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The Effects of Domain Knowledge and Instructional Manipulation on Creative Idea Generation

ABSTRACT

The experiment was designed to explore the effects of domain knowledge, instructional manipulation, and the interaction between them on creative idea generation. Three groups of participants who respectively possessed the domain knowledge of biology, sports, or neither were asked to finish two tasks: imagining an extraterrestrial animal and creating a new sport. Participants in each group were randomly assigned to one of three instructions, in order to encourage them to perform the tasks using a *specific instance strategy* (relying on specific instances), an *abstract strategy* (relying on abstract principles), or their habitual ways. Based on an analysis of the participants' verbal reports and their creations, the results suggested that domain knowledge enhanced the tendency to use the abstract strategy, and improved the originality and practicality of the generated ideas. Instructions also influenced the strategy participants used in creative idea generation. The instruction to use abstract principles brought forth the most original creations. Moreover, there was an interaction between domain knowledge and instructions. Encouraging participants to use the specific instance strategy blocked the knowledgeable people from developing novel ideas. Other factors, such as age, grade and gender, were found to be unrelated to either the originality or the practicality of the creations. The implications of the results were discussed in detail.

Keywords: Domain knowledge; Creative idea generation; Instructional manipulation; Expertise

INTRODUCTION

Over the past few years, researchers have been making great efforts to know whether domain knowledge can benefit one's creative thought. In the study of creative thought, domain knowledge was usually subsumed under the rubric of expertise (Mumford, Blair, & Marcy, 2006), which is defined as extensive, elaborate, well-organized, interconnected, and easily accessible knowledge structures in one domain (Ericsson & Smith, 1991; Sternberg, 1998; Adams & Ericsson, 2000). Some early findings seemed to imply that expertise might be independent of creativity in given domains. For example, creative productivity only increases at the beginning of one's career, whereas after attaining the career peak, the output tends to decline (Dennis, 1966; Lehman, 1962; Simonton, 1989). The most innovative individuals are those whose training is marginal rather than central to the field of major achievement (Hudson & Jacot, 1986). The creators are not merely extreme experts in their chosen domains (Simonton, 1996). Accordingly, accumulated expertise (or domain knowledge) was considered to provide no boost to creativity. Meanwhile, some other scholars (e.g., Sternberg, 2006) suggested that domain knowledge might be a double-edged sword in creative thought. That is, while domain knowledge provides guidance in formulating and exploring new ideas and allows individuals to make assumptions and infer missing information, it also restricts their thinking, limits the possibilities they consider, and leads to a narrower search for a solution. In brief, domain knowledge would put individuals at a disadvantage, given that problems must be considered or solved in novel, original or creative ways.

On the other hand, considerable research also supports the idea that domain knowledge should be highly valued and regarded as an extremely effective predictor for creativity. Chi, Glaser, and Rees (1988) and other scholars (e.g., Simon, 1999) demonstrated that outstanding contributions in many fields depend on the acquisition of knowledge about the domain. Ericsson and his colleagues (e.g., Ericsson, Krampe, & Tesch- Römer, 1993; Krampe & Ericsson, 1996; Ericsson, 2006; Ericsson, Roring, & Nandagopal, 2007) suggested that even the most accomplished creative geniuses must engage in intense and regular practice in their domains for at least 10 years before they generate their remarkable creative products, which implies that accumulated domain knowledge may be necessary for high levels of creativity. Moreover, Weisberg (1995, 1999) posited that the ability to do creative work depends on deep knowledge in a domain. He suggested that after controlling for some intellectual and personality differences, the basic difference between a creative and noncreative thinker in the same domain is the type of knowledge that the thinker transfers to the problem situation. Furthermore, Simonton (2000) analyzed the careers of 59 classical music composers and found domain-relevant experiences are an important factor behind their creative achievement. Maker and Sak (2006) reported that domain knowledge is associated with fluency, originality, flexibility, and elaboration of creative mathematical thinking; knowledge at the level of two standard deviations above the mean is found to be the threshold for creativity at the level of one standard deviation above the mean.

Recently, many researchers, especially North American theorists, have held that expertise or domain knowledge is a predictor of creativity (Reilly, 2008). It should be noted that the previous findings which revealed a positive relationship between expertise and creativity actually provided some support to the notion; nevertheless, research is needed to clarify how domain knowledge influences various processes of creative thought. That is to say, rather than asking the simpler questions of whether knowledge influences creativity or whether more knowledge is better for creativity than less knowledge, researchers should begin to focus on clarifying the specific ways in which domain knowledge benefits information gathering, problem construction, conceptual combination, idea generation, idea evaluation, or other processes of creative thought (see Mumford, Blair, & Marcy, 2006).

Following the research line mentioned above, the present study investigated the role of domain knowledge in creative idea generation. Previous studies revealed that when people generate new ideas for a domain, their predominant tendencies are to retrieve fairly specific, basic level exemplars from that domain, select one or more of those instances as a starting point, and project many of the stored properties of the instances into the novel ideas (Ward, 1994; Ward, 1995; Ward, Dodds, Saunders, & Sifonis, 2000). Meanwhile, a minority of people tested depend on more abstract information (e.g., features of category membership) and generate more original ideas than those relying on specific instances (Ward, Patterson, Sifonis, Dodds, & Saunders, 2002). Furthermore, instructions can be adopted to induce individuals to utilize an abstract approach; as a result, more original and novel ideas are developed (Ward, Patterson, & Sifonis, 2004). Three conclusions might be drawn based on the studies mentioned above. (a) Individuals prefer the strategy of relying on specific instances (exemplar approach) to the strategy of depending on abstract information (abstract knowledge-based approach) in creative idea generation. (b) Instructional manipulations can be conducted to induce individuals to choose the alternative strategies. (c) The strategy of depending on abstract information brings forth more original and novel ideas.

Nevertheless, caution is necessary in extending such results to the situation in which people with high level expertise engage in creative idea generation in their own domains. Lubart (2001) and Perkins (1992) proposed that different heuristics may be used in the process of creative thought depending on the domain in which the individual is working, the structure of available knowledge, and the demands made by the situation. That means the available knowledge probably influences the approaches being used in creative thought. Meanwhile, classic works have shown that individuals with high level expertise possess not only more abstract, principle-based representations in the domain (see Chi, Glaser, & Rees, 1982), but also their knowledge extends the privileged status of basic level categories to subordinate exemplars in the domain (e.g., Johnson & Mervis, 1997; Tanaka & Taylor, 1991). Thus, a host of questions has arisen. Will such characteristic domain knowledge impact the approaches adopted in creative idea generation? What particular effects will the distinctive domain knowledge exert in creative idea generation? And, what interaction between domain knowledge and instructional manipulation will happen?

