

Boosting Scientific Creativity Among Researchers: How Efficient are Creativity Trainings?

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ABSTRACT

How can scientific creativity be fostered or encouraged among researchers? The present contribution proposes a critical and constructive review of programs or methods designed to develop the creative abilities of individuals, the so-called '*creativity trainings*'. More specifically, it examines whether these trainings can be used in the specific context of scientific disciplines, and how efficient they are. At first glance, the literature seems to indicate that creativity trainings are effective when it comes to stimulating individual creativity, including scientific creativity. However, these general conclusions should not overshadow the serious limitations of these studies. Some of these theoretical and methodological limitations are common to all creativity trainings (e.g., difficulties in defining creativity itself), while others are specific to scientific creativity trainings (e.g., linked to specificities of scientific work). In a nutshell, all trainings are not made equal and do not look as efficient as they seem to be. This contribution also proposes some rec-

ommendations that would allow researchers to produce more valid results and to make it easier to interpret the results of creative training studies in the scientific domain and beyond.

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Modern societies face many current and future challenges (e.g., climate change, poverty, famine, poor health, migration, war; United Nations). To address these societal issues, creativity and innovation represent essential resources (e.g., Jenaro-Río et al., 2019; Lucchiari et al., 2019; Marope et al., 2017; Ruiz-del-Pino et al., 2022; Siew & Ambo, 2018). Indeed, creativity is intrinsically prospective rather than retrospective (Tsai, 2014). Creativity stands at the root of innovation, it allows us to imagine original responses to societal challenges and drives the evolution of our societies (Bonetto et al., 2022; Ma, 2006; OECD, 2023). In other words, *'few attributes of human performance have as much impact on our lives, and our world, as creativity'* (Scott et al., 2004a, p. 361; see Qian et al., 2019).

In this context, scientific creativity contributes significantly to the progress of human civilization (e.g., OECD, 2023). Broadly defined as *'any thought or behavior in science that is both novel and useful'* (de Vries & Lubart, 2019, p. 2), this domain-specific creativity plays a particularly important role in the development of knowledge and innovations useful to the economy and society as a whole.

It therefore seems important to stimulate researchers' creativity and innovation capacities. The question then arises: how can scientific creativity be fostered or encouraged among researchers? The present contribution focuses on programs or methods designed to develop the creative abilities of individuals, the so-called *'creativity trainings'* (Valgeirsdottir & Onarheim, 2017; e.g., Hu et al., 2013; Raj & Saxena, 2016; Ritter & Mostert, 2017; Ritter et al., 2020; Sun et al., 2020). More specifically, it will examine whether trainings intended to develop individuals' creativity can be used in the specific context of scientific disciplines, how efficient they are, and among which populations they were tested. Various perspectives and suggestions are proposed.

WHAT ARE (SCIENTIFIC) CREATIVITY TRAININGS?

Individuals' creativity relies on specific combinations of knowledge, abilities, and intellectual skills (Watts et al., 2017), but is also influenced by individual motivational characteristics (e.g., personality traits such as the willingness to take risks or be afraid of negative evaluation; Bonetto et al., 2020; Kaufman et al., 2016) and contextual factors (e.g., social norms, cultural values; Bonetto et al., 2022; Haslam et al., 2013). As a consequence, there seem to be several pathways through which individuals' creativity can be acted upon, including physical activity (e.g., squeezing a ball, walking; Kim, 2015; Oppezzo & Schwartz, 2014), organizational changes (e.g., breaks, leadership practices; Ellwood et al., 2009; Lee et al., 2019), modifying consumption habits (e.g., cannabis use; Warnick et al., 2021), using technology-based tools (e.g., Bonnardel & Pichot, 2020; Toumi et al., 2021), or various creativity trainings (Valgeirsdottir & Onarheim, 2017).

