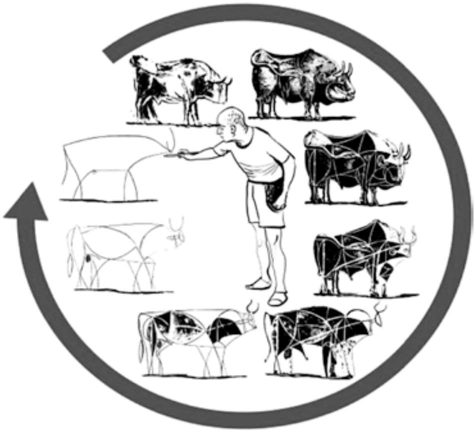

Fig. 2 Illustration of Picasso's lithographic series: from realism to line-drawing style

Fig. 3 Illustration of Picasso's line-drawing style applied to other objects

The same process of style development is illustrated in *Abstraction of a Cow*, by Theo van Doesburg (see Fig. 4), a Dutch painter belonging to the Dutch artistic courant De Stijl (the Style), whose series probably inspired Picasso's bull. The difference is that whereas Picasso's bull is a planned series, Doesburg's work is a sequence of sketches meant to support the design of the final abstract painting.

If we had only the last images from the two series, the process of style development necessary to "get there" would go unnoticed, as well as the needed skills.

Style: Uniqueness and Novelty

Style development, as part of the creative process, involves extensive interpretation and transformation of creative material by oneself and by others.

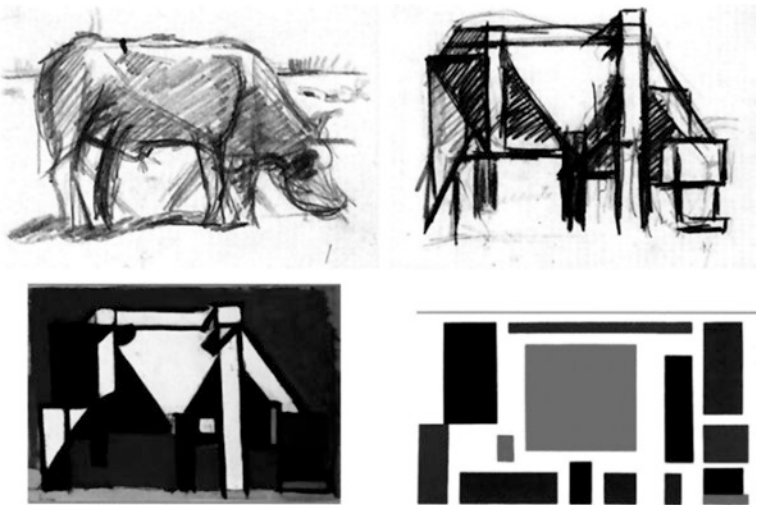

Fig. 4 Theo van Doesburg, "Abstraction of a Cow, Four Stages" (1917)

For example, visual artists often find a style that feels as 'theirs' only after prolonged periods of exploration with different media and established styles and art forms (Ericsson 1996). Similarly, writers and musicians speak of the transition from a stage in which they were merely imitating the styles of creators they admired to a stage in which they felt they had discovered their own authentic 'voice' (Feinstein 2006). Indeed, when artists have found their own voice, their creative outputs are characterized by originality and uniqueness, while expertise and experience in non-creative domains are more likely to lead to standardized performances (Ackerman 2007).

Actualising one's uniqueness could be a motivation for style development, since a sense of self-discovery due to creative activities has been observed by (Singer 2010) and is mirrored by the tendency for artists to have a more developed sense of who they are than less creative persons. Moreover, both laypeople and eminent creators assert attaining a stronger sense of themselves as unique individuals from carrying out creative activities (Gabora et al. 2012).

Another drive of style development is the need for novelty, which for instance Martindale (1990) explains from a historiometric point of view. Martindale posits that, when a new artistic style is developed, the works in that style are relatively simple because the style itself is so novel that they do not induce habituation (in psychology, the gradual loss of interest in repeated stimuli). Yet the longer the style is exploited, the more the society and the public will habituate to works in that style. Eventually, the potential for that style to incorporate novelty has run out, and the only way to keep avoiding habituation is to develop a new style.