In a recent study, Ward (2008) tried to explore the effects of domain knowledge on creative idea generation. He requested some undergraduates to rate their own knowledge about sports firstly, then asked them to finish the idea generation task of designing a novel sport. Based on the analyses of participants' verbal reports and their creations, he probed into the effects of domain knowledge on the tendency to use an exemplar or abstract approach and on the originality and practicality of the creations. The results showed that more domain knowledge did not make individuals more likely to gravitate toward abstract strategies in generating novel ideas. In addition, greater domain knowledge was not related to the originality of the creations, but was associated with greater practicality of the products. As Ward (2008) acknowledged, however, the participants were from introductory psychology classes, who likely did not possess extensive domain knowledge of sports. Moreover, since their knowledge about other topics was not tested, it is not certain whether the findings are specific to sport domain knowledge or to more knowledge in general about a range of (untested) topics.

All in all, research aimed at investigating the effects of domain knowledge on creative idea generation is comparatively rare now. Further well-designed studies should be conducted to increase our understanding about this topic. First, it is critical to enroll participants with truly extensive domain knowledge related to the task of creative idea generation. Second, it is necessary to examine the interaction between domain knowledge and instruction, because the later has been proven to be an effective moderator in creative idea generation. The present study is intended to provide more information about the effects of domain knowledge, instruction, and the interaction between them on creative idea generation. We carefully selected the participants who respectively possess domain knowledge of biology, sports, or neither. Subsequently, we asked them to finish two tasks of creative idea generation (imagining an extraterrestrial animal and creating a new sport) under three instructional conditions. Then we analyzed the effects of domain knowledge and instruction on the strategies used and the originality or practicality of the creations. The primary hypotheses were as follows. (a) Using stricter approaches than those utilized by Ward (2008) to select participants and test their domain knowledge, we can ensure the participants with distinctive and extensive domain knowledge about their topics. Considering that available knowledge probably influences the approaches being used in creative thought (Lubart, 2001; Perkins, 1992), we expect that greater domain knowledge about biology (or sports) will be associated with a greater reliance on abstract principles rather than specific instances in imagining an extraterrestrial animal (or creating a new sport). (b) Based on previous findings (Ward, Patterson, & Sifonis, 2004), we expect that instruction will affect the strategies chosen in creative idea generation. If hypothesis (a) is supported, we expect there might also be an interaction between domain knowledge and instruction on the strategies used. (c) If hypotheses (a) and (b) are supported, we expect that domain knowledge and instruction exert main effects and interact in influencing the originality of new ideas, because these two factors and their interaction influence the strategies adopted, and strategies influence the originality of the creations (Ward, Patterson, Sifonis, Dodds, & Saunders, 2002). (d) We also expect that more domain knowledge might bring forth more practical ideas. Based on Ward's (2008) finding that specific exemplar approaches are associated with greater practicality, it is expected that instruction to use an exemplar approach will improve the practicality of the creations.

METHODS

PARTICIPANTS

The present study needs three groups of individuals who possess domain knowledge of biology, or sports, or neither as the participants. For selecting suitable participants, four steps were used. Firstly, we enrolled the junior or senior undergraduates from departments of biology, sports, or other social science in East China Normal University, Shanghai. Generally, full-time study in a domain for at least 2 years would be expected to result in the undergraduates possessing higher level of domain knowledge in their own domains than the other two groups. Initially, 308 undergraduates volunteered to join in the study. Secondly, we compiled a 20-item Biology Knowledge Test (BKT) and a 19-item Sports Knowledge Test (SKT), which covered some common knowledge about biology or sports. A sample item in BKT is: What family does the crocodile belong to? A sample item in SKT is: How many swimming strokes are there in formal swimming contest? We used these two tests to 90 undergraduates who were not potential participants in the experiments to assess the reliability and calculate the *M* and *SD* of them (BKT, Cronbach's alpha = .72, $M = 8.37$, $SD = 3.95$; SKT, Cronbach's alpha = .88, $M = 8.77$, $SD = 3.59$). Thirdly, we requested the volunteers to finish BKT and SKT. Performance on the two tests was used to eliminate volunteers who had more knowledge than expected about a domain they were not studying. That is, we intended to remove the volunteers who majored in biology (or sports) but were knowledgeable about sports (or biology), and who majored in social science but are knowledgeable about biology or sports. Thus the selected three groups of participants should possess distinctive domain knowledge respectively. Fourthly, based on the *M* and *SD* of the two tests, the individuals majoring in biology who were knowledgeable about sports (scores in SKT were higher than 15.95, 2 SDs above the mean) were removed. In the same way, the individuals majoring sports who were knowledgeable about biology (BKT > 16.23) and the individuals majoring social science who were knowledgeable about biology or sports (SKT > 15.95, or BKT > 16.23) were removed. As a result of these steps the selected groups of participants were composed of 276 undergraduates. There were 119 males and 157 females, whose average age was 21.9 ($SD = 1.72$). Among them, 85 participants majored in biology (Biology Knowledge Group, BKG), 108 participants majored in sports (Sports Knowledge Group, SKG), and 83 participants majored in social science (Control Group, CG). It is reasonable to say BKG possesses higher level of biology domain knowledge than SKG and CG, and SKG possesses higher level of sports domain knowledge than BKG and CG.

PROCEDURE

Participants were asked to finish two tasks of creative idea generation in 40 minutes, which included imagining an extraterrestrial animal and creating a new sport respectively in 20 minutes. In creating an animal, participants were asked to draw both front and side views and write down a brief description of the animals, which could provide disambiguating and detailed information on the properties of the creations. In creating a sport, participants were required to draw what the sport looked like, such as the square, implements, and so on; write down the description of how, where and by whom it would be played, and what sorts of rules were adopted. Briefly, participants were asked to give enough details that someone would know how to play it just from the drawing and description. In each task, when participants finished the creations, they responded to some open-ended questions about how they had developed their creations, whether they had utilized the instances of Earth animals or specific sports, and which instances they had called to mind. These two tasks were counterbalanced. Half of participants created the animals and then the sports, the other half did in the reverse order.