Creativity Trainings

Valgeirsdottir and Onarheim (2017, p. 432) defined creativity training as *"a pre-defined and structured program consisting of one or multiple sessions, with the main purpose of increasing the creativity of*

one or multiple participants." Since the first attempts to develop creative skills in individuals in the early-mid 20th century (see Shavinina, 2013), numerous trainings have been developed and implemented in various organizations and educational institutions (Scott et al., 2004). These trainings can include a wide variety of activities, such as problem-solving activities (Im et al., 2015), thinking courses (Byrge & Hansen, 2013), meditation (Ben-Soussan et al., 2015), idea marathons (Higuchi et al., 2012), or role-playing (Karwowski & Soszynski, 2008).

Numerous studies tested the effectiveness of creativity trainings (for recent examples, see Marcos et al., 2020; Ritter et al., 2020). Several meta-analyses were also conducted in order to summarize the literature on the topic and to provide a more precise estimate of the effects of trainings on individuals' creativity (Bi et al., 2020; Haase et al., 2023; Rose & Lin, 1984). They focus sometimes on the enhancement of a general creative ability (e.g., Scott et al., 2004a, 2004b) and, at other times, on that of creative abilities in a specific domain (e.g., scientific creativity; Bi et al., 2020). In addition, some meta-analyses focused on the effects of trainings in specific populations—often children (Alves-Oliveira et al., 2022; Ruiz-del-Pino) or students (Bi et al., 2020; Tsai, 2014; Yasin & Yunus, 2014), while others aggregated the effects obtained in heterogeneous populations (Ma et al., 2006; Parnes & Brunelle, 1967; Rose & Lin, 1984; Scope, 1998; Scott et al., 2004a, 2004b; Torrance, 1972a). Some meta-analyses included only a few effect sizes (e.g., Tsai, 2014), others several dozen or hundreds (e.g., Ma, 2006). Finally, we also observed a disparity in the measures of creativity considered (Alves-Oliveira et al., 2021), despite the fact that these measures are all issued from the scientific literature dealing with the measurement of creativity.

Despite these variations from one meta-analysis to another—and we will see that these differences are nonetheless important to examine—these studies conclude quite unanimously that creativity trainings tend to be effective, with large to very large effect sizes (Cohen, 1977, 1988; Funder & Ozer, 2019). For example, Scott et al. (2004a) or Ma (2006) both aggregated the results of several dozens of studies and found such large effect sizes for creativity trainings, respectively $d = .68$ and $d = .77$, and the same goes for the other meta-analyses cited above (despite considerable variations from one study to another; e.g., Haase et al., 2023).

Scientific Creativity Trainings

Similar results have been obtained regarding trainings specifically aimed at fostering scientific creativity in individuals, generally among young people (children, adolescents, students). Several studies investigated approaches to stimulating creativity in scientific disciplines among these populations. For example, Sun et al. (2019) tested the effectiveness of a '*Divergent thinking training program*' that aimed to help high school students to master divergent thinking strategies and use them in scientific creativity related tasks. The training lasted 100 min. Prior to the training itself, participants completed a first series of scientific creativity performance tasks, as well as measures of domain knowledge (including physics, chemistry and biology), creative potential, and perceived value of the training. The training then contained 4 consecutive steps. First, the trainer presented divergent thinking and compared it to conventional thinking. Second, the way thinking can be influenced by

habitual patterns was discussed. Third, participants were introduced to a set of divergent thinking strategies (i.e., association, decomposition, combination with adjustment; see Sun et al., 2019) as well as examples of their application to real-world problems. Fourth, the participants worked in small groups to discuss and practice the application of these strategies to the scientific creativity performance tasks previously faced. During this step, the trainer offered responses to their questions. After the training, participants completed a second series of scientific creativity performance tasks in order to compare their pre- and post-training performances. For their part, Hu et al. (2013) proposed a '*learn To think*' intervention program that aimed to help primary and secondary school students to increase scientific creativity through a training on relevant thinking strategies, some of which were based on creative thinking (e.g., analogy). These two programs, which are just two examples, have proved highly effective in fostering people's creative abilities in science ($\eta^2p = .50$ for Sun et al., 2019; $.64 < d < .84$ for Hu et al., 2013). Finally, in their meta-analysis of interventions aiming to foster students' scientific creativity, Bi et al. (2020) found that four types of interventions proved efficient: problem-solving interventions ($g = 1.54$), collaborative learning ($g = 0.76$), conceptual construction ($g = 0.20$), and scientific reasoning ($g = 0.89$). Taken together, these results suggest that trainings in scientific creativity are highly effective, at least in the populations in which the studies were conducted.