Style: Perception

Gombrich (1960) considered that compiling a list of stylistic properties precisely defining artistic style was impossible. However, recent research in computer science showed successful attempts at detecting styles in the visual domain (Castro et al. 2014) as well as in music (Hedges et al. 2014).

Empirical studies demonstrate the role of colour and texture in style recognition for the visual arts (Gardner 1970) and many other features, such as complexity, order, balance, and arousal potential (Berlyne and Ogilvie 1974). These studies show that, in absence of training, style recognition is a property which is acquired after fourteen years of age (Gardner 1970). Nevertheless, young children can potentially discern stylist features if they know how to “look” for them after a period of training (Gardner 1970). On the other hand, musical style appears to be more discernable even among children from first through sixth grade (Campbell 1991); even three year old children are able to make accurate discrimination between musical styles (Marshall and Shibazaki 2011).

Flow Machines: Tools for Style Development

The above quoted study by Gardner (1970) on style recognition demonstrated that training children in recognising styles has an effect on children’s own drawing. With Flow Machines, we exploit and expand this concept.

Flow Machines are a new generation of authoring tools aiming to foster users’ creativity. Flow Machines are not creative systems per se: they are interactive computer programs that let users literally *play* with styles.

We focus here on sequential content, i.e. content that can be faithfully represented as sequences of items, such as text or music. In this context, we equate styles with corpora Pachet et al. (2013): the style of a composer, for instance, is defined by the corpus of sequences he/she has composed, or a subset deemed representative. Of course, there is more to style than corpora, but we consider that the core problem lies not in the definition of style, but in the way styles can be playfully manipulated and tweaked to explore new ideas. How is this possible?

We consider style as malleable texture that can be applied to a structure, defined by arbitrary constraints. Applying style to well-chosen structure may lead to creative objects. Figure 5 illustrates this idea in the graphical domain: the texture of a leopard skin (the style) is applied to the structure consisting in the body shape of a rhinoceros (the constraint), resulting in the new creature on the right. The goal of Flow Machines is precisely to implement such a sum operation. Of course, no guarantee is given regarding the intrinsic quality of the produced artefact. Users play until they produce an object that they find interesting.

Fig. 5 Constraint (structure) + Style (texture) = New object

The Core Technical Problem

The core technical issue we are faced with is the representation of style as a computational object, amenable to such application of user-defined constraints. The project has produced novel techniques to solve this problem in the sequential domain. Style is represented by so-called Markov models, and constraints by arbitrary relationships between items of a sequence, representing situations that the user wants to explore. The description of these techniques is outside the scope of this paper and the interested reader is referred to Pachet and Roy (2011) and Roy and Pachet (2013).[3] We illustrate here how these techniques may be used in three domains: music composition, music harmonization, and text writing, under this "style + constraint" scheme.

Music Composition

The so-called "Boulez Blues" is the result of applying the style of Charlie Parker Blues compositions (we consider here only harmony, i.e. sequences of chords) to a "Boulez" constraint that all chords be different).[4] We exhibited the most probable of them, i.e. a chord sequence that sounds optimally like Charlie Parker (which has the highest probability in the model of Charlie Parker), while satisfying the *all different* constraint: a strange object that lies on the fringe of bebop harmony (see Fig. 6).

The Flow Composer system pushes this idea further Pachet and Roy (2014a). Flow Composer lets users generate leadsheets, i.e. monophonic melodies with an underlying chord sequence, in the style of arbitrary composers (e.g. Coltrane, Miles Davis, Wayne Shorter, Michel Legrand, etc.), or corpora (e.g. the Real Book). Users can generate melodies and harmonies in the style of a composer, and set arbitrary melodic and harmonic constraints (Pachet and Roy 2014b).

[3]See http://francoispachet.fr/markovconstraints/markov_ct.html.