Each group (BKG, SKG and CG) was respectively assigned into one of three conditions randomly to perform the tasks. (a) Exemplar condition. Participants were asked to try to think of specific Earth animals and sports in our society, and to use them to imagine what the animals on other planets and the new sports would be like. (b) Abstract condition. Participants were asked to think of the common characteristics of living things, such as receptors for adjusting to special environments, organs for ingesting food, etc. in generating their ideas about animals on other planets; or think of the common properties of sports, such as the square, rules, implements, contest and etc., to develop a new sport. (c) Control condition. Participants received no special instructions about how to develop their novel creations.

CODING

The coding scheme for the created animals established by Ward et al. (2004) was also used in the present study. Two coders examined each participant's drawing to find out whether it used standard attributes of Earth animals, including eyes, ears, mouth, nose, arms, legs, wings and bilateral symmetry. Unusual variations on the appendages and sense organs were also examined. Appendages were considered unusual if there was an atypical number of any major appendage (e.g., three legs), appendages which had special functions (e.g., absorbing nutrients with legs), or appendages which Earth animals did not have (e.g., wheels). Senses were considered unusual if there was an atypical number of any major sense organ (e.g., one eye), odd arrangement of the sense organs (e.g., mouth above the eyes), fantastical sensory ability (e.g., ability to hear up to 10 kilometers away), or any sense organ which was not normally found in Earth animals (e.g., telepathic receptors). Then, coders labeled each product with a "difference" score according to the following five factors: asymmetry, no typical appendage, no typical sense, atypical appendage, and atypical sense, with one "difference" point assigned to the product for each factor it matched. Two coders achieved a minimum 90 percent agreement on the items examined above. Finally, three other raters who had no idea about the purpose of the study rated the "originality" of the creature on a 7-point scale respectively, with a higher number reflecting more originality. The inter-rater reliability for the originality rating was .76.

The coding scheme for the created sports was established as follows. The same two coders examined participants' drawings and descriptions of the created sports to identify whether any unusual characteristics were developed in comparison with existing sports. Square was considered unusual if it was irregularly shaped (e.g., diamond or star), or located in irregular places (e.g., in the air or under the water). Implement was considered unusual if it was not normally found in specific sports (e.g., electronic ball, spiked club), or had a fantastical function (e.g., a bat which can beat a ball to 200 meters away). Grouping was considered unusual if the members of two teams were unequal (e.g., 2 person VS. 6 person), the members of a team were different from those of the existed sports (e.g., 25 people on a team), or the team consisted of atypical members (e.g., children and adults on one team). Rule was considered unusual if there was any new way of playing (e.g., beating a ball to far away with a bat), scoring (e.g., people receive different scores when they shoot a goal from different location in the ground), or the peculiar way to judge the winner or loser (e.g., one who rides a bike backwards most slowly is the winner). In addition, the property of contest, which means having purposes, requiring skills, competing to win, having standards to judge the winner and loser, aiming to be quicker, higher and stronger, was also examined. Then, coders assigned each new sport a "difference" score based on the four factors: novel square, novel implements, novel grouping, and novel rules. When the product matched one factor, it received one point of "difference," and so on. Two coders achieved a minimum 90 percent agreement on the items examined above. Subsequently, the same three raters who evaluated the created animals also rated the "originality" and "practicality" of the created sports. Because a truly practical sport should be playable (people like to play) and enjoyable (people like to watch), the raters evaluated the "practicality" of the created sports on two dimensions: the "playability" (to what extent people would like to play), and the "enjoyment" (to what extent people would like to watch). Rating was done on a 7-point scale, with a higher numbers reflecting greater originality, playability and enjoyment. The inter-rater reliabilities for rating of originality, playability and enjoyment were respectively .72, .73, and .86.

In order to identify what strategies were used in creating animals or sports, coders also examined participants' statements about their approaches separately from the drawings. For example, if people included references to specific Earth animals as starting points, they were labeled as using the specific strategy. If they thought of the common characteristics of living things, they were labeled as using the abstract strategy. Of course, some people used both of them, and some people used neither of them. In the same way, coders identified who used the specific strategy, the abstract strategy, both of them, or neither of them in creating new sports. Two coders achieved a minimum 90 percent agreement on these items.

RESULTS

ON THE STRATEGIES USED

As can be seen in Table 1, the strategies used in creating animals in the Control condition varied across participant groups. The percentages using abstract strategies for BKG, SKG and CG were 46%, 13%, and 25% respectively, which differed from what would be expected by chance alone, x^2 (2, N = 92) = 19.93, $p < .01$. Participants in the BKG had a greater tendency to use the abstract strategy in imaging extraterrestrial animals. Likewise, the percentages reporting the use of abstract information for BKG, SKG and CG in creating sports under the Control condition were 8%, 30%, and 11% respectively, x^2 (2, N = 92) = 17.43, $p <$ .01, Participants in the SKG had a greater tendency to use the abstract strategy in developing new sports. It appears that the strategies used in creative idea generation are influenced by domain knowledge. When developing new ideas in a given domain without any special instructions about how to approach the task, a more knowledgeable person has a greater probability of using an abstract strategy.

TABLE 1. Percentages of different types of strategies used by participants across the conditions in two tasks.

Condition	Create an extraterrestrial animal				Create a new sport			
	Specific strategy	Abstract strategy	Both	Neither	Specific strategy	Abstract strategy	Both	Neither
Abstract								
BKG	.16	.19	.59	.06	.63	.00	.34	.03
SKG	.67	.03	.19	.11	.42	.03	.56	.00
CG	.33	.30	.33	.04	.81	.00	.19	.00
Total	.40	.16	.37	.07	.60	.01	.38	.01
Exemplar								
BKG	.76	.00	.24	.06	.93	.00	.07	.00
SKG	.92	.00	.03	.07	.88	.00	.09	.03
CG	.71	.00	.25	.04	.86	.00	.14	.00
Total	.80	.00	.17	.03	.89	.00	.10	.01
Control								
BKG	.42	.04	.42	.12	.92	.00	.08	.00
SKG	.70	.08	.05	.17	.69	.13	.18	.00
CG	.54	.00	.25	.21	.82	.00	.11	.07
Total	.58	.04	.21	.17	.79	.05	.13	.02

Note: Specific strategy means relying on some kinds of specific instances. Abstract strategy means utilizing certain abstract information.