PROBLEMS WITH SCIENTIFIC CREATIVITY TRAININGS

However, these conclusions should not overshadow the serious limitations of these studies. These limitations—some of which having long been identified in the literature—may call into question this encouraging picture.

Theoretical and Methodological Issues in Creativity Trainings

Certain limitations are common to all creativity trainings, whatever the domain under consideration. Indeed, these limitations are rooted in challenges that creativity researchers have been facing for a long time. In particular, it seems that the definition of creativity itself (Pichot et al., 2022; Weisberg et al., 2021) as well as the ways of measuring it (Cropley, 2000; Said-Metwaly, 2017) are fiercely debated in the scientific literature. This obviously complicates the task of trainings and studies aimed at evaluating their effectiveness, insofar as there is no consensus (and therefore no homogeneity from one study to another) in the conceptions of creativity and the measures used to assess the effects of the trainings implemented. It is therefore often difficult to compare these trainings with each other and to make unambiguous recommendations as to which are the most effective.

In addition, the scientific literature on creativity has long wondered whether creativity is domain-general or domain-specific (e.g., Kaufman, 2005; Qian et al., 2019). This distinction raises many questions for creativity trainings. For instance, is it possible (and effective) to use methods

designed to foster general creativity to foster scientific creativity? Similarly, would it be possible to apply a method designed to foster creativity in a specific domain in order to foster creativity in another domain? Valgeirsdottir and Onarheim (2017, p. 432) stated that *“the definition [of creativity trainings] deliberately does not distinguish between domain-specific creativity training (e.g., creative writing; e.g., Baer, 1996) and general cognitive creativity training (e.g., divergent thinking abilities; e.g., Feldhusen, 1983), as this distinction is not considered relevant for the purpose of investigating the effectiveness of training programs.”* However, this question seems crucial when it comes to establishing which studies (and therefore which trainings) we should include in our meta-analyses when the outcomes measured are no longer linked to general creativity but to creativity in a specific domain, as is the case for scientific creativity. Should we only include creativity trainings designed specifically to foster scientific creativity, or should we include any creativity training that can foster scientific creativity (even if it was not designed for this specific purpose)? It would also be useful to compare the effectiveness of general and specific creativity trainings. In other words, are trainings designed specifically to foster participants’ scientific creativity more effective than trainings designed to foster general creativity?

Still from a definitional point of view, attempts to reach a consensual definition of what is meant by creativity training—which then constitutes an inclusion criterion in the meta-analyses on these trainings—were relatively recent. In their systematic review published in 2017, Valgeirsdottir and Onarheim (2017) point out that they have not found a clear, consensual definition of these trainings. And yet, at this relatively recent time, studies on the subject were already abundant, and meta-analyses had already been published on the effectiveness of trainings. It is therefore difficult to have a reliable estimate of the effectiveness of these trainings if each meta-analysis on the subject includes different studies based on different definitions of creativity trainings.

These definitional problems are accompanied by methodological issues. These issues prevent any clear, precise and unambiguous interpretation of the results of studies designed to assess the effectiveness of creativity trainings. A first issue regards the way creativity is assessed. More precisely, in the context of meta-analyses regarding creativity trainings, it is worth noting that despite the diversity in definitions and measurement approaches, these analyses predominantly focus on measures of divergent thinking (Bi et al., 2020; Ma, 2006; Rose & Lin, 1984; Ruiz del Pino et al., 2022; Scott et al., 2004), employing criteria formulated by Torrance (1972b). By contrast, to our knowledge, although prevailing definitions of creativity argue that it is the ability to produce novel (i.e., the distance from what already exists) and useful (i.e., effectiveness in solving a problem) ideas in relation to a given problem, few studies having assessed creative trainings use pre- and post-test measures of this ability. This relatively narrow focus on a specific aspect of creative performance (i.e., divergent thinking) constitutes an important limitation that needs to be addressed by seeking a more comprehensive operationalization of creativity. In the field of scientific creativity, it could be important to consider measures that assess the relevance of solutions in relation to the problem at hand—their novelty and usefulness, as discussed by Runco and Jaeger (2012).