[4]This constraint actually originates from the second Viennese School (Schoenberg, Berg, Webern), and the invention of the serial, dodecaphonic music principle, which states that all 12 pitch classes should appear the same number of times in a musical piece. Boulez was a major proponent of this school in France.

C7 (.03)	***Fm (.06)***	***Bb7 (.57)***	***Ebm (.06)***	***Ab7 (.57)***	***Db7 (.13)***	***Dbm (.01)***	***Cm (.08)***
F7 (.57)	***Bbm (.06)***	***Eb7 (.57)***	***Abm (.06)***	***Gm (.08)***	***Gbm (.08)***	***B7 (.57)***	***Gb7 (.07)***
Bm (.06)	***E7 (.57)***	***Am (.06)***	***D7 (.57)***	***Em (.04)***	***A7 (.57)***	***Dm (.06)***	***G7 (.57)***

Fig. 6 The Boulez Blues is a unique sequence of chords that is the most probable sequence in the style of Charlie Parker Blues compositions that satisfies an all different constraint

Fig. 7 An example of leadsheet generated by the flow composer, in George Gershwin's style with user constraints. Tones of grey indicate the origins of the various chunks making up the leadsheet in the leadsheet database

For example, it is possible to apply the style to specific segments of a targeted sequence (e.g. a beginning in Miles Davis' style, a segment in Wayne Shorter's style) and adding specific properties, such as "have one occurrence of a F#7 in this sequence", etc. Figure 7 is an example of a leadsheet generated in the style of George Gershwin[5] with such user constraints.

We have also shown that virtuosity in solo improvisation can also be modelled as a constrained Markov sequence generation problem with unary constraints holding on specific notes of the melody (Pachet 2012).

Text Writing

Flow Machines can be applied to text in the same spirit. We have shown that Markov Constraints can be used to generate text sequences that were hitherto unreachable with conventional techniques. In Barbieri et al. (2012) we rewrite the lyrics of songs such as Yesterday by the Beatles in the style of any author for

[5]Generated leadsheets can be found at www.flow-machines.com/leadsheetGeneration.

Yesterday	Rhythmic templates	Rhyme structure
Yesterday all my troubles seemed so far away	101, 1, 1, 10, 1, 1, 1, 01	A
Now it looks as though they are to stay	1, 1, 1, 1, 1, 1, 1, 1, 1	A
Oh I believe in yesterday	1, 1, 01, 1, 101	A
Suddenly I'm not half to man I used to be	100, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	B
There's a shadow hanging over me	1, 1, 1, 10, 10, 10, 1	B
Oh yesterday came suddenly	1, 101, 1, 100	C
Why she had to go I don't know she wouldn't say	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	A
I said something wrong now I long for yesterday	1, 1, 10, 1, 1, 1, 1, 1, 101	A
Yesterday love was such an easy game to play	101, 1, 1, 1, 1, 10, 1, 1, 1	A
Now I need a place to hide away	1, 1, 1, 1, 1, 1, 1, 01	A
Oh I believe in yesterday	1, 1, 01, 1, 101	A

Fig. 8 "Yesterday" by the Beatles yields a set of constraints, taken as a structure

Innocence of a story I could leave today
When I go down in my hands and pray
She knocked upon it anyway
Paradise in the dark side of love it is a sin
And I am getting weary looking in
Their promises of paradise
Now I want to know you would be spared this day
Wind is blowing in the light in your alleyway
Innocence in the wind it whispers to the day
Out the door but I could leave today
She knocked upon it anyway

Fig. 9 The style of Bob Dylan is applied to constraints, to yield new lyrics

which we have a sufficiently large corpus. We consider properties of the original song, such as its prosody, rhymes and syntax as constraints. We then apply the style of Bob Dylan (see Fig. 7), the Beach Boys or ACDC to these constraints. The resulting texts[6] satisfy the constraints, while being "in the style of" the selected author. More complex constraints can be specified on the text such as meter (Roy and Pachet 2013). This enables users to generate, for instance, alexandrines (verses with 12 syllables) in the style of Marcel Proust or Churchill. More prosaically, we envision email assistants able to generate phrases or paragraphs in the style of the user, while being controlled by high-level targets such as structural properties or semantics (a phrase that talks about a particular subject) (Figs. 8 and 9).