Consistent with previous findings, the strategies used varied systematically across the instructional conditions. For example, the percentages of participants reporting that they relied on abstract information in creating animals under Abstract, Exemplar, and Control conditions were 53%, 17%, and 25% respectively, x^2 (2, N = 276) = 22.57, p < .001. The corresponding scores in creating sports were 39%, 10%, and 18% respectively, x^2 (2, N = 276) = 20.09, $p < .001$. It seems that instructions actually can induce people to make choices to adopt alternative strategies. However, such effects are regulated by domain knowledge in some way. As can be seen in Table 1, under the Abstract condition in creating animals, BKG reported more tendency to rely on abstract information than SKG and CG (78% vs. 22% vs. 63%), x^2 (2, N = 95) = 25.5, $p < .01$. Under the Abstract condition in creating sports, SKG reported more tendency to depend on abstract information than BKG and CG (59% vs. 34% vs. 19%), x^2 (2, N = 95) = 12.63.5, $p < .05$. The results show that less knowledgeable people, even when instructed to rely on abstract principles, still have less likelihood to choose the abstract strategy in creative idea generation.

ON THE PROPERTIES OF CREATIONS

There were significant differences across the conditions in the likelihood of including typical properties of Earth animals (see Table 2), with the most and least occurring in the Exemplar and Abstract conditions, such as eyes, x^2 (2, N = 276) = 8.289, $p < .05$, ears, x^2 (2, N = 276) = 11.674, $p < .01$, mouth, x^2 (2, N = 276) = 8.658, $p < .05$, nose, x^2 (2, N = 276) = 9.596, $p < .01$, arms, x^2 (2, N = 276) = 10.168, $p < .01$. However, such a trend was not found in the properties of legs, x^2 (2, N = 276) = 2.241, $p > .05$, wings, x^2 (2, N = 276) = .548, $p > .05$, and symmetry, x^2 (2, N = 276) = .791, $p > .05$. It could be that legs and symmetry are such extremely typical and important properties of all Earth animals that people under each condition have about an equally high probability of including them in their created animals. Conversely, wings are less typical properties of Earth animals and may therefore be less likely to be included regardless of condition. Furthermore, there were also significant differences across the conditions in the likelihood of including some novel variations on appendages, x^2 (2, N = 276) = 11.322, $p < .001$, and senses, x^2 (2, N = 276) = 47.053, $p < .001$, with the most occurring in the Abstract and the least in Exemplar conditions.

Similar phenomena were observed in the task of creating new sports as well. As can be seen in Table 2, the sports developed under the Abstract condition exhibited the most likelihood to include novel ground, x^2 (2, N = 276) = 18.059, $p < .001$, novel implements, x^2 (2, N = 276) = 9.08, $p < .05$, novel grouping, x^2 (2, N = 276) = 8.339, $p < .05$, and novel rules, x^2 (2, N = 276) = 7.699, $p < .05$. Nevertheless, such a difference did not appear for the property of contest, which could mean that contest is usually considered as a very typical property of sports so it has a high probability to be included in the new creations regardless of condition.

Domain knowledge affected the properties of the creations, as was shown in Table 2, but such effects were regulated by instructional manipulations.

TABLE 2. Percentages of properties of two creations developed by participants across the conditions.

Condition	Extraterrestrial animals in other planets										New sports				
	Eye	Ear	Mouth	Nose	Arm	Leg	Wing	Symmetry	Novel appendages	Novel senses	Novel square	Novel implements	Novel grouping	Novel rules	Contest
Abstract															
BKG	.31	.28	.59	.28	.25	.47	.06	.66	.84	.84	.63	.34	.41	.88	.69
SKG	.77	.42	.67	.42	.53	.69	.22	.97	.67	.67	.83	.39	.39	.92	.94
CG	.62	.15	.67	.37	.56	.59	.15	.96	.56	.85	.33	.19	.22	.81	.56
Total	.58	.29	.64	.36	.44	.59	.15	.86	.69	.78	.62	.32	.35	.87	.75
Exemplar															
BKG	.82	.45	.86	.55	.69	.72	.14	.86	.55	.34	.28	.21	.14	.72	.62
SKG	.81	.72	.91	.81	.75	.78	.06	1	.31	.28	.22	.09	.25	.81	.75
CG	.57	.36	.68	.36	.57	.50	14	.82	.50	.32	.50	.11	.25	.67	.68
Total	.78	.54	.82	.58	.67	.67	.11	.90	.45	.31	.33	.13	.21	.74	.69
Control															
BKG	.71	.21	.75	.29	.46	.63	.17	.79	.83	.58	.38	.13	.13	.75	.46
SKG	.75	.48	.80	.60	.70	.80	.18	.93	.40	.35	.50	.38	.23	.78	.88
CG	.61	.18	.79	.36	.50	.57	.07	.82	.61	.25	.25	.29	.14	.61	.46
Total	.70	.32	.78	.45	.58	.68	.14	.86	.58	.38	.39	.28	.17	.72	.64

Firstly, the Abstract condition seemed to induce people with more domain knowledge to develop more novel properties of creations. Under the Abstract condition in creating animals, the animals produced by BKG had the least likelihood to include typical properties of Earth animals, such as eyes, x^2 (2, N = 95) = 15.442, p <.001, arms, x^2 (2, N = 95) = 7.268, p < .05, and symmetry, x^2 (2, N = 95) = 17.501, p <.001. Such trends were also observed in other properties, such as mouth, nose, legs, and wings, although the differences fell below the level of significance. In addition, their creations were more likely to include novel appendages, x^2 (2, N = 95) = 5.95, p = .05. Likewise, under the Abstract condition in creating sports, SKG developed new sports exhibiting more likelihood to include novel ground, x^2 (2, N = 95) = 16.392, p <.001, and contest, x^2 (2, N = 95) = 13.274, p <.01.

Secondly, the Exemplar condition appeared to block the knowledgeable people from generating novel properties of the creations to certain extent. Under the Exemplar condition in creating animals, the animals developed by BKG were similar to the creations of SKG and CG. Compared with the results under Abstract condition, the significant differences disappeared in the properties of eyes, x^2 (2, N = 89) = 2.213, p >.05, arms, x^2 (2, N = 89) = 2.215, p >.05, and symmetry, x^2 (2, N = 89) = 5.88, p >.05. Meanwhile, the difference in appendages fell below the level of significance, x^2 (2, N = 89) = 3.941, p >.05. Similar findings were also observed in the task of creating sports, in which the sports developed by BKG, SKG, and CG under the Exemplar condition were not significantly different in the properties of ground, x^2 (2, N = 89) = 5.867, p >.05, and contest, x^2 (2, N = 89) = 1.189, p >.05.