A second methodological issue relates to generalizability. To begin, creative training studies are based on the use of various creative tasks whose ecological validity (i.e., their ability to translate real creative behaviors) is rarely demonstrated (Bonetto & Arciszewski, 2023). Then, creative training studies frequently suffer from insufficient sample sizes (Valgeirsdottir & Onarheim, 2017). In their meta-analysis, only 5 of the 22 studies exceeded $N = 100$ (which, depending on the effect size sought, is still an insufficient sample size; Faul et al., 2007; Lakens, 2013). Therefore, creative training studies commonly lack statistical power, which increases the risk of type I error (i.e., false positives) and tends to lead to inflation in the effect sizes observed (e.g., Button et al., 2013). This limitation applies as much to individual studies as to meta-analyses of these studies and is all the more problematic in that meta-analyses themselves generally tend to overestimate evidence for and size of effects (Bartos et al., 2023). These problems of effect size inflation could explain the surprisingly large effect sizes observed with creativity training (well beyond the effect sizes generally observed in psychological research; Funder & Ozer, 2019). Finally, as Valgeirsdottir and Onarheim (2017) noted, several creative training studies show serious inclusion biases and often lack control groups (Maydeu-Olivares & Millsap, 2009; see also Dovha et al., 2023 for a recent example). Only 13 of the 22 experiments reviewed by these authors included a control group.

Specific Issues in Scientific Creativity Trainings

These issues also hold more specifically for the stimulation of scientific creativity among researchers. In addition to the theoretical and methodological problems described above, which are common to all creativity trainings (whatever the domain considered), there are limitations specific to trainings designed to promote scientific creativity.

We previously mentioned the debates on whether creativity is domain-general or domain-specific and explained why it is possible that the specificities of scientific work—and therefore of scientific creativity—prevent the direct use of trainings developed to stimulate creativity in other domains of activity. Here we can consider in more detail the consequences of this debate for scientific creativity trainings. Scientific creativity melts with epistemology as the possibility for innovation and progress of human knowledge. Noticeably, the Nobel prize laureate Medawar (Medawar, 1990, 2021) was one of the major voices about such creativity. He tried to bring together art and scientific imagination, relying on Koesler insights (Koestler, 1964; see also Dutton & Krausz, 2014) after Guilford's work (Guilford, 1950). His idea was that narrative imagination was always the first step of any scientific inquiry, then validated by a specific methodology, in his case mostly inherited from Popper (Calver, 2013). Simonton (2004) mentions two relevant examples: '(...) Max Planck (1949) held that creative scientists "must have a vivid intuitive imagination, for new ideas are not generated by deduction, but by an artistically creative imagination" (p. 109). Similarly, Albert Einstein reported "to these elementary laws there leads no logical path, but only intuition" (Holton, 1971–72, p. 97).'

Moreover, even though researchers attempted to specifically improve scientific creativity, they would encounter difficulty determining which types of process to target. If we follow Simonton

(2004), scientific creativity is made of logic, chance, genius and zeitgeist. Logic is based on previous knowledge, so improvement can only come from learning and work. Chance (serendipity for example) and Zeitgeist seem quite out of our action scope. Finally, genius is for Simonton, following other scholars, an intellectual capacity (not relying on logic) that can bring up ideas not derived from inductive or deductive methods. Among these four dimensions, only logic and genius seem to be targeted, the former by training on new hypotheses and problematization like in existing programs, the later by more classical creativity training if we believe (1) that genius is not only a capacity held by some already creative people, and (2) that general creative training also improves scientific creativity even if it also relies on logic. In brief, defining a clear goal seems much needed even before trying to find a solution for making scientific creativity training feasible.