[6]See www.francoispachet.fr/markovconstraints/markov_applet_style/lyricsgenerator.html to explore all the generated lyrics.

Harmonisation

In the same vein, Flow Harmoniser lets users harmonise leadsheets in the style of any arranger (Pachet and Roy 2014b). With this system, styles of arrangers can be applied to melodies (considered as constraints) which are outside of their original context. With Flow Harmoniser, users can generate harmonisations[7] in the style of award-winning vocal group Take 6, as well as in the style of classical composers such as Wagner. Figure 10 shows the jazz tune "Giant Steps", composed by John Coltrane, harmonised in the style of Wagner. The musical output definitely sounds Wagnerian yet follows strictly the Giant Steps melodic line.

The Big Questions

The Flow Machines project raises many conceptual and technical issues concerning the reification of style, i.e. its representation as a computational object. A key question concerns the relation between style and probabilities. A sequence that has a high probability in a given statistical model is not necessarily stylistically recognizable for humans, because it may use many commonly used words: notions of typicality should ideally be incorporated to control generation more intuitively. Other questions concern the mathematics of style exploration. Generating sequences from a statistical model that satisfy arbitrary constraints raise, in general, complex combinatorial problems. Some of them have been solved in the course of the project: unary constraints, cardinality and meter, as well as max order (Papadopoulos et al. 2014). Others are still subjects of research. For instance, "nice melody" generation should involve not only Markovian properties but also specific *distributions*, such as 1/f (Voss and Clarke 1975).

Beyond these technical issues, we believe that explicit style manipulation is a key mechanism in style creation, and therefore in creativity development. Preliminary results show that this vision can be turned into practical applications, and related experiments will allow us to generate novel data. In particular, it will be possible (1) to track the evolution of one's style in correlation with creativity assessments, and (2) to evaluate the impact of a computational "creative assistant" such as a Flow Machine on style development. Preliminary results have been obtained in the domain of musical creativity, where the positive effects of a computational system conceived by our team (MIROR IMPRO) on untrained children and young pianists have been measured (Alexakis et al. 2013).

We therefore envision that a computational study of style could improve and expand not only individual artistic productions but also our general understanding of the creative process.

[7]See www.flow-machines.com/harmonization for more examples of harmonisations.

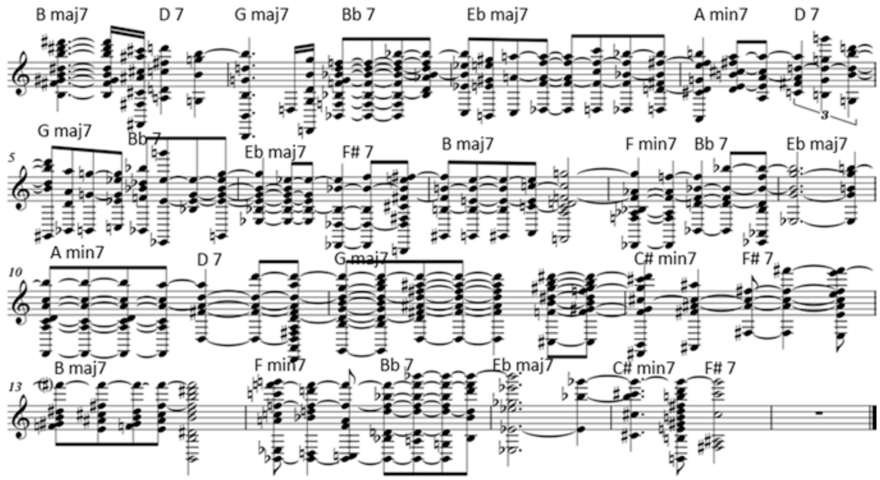

Fig. 10 Giant Steps harmonised by Wagner: yet another novel object created by applying a style (Wagner) to a new constraint (a leadsheet)

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