Thirdly, under the Control condition, the creations produced by people who possessed a higher level of domain knowledge exhibited more likelihood to include the novel properties. In the task of creating animals, the animals developed by BKG under the Control condition had more likelihood of including novel appendages, x^2 (2, N = 92) = 11.693, p <.01, and novel senses, x^2 (2, N = 92) = 6.37, p <.05. In the task of creating sports, the sports developed by SKG under the Control condition seemed to have more likelihood of including novel ground, grouping, implements, and rules, although the differences were below the level of significance.

ON THE ORIGINALITY OF CREATIONS

Figure 1 shows the originality rating of animals developed by participants across the conditions. A two-way ANOVA with domain knowledge and instructional manipulation as between-subjects variables was conducted to examine the effect of knowledge and instruction on the originality of animals. The results showed there was a significant main effect for domain knowledge on the originality of the generated animals. BKG who possessed more biology domain knowledge developed animals rated highest in originality, F (2, 267) = 14.08, p < .001. Post Hoc tests showed the animals developed by BKG (M = 3.99, SD = 1.28) exhibited higher originality than the creations of SKG (M = 3.24, SD = 1.32), p < .001, and were marginally more original than the creations of CG (M = 3.77, SD = 1.08), p = .061. As expected, there was a significant difference in mean originality rating across the conditions, F (2, 267) = 16.205, $p < .001$, with the highest score in the Abstract condition (M = 4.19, SD = 1.2), lower in Control condition (M = 3.66, SD = 1.22) and the lowest in Exemplar condition (M = 3.20, SD = 1.26). Post Hoc tests showed there were significant differences between any two of them. The interaction between domain knowledge and instructional manipulation was also significant, F (4, 267) = 2.851, p <.05,it seemed that the Exemplar condition decreased the originality of animals developed by BKG greatly. According to a one-way ANOVA, the originality of animals developed by BKG under the Exemplar condition scored lowest across the three conditions, F (2, 82) = 12.935, $p < .001$. Post Hoc tests showed BKG in the Exemplar condition developed animals with lower originality (M = 3.12, SD = 1) than those produced in the Abstract condition (M = 4.5, SD = 1.26), $p < .001$, and those in the Control condition (M = 4.36, SD = 1.1), $p < .001$.

Similar findings occurred for the mean difference score of the generated animals (see Figure 2). BKG produced animals with the highest difference score of all participants, F (2, 267) = 14.105, $p < .001$. Post Hoc tests showed the difference score of animals developed by BKG (M = 2.15, SD = 1.57) was higher than the creations of SKG (M = 1.20, SD = 1.14), $p < .001$, and CG (M = 1.48, SD =

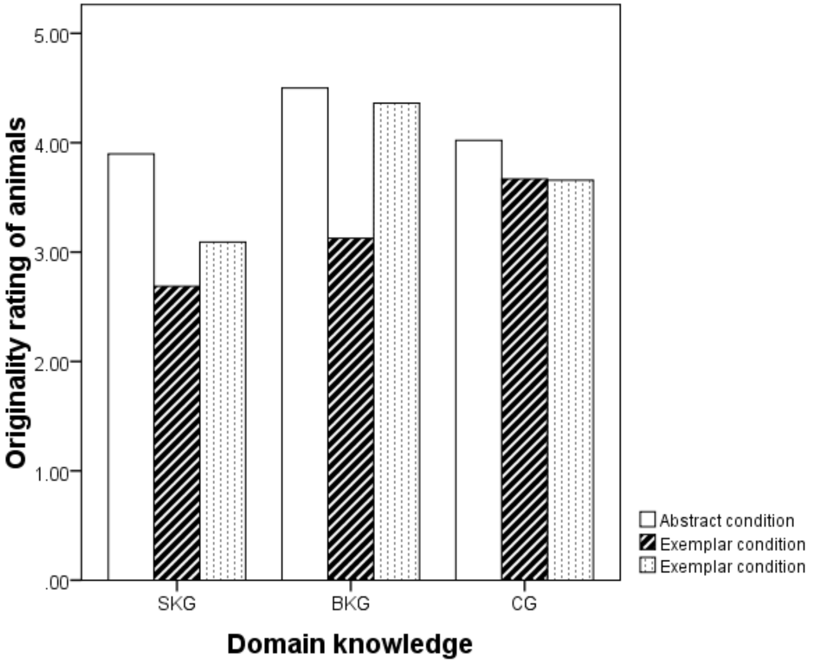

FIGURE 1. Originality rating of animals developed by participants across the conditions.

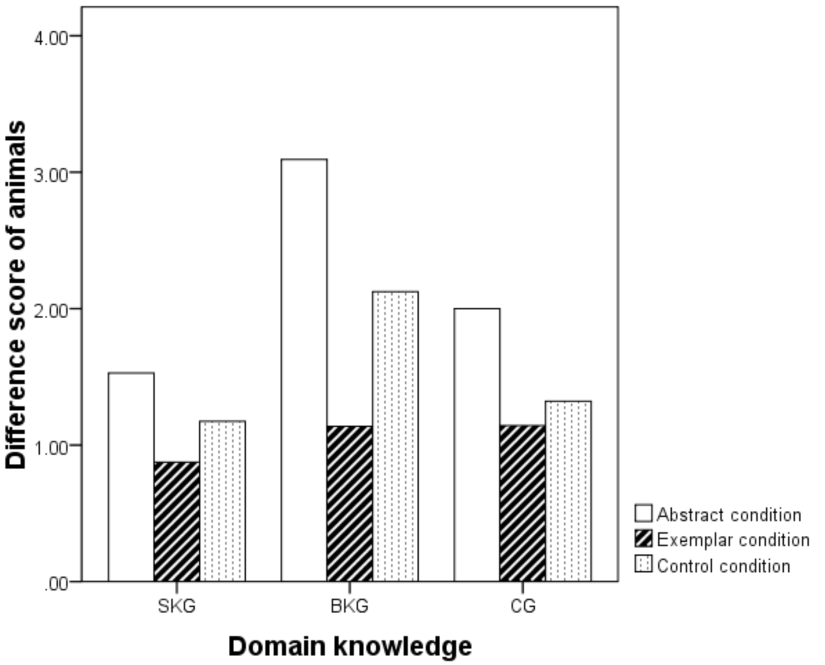

FIGURE 2. Difference score of animals developed by participants across the conditions.