Defining a clear goal of which type of process to target may also be complicated because creativity is not just determined by ability-related factors (e.g., logic), but also motivational and metacognitive factors. For instance, some researchers suggest that curiosity and emergence—an idea that emerges in the current ocean of tested ideas—should be targeted in specific trainings that would not be directly related to creativity but more to how to manipulate knowledge (Sherwood, 2022). On this basis, creativity may actually be fostered by motivational and metacognitive changes through critical learning, thinking, and developing self-efficacy belief (Qiang et al., 2020). What we can then train is more the use of knowledge, problematizing (Phillips et al., 2017), and generation of alternative hypotheses as well as knowledge interdisciplinary mix.

The four dimensions as well as the motivational factors mentioned above consist of individual characteristics. However, we can raise the question of whether scientific creativity is mainly individual or a human collective activity (Bonetto et al., in press) relying on many constraints (e.g., the scientific methods, the peer reviewing process). Although some researchers see creativity as mainly determined by individual characteristics like genius or the personality dimension of openness (Grosul & Feist, 2014), other researchers have long argued that creativity could be largely determined by the environment, relying mostly on freedom, time, autonomy, and collaboration (Anders & Walsh, 2009). All in all, the idea of the lonely genius seems to vanish in the myth cemetery (even if some rare cases may remain). On this basis, creativity training might be quite inefficient without organizational and collaborative improvements.

In addition, it seems that some of the populations most concerned by scientific creativity, namely researchers (PhDs and PhD candidates involved in scientific research), represent populations that remain rarely targeted by studies on this topic. It seems that studies on samples of children and high school students are much more frequent in studies testing scientific creativity training effectiveness (e.g., Bi et al., 2020; Hu et al., 2013; Sun et al., 2020). Related to this point is the question of whether it is possible (and effective) to transfer a method designed to foster creativity in other populations to a population of researchers, and under what conditions. This question is all the more important as scientific trainings designed for populations other than researchers cannot be based on a solid core of scientific knowledge in the same way as trainings designed for researchers (who do possess this knowledge). Yet, as we have seen, scientific creativity is particularly

dependent on this knowledge and on the ability of individuals to manipulate this knowledge (e.g., Sherwood, 2022).

These are just a few examples of the many questions for which, it seems to us, we have received no answers to date and that constitute important perspectives for future research.

Training Scientific Creativity Among Researchers: Some Recommendations

On the basis of what we described above, we propose six recommendations which we believe will (1) produce more valid results and (2) make it easier to interpret the results of creative training studies in the scientific domain and beyond.

1. Improve the comparability of studies. This recommendation calls for the most consensual definitions possible, especially of the concept of creativity and of what is meant by training. It also seems necessary to decide on the measures to be used to quantify training results. These points would make it easier to compare studies, to compare training programs with each other, and thus to make recommendations and choose one training over another. This homogenization will also make it possible to lend greater weight to the results of meta-analyses, which are otherwise condemned to bringing together results that are difficult to aggregate.
2. Encourage ecological validity of results. Studies testing the effectiveness of scientific creativity trainings generally use various creative tasks whose ability to translate real creative behaviors, in this case in relation to the participants' everyday scientific activities, is rarely demonstrated (Bonetto & Arciszewski, 2023). It seems important to recommend the use of the most direct possible measures of creative behavior in the scientific field. For example, quantifying the original output of researchers (e.g., articles proposing new theories or hypotheses, new methods) would provide a far more interesting measure of the effectiveness of training than the results of these same researchers on decontextualized tasks that are relatively distant from their actual scientific activities. This type of measurement is in line with the idea that scientific creativity is measured in terms of the final output of the activity. As far as we know, very few studies have really challenged what is a creative output in science, some taking the solution to rely on scientific publication (Grosul & Feist, 2014). That solution seems, for every researcher, quite satisfying since a lot of publications are not creative but are part of the normal scientific replication process (Kuhn, 1962; see Bonetto et al., 2023). Moreover, a lot of researchers won prizes for the novelty of their research very late in their scientific career. Our possibility of assessing increased creativity seems to take those points quite limited.
3. Generating processual hypotheses. A recurring limitation of studies on creative trainings is the inability of a number of them to explain their effectiveness in processual terms (see Hu et al., 2013). These explanations in terms of processes seem all the more necessary given that cognitive trainings, aimed precisely at stimulating and improving individuals'