1.19), $p < .001$. There was a significant main effect for instructional manipulation on the difference score, F (2, 267) = 21.117, $p < .001$, with the highest score in Abstract condition (M = 2.19, SD = 1.46), lower in Control condition (M = 1.47, SD = 1.35), and the lowest in Exemplar condition (M = 1.04, SD = .96). Post Hoc tests showed there were significant differences between any two of them. There was also a significant interaction between domain knowledge and instructions, F (4, 267) = 2.748, $p < .05$, it was found that the Exemplar condition reduced the difference score of animals produced by BKG greatly. According to a one-way ANOVA, BKG under the Exemplar conditions produced animals with the lowest difference scores across the three conditions, F (2, 82) = 15.83, $p < .001$. Post Hoc tests showed the difference score of animals produced by BKG under the Exemplar condition (M = 1.14, SD = .95) was lower than the creations developed under the Abstract condition (M = 3.09, SD = 1.61), $p < .001$, and the creations formulated under the Control condition (M = 2.13, SD = 1.39), $p < .05$.

Figure 3 shows the originality rating of sports developed by participants across the conditions. A two-way ANOVA revealed that there was a significant main effect for instructional manipulation on the originality of the created sports, F (2, 267) = 12.836, $p < .001$. Post Hoc tests showed the sports developed in the Exemplar condition (M = 2.82, SD = .95) exhibited lower originality than those produced in the Abstract condition (M = 3.54, SD = .97), $p < .001$, and those in the Control condition (M = 3.29, SD = 1.09), $p < .01$. Oddly, domain knowledge did not exert a significant main effect on the originality of new sports, F (2, 267) = 1.095, $p > .05$. Based on the analysis of the interaction between domain knowledge and instructional manipulation, F (4, 267) = 4.434, $p < .01$, a surprising phenomenon was revealed; the originality of new sports produced by SKG under the Control condition was at a very low level, although SKG under the Abstract condition produced new sports with the highest originality rating among all participants' creations.

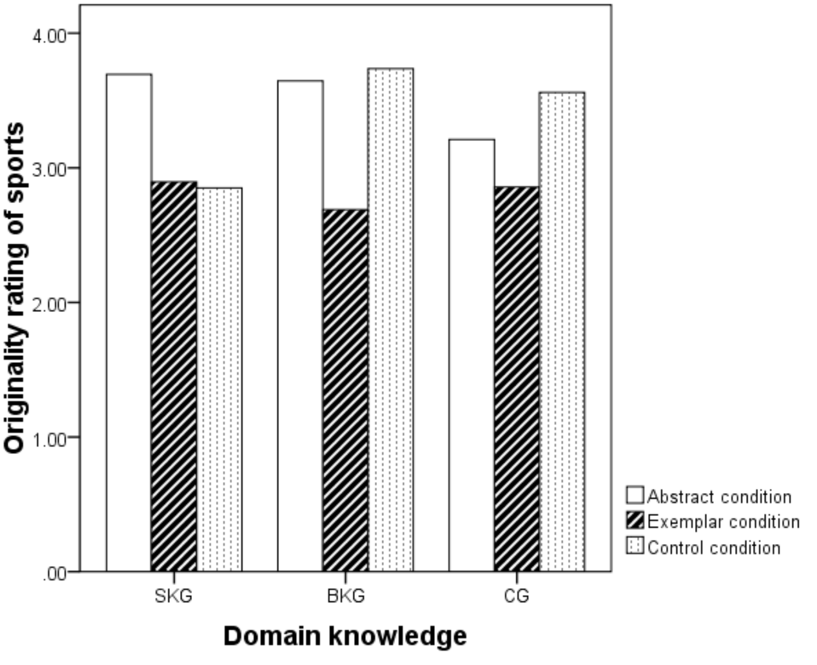

FIGURE 3. Originality rating of sports developed by participants across the conditions.

Figure 4 shows the difference score of sports developed by participants across the conditions. A two-way ANOVA revealed domain knowledge exerted main effect on the difference score of the created sports, F (2, 267) = 4.325, $p < .05$. Post Hoc tests showed the difference score of sports developed by SKG (M = 1.94, SD = 1.13) was higher than for the creations of CG (M = 1.46, SD = 1.09), $p < .01$. Instructional manipulation also exerted a main effect on the difference score of the created sports, F (2, 267) = 10.743, $p < .001$. Post Hoc tests showed the sports developed in the Abstract condition (M = 2.16, SD = 1.16) exhibited higher difference scores than those produced in the Exemplar condition (M = 1.42, SD = 1.11), $p < .001$, and those in the Control condition (M = 1.57, SD = 1.1), $p < .01$. There was also a significant interaction between domain

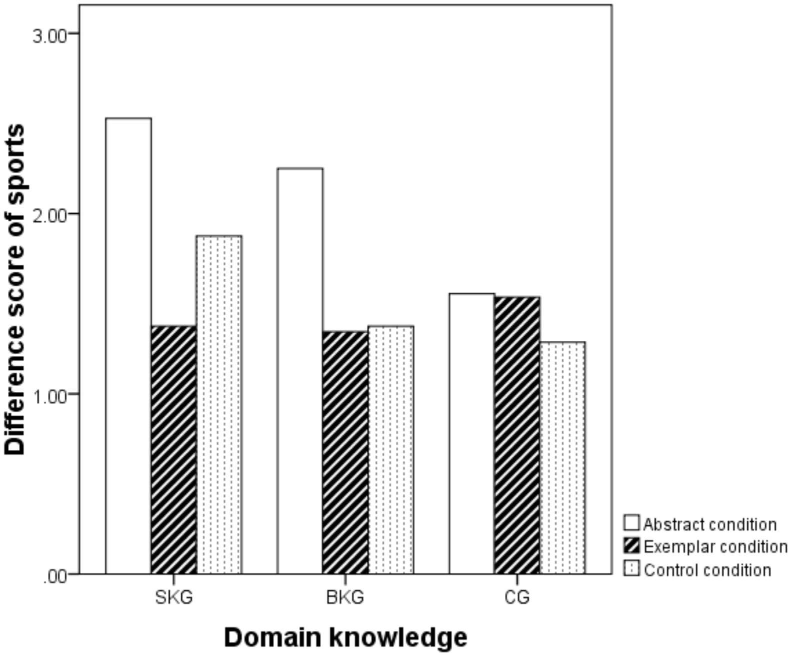

FIGURE 4. Difference score of sports developed by participants across the conditions.

knowledge and instructions, F (4, 267) = 2.41, p = .05, it seemed that the Exemplar condition reduced the difference score of sports produced by SKG greatly. A one-way ANOVA showed SKG in the Exemplar condition produced sports with the lowest difference scores across the three conditions, F (2, 105) = 10.43, $p <$ .001. Post Hoc tests showed SKG in the Exemplar condition developed sports with lower difference scores (M = 1.38, SD = .98) than those produced in the Abstract condition (M = 2.53, SD = 1), $p <$ .001, and those in the Control condition (M = 1.88, SD = 1.14), $p <$ .05.

ON THE PRACTICALITY OF CREATIONS

As stated in the Methods, the practicality of the created sports was evaluated in two dimensions (playability and enjoyment). Figure 5 shows the playability rating of sports developed by participants across the conditions. A two-way ANOVA revealed that domain knowledge exerted a significant main effect on the playability of the new sports, F (2, 267) = 4.421, $p <$ .05. Post Hoc tests showed the sports developed by SKG displayed higher playability (M = 4.64, SD = .91) than the creations of CG (M = 4.28, SD = .99), $p <$ .05, and were marginally different than the creations of BKG (M = 4.34, SD = .92), p = .09. Such a result suggests that a higher level of domain knowledge might bring forth more practical creations in the domain. There was also a significant difference across the conditions in

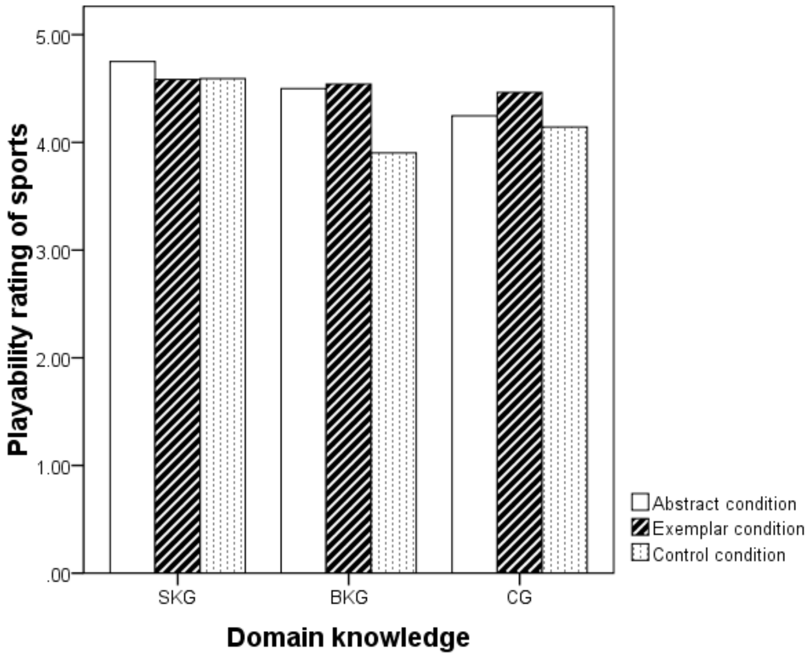

FIGURE 5. Playability rating of sports developed by participants across the conditions.

the playability of new sports, F (2, 267) = 3.128, $p < .05$, with the highest in the Exemplar condition (M = 4.53, SD = .77) and the lowest in the Control condition (M = 4.28, SD = 1.01). However, this does not indicate that the instruction to use specific instances is the unique way to promote the playability of new sports. Post Hoc tests showed that the sports developed in the Exemplar condition and the Abstract condition (M = 4.52, SD = 1.02) possessed similar playability, $p > .05$.

Figure 6 shows the enjoyment rating of sports developed by participants across the conditions. A two-way ANOVA revealed that domain knowledge exerted a main effect on enjoyment of the new sports, F (2, 267) = 7.799, $p < .01$. SKG created sports with higher enjoyment (M = 4.52, SD = 1.21) in comparison with the creations of BKG (M = 4.21, SD = 1.21) and CG (M = 3.82, SD = 1.18). There was no significant difference across the conditions in the enjoyment of the new sports, F (2, 267) = 1.782, $p > .05$, but the instructional manipulation still played a role in the creations of SKG who possessed more sport domain knowledge. According to a one-way ANOVA, the enjoyment of sports developed by SKG displayed a significant difference across the conditions, F (2, 105) = 4.546, $p < .05$, with the highest in the Abstract condition (M = 4.95, SD = 1.11), lower in the Control condition (M = 4.46, SD = .98), and lowest in the Exemplar condition (M = 4.10, SD = 1.42).

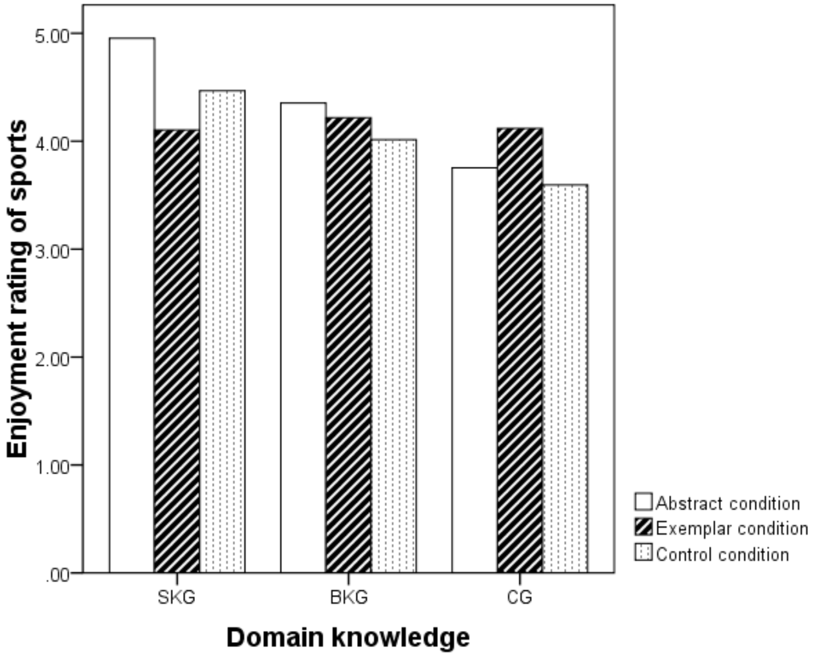

FIGURE 6. Enjoyment rating of sports developed by participants across the conditions.