cognitive abilities, have been shown to be globally ineffective (Gobet & Sala, 2023). If we cannot improve the cognitive abilities that underpin creativity, then perhaps other approaches should be considered in creativity trainings. This literature on cognitive trainings could thus lead to the switch from trainings aimed at improving the cognitive abilities involved in creative activities (e.g., Ritter & Mostert, 2017), to trainings aimed at fostering the motivation to create and the creative self-efficacy of individuals (e.g., Karwowski & Kaufman, 2017; Silvia et al., 2016).

4. Varying study populations. As we said earlier, studies take very little interest in the populations most concerned with the issues linked to scientific creativity: scientific researchers. These studies often focus on samples of children and adolescents, and it remains difficult to extrapolate their results to researcher populations. We do not intend to minimize the importance of scientific creativity trainings in populations other than researchers, which may be able to stimulate an appetite for scientific work in the short or even long term (although longitudinal studies over several years would be necessary to ascertain this last point). However, it is striking that so few scientific creativity trainings are dedicated to scientists themselves, that is to a population whose activity largely depends on the ability to generate new ideas, theories, methods and technologies.
5. Ensure the experimental quality of experiments. We mirror here the recommendations of Valgeirsdottir and Onarheim (2017) regarding this point. Thus, we can only encourage studies to use a sample that guarantees sufficient statistical power, to include control groups, and to prevent the inclusion biases that are common in these studies. These points are all the more important as the validity of the conclusions reached in subsequent meta-analyses is totally dependent on the methodological quality of the studies included.
6. Finally, we would like to argue in favor of the application of open science practices (Foster & Deardorff, 2017), often neglected in creativity training studies. Indeed, preregistration of hypotheses and materials reinforces confidence in the results. For their part, open access to raw data, statistical analysis scripts and materials enhances the transparency of the procedures implemented, enables re-analysis and replication of results, and provides access to data for meta-analysis. In addition, open research practices are associated with increases in citations, media attention, collaborations, and funding opportunities (McKiernan et al., 2016; Woelfle et al., 2011), and would therefore benefit both researchers and the field of research as a whole.

CONCLUSION

If so many methods are used trying to make scientists more creative, we have to admit that there is a need for such training. In a competitive scientific world, and more generally within the science framework in which we all seek new and valuable findings, looking for more creativity seems rather

logical. Nevertheless, all trainings are not made equal and do not look as useful as they seem to be. We believe that there are two main issues that prevent effective trainings. First, we lack proper research on their real efficacy, and second, we are still not so sure what we need to stimulate in such trainings and how. Many existing propositions, mostly for students in science, are already in action, but we may shed some doubt on whether they really improve scientific creativity or just scientific curiosity. Moreover, we have to clarify whether researchers need creativity support through creativity trainings, or if their creativity is (more than in any other field) deeply linked to their knowledge, organizational situation, and goals within their disciplines. Some creativity researchers and practitioners focusing on the working environment for scientists. For example, Creative Knowledge Environments (Hemlin et al., 2004, 2008) consists in a large descriptive set of environmental features like the nature of tasks, group characteristics, organization settings, and physical environment. The authors show that creativity relies for example on clear goals, focus on research, a research culture, a participatory leadership or staff selection. They also suggest taking a more specific look at leadership, which according to these authors, should be providing expertise, coordinating group research, assigning tasks, supporting group conditions, enhancing external contacts, and promoting independence (Hemlin & Olsson, 2011). Finally, trainings could also target active researchers already having a position to offer new stimulating ways of doing creatively scientific research.

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