DISCUSSION

The results of the present study confirm and qualify previous findings (e.g., Ward, 1994; Ward, Patterson, Sifonis, Dodds, & Saunders, 2002; Ward, Patterson, & Sifonis, 2004). In creative idea generation, some people access and rely on specific known exemplars as the beginning point of developing new ideas; meanwhile, some others consult more abstract information. But such individual differences are not based on rigid constraints or fixed processing abilities. In other words, the approaches used in creative idea generation are malleable. People can be induced to adopt approaches that are relatively more abstract or more specific in character, and their creations become more or less novel as a result. When people use the approach of relying on abstract information, they have greater tendencies to project novel variations into the creations, and less likelihood of carrying over typical properties of existing instances to the products. Thus, they produce more original and novel new ideas.

A noteworthy and interesting finding revealed in this study seems to be that the strategy people select in creative idea generation is influenced not only by instructional manipulation but also by their domain knowledge. When performing a creative generation task in a domain, individuals who possess a higher level of domain knowledge have greater tendencies to adopt abstract approaches. It appears that the abstract, principle-based, well-organized representations of domain knowledge possessed by more knowledgeable persons (Chi, Glaser, & Rees, 1982) facilitate retrieving abstract information and enhance the tendency of choosing the abstract approaches. Broadly speaking, such results support the statements of Lubart (2001) and Perkins (1992), who pointed out that the structure of available knowledge influences the heuristics used in the process of creative thought. Similar to the findings of Scott, Lonergan, and Mumford (2005), which stated that conceptual combination in creative thought might proceed using alternative approaches (analogical or case-based approach) according to the nature of the knowledge being applied, the present study demonstrates the strategies used in creative idea generation might be regulated by domain knowledge.

However, such results would not refute the path-of-least-resistance model (Ward, 1994; Ward, 1995; Ward, Dodds, Saunders, & Sifonis, 2000), which suggests that people's predominant tendency, when they develop new ideas in a domain, is to retrieve fairly specific, basic level exemplars from that domain as a beginning point. Once again, the present study confirms this notion. As can be seen in Table 1, the strategy of relying on specific instances is still the primary choice of participants, no matter what domain knowledge they possess and what instruction is given. People with a higher level of domain knowledge, in comparison with those with less domain knowledge, are only characterized by a greater tendency to utilize the abstract information while relying on specific instances. Nevertheless, it must be noticed that generating extraterrestrial animals and developing new sports are both low level creative (or small c) tasks. In addition, the participants involved in the present study do not possess the highest level of domain knowledge about biology and sport. Therefore, such findings should not be arbitrarily extended to situations in which people with the highest level of domain knowledge perform higher level creative tasks.

The present study shows that domain knowledge can serve as a predictor of the originality of new ideas, which is consistent with some previous statements (e.g., Weisberg, 1999), instead of an agreement with the finding of Ward (2008). The merit might be that individuals with higher levels of expertise possess more abstract and well-organized schematic knowledge (Chi, Glaser, & Rees, 1982); as a result, the abstract principles embedded in schematic knowledge (Sakamoto & Love, 2004) are more easily accessible. Just because of this, BKG with higher level of biology domain knowledge could readily activate more abstract principles from their schematic knowledge in the Abstract or Control conditions, thus they developed more novel and original animals. Understandably, BKG produced relatively equally original animals with other participants under the Exemplar condition, for the activation of their schematic knowledge was inhibited by the deliberate instructional manipulation. Now, a noteworthy inference emerges that the schematic knowledge contained in domain knowledge might be the true contributor to the originality of new ideas, yet the case-based knowledge has little benefits to the novelty of creations.

In contrast to predictions, sports domain knowledge exerted no significant main effect on the originality of new sports, which seems to disprove the conclusion listed above at the first glance. But if informed about the characteristics of the undergraduates majoring in sports in China, explanations could be easily sought. Different from the undergraduates of Western countries, the primary reason why the students in China choose sports as their majors in universities is just for passing the *College Entrance Examination (CEE)* of China more easily. Generally, their academic achievements in high schools are much worse than their peers, which impels them to take up some kinds of sports and become what we called "Sports Students". That designation can help them enrol in sports departments of universities with very low CEE scores. When entering universities, they usually focus on the practice and contest without much time devoted fully to theoretical studies. Consequently, they are actually more knowledgeable about sports than others, but only a little superior to others in schematic knowledge of the sports domain. Thus, the new sports developed by them, especially under the Control condition, did not exhibit more originality. If the study selected the people who were really experts in sports domain (e.g., doctoral candidates or professors in sports department) as the participants, a significant effect of domain knowledge might have been revealed.

The present study confirms the finding of Ward (2008) that domain knowledge is linked to the practicality of generated ideas, with greater sports knowledge being associated with the production of more playable and enjoyable novel sports. Meanwhile, an expected finding appears that the instruction of inducing people to utilize an exemplar approach can improve the playability of new sports. Such results reinforce the potential advantage of relying on specific known domain instances in creative thought once again. Basala (1988) pointed out that many advances in a wide range of domains are based on a slow incremental process of patterning new ideas after specific earlier ones. Rich and Weisberg (2004) found that the transformation of case elements derived from British situational comedies provided a basis for American situational comedies. Weisberg (2004) provided evidence indicating a similar phenomenon may also have a role in scientific and artistic creativity. Notably, the present study also provides a new perspective that to adopt an exemplar approach might not be the only way to promote the practicality of creations. Based on the present study, it is found that to utilize the abstract approach can bring forth nearly equally practical new sports. Furthermore, there is not any negative correlation between practicality and originality of the new sports [originality and playability, r (274) = .058, $p > .05$; originality and enjoyment, r (274) = .286, $p < .01$; playability and enjoyment, r (274) = .477, $p < .01$]. Such results imply the statement of Ward (2008) that originality may come at a cost of practicality should be evaluated carefully.

Other factors, such as age, grade and gender, were found to be unrelated to both originality and practicality of the creations. Domain knowledge and instructions could be regarded as the effective influential factors in creative idea generation. These two factors and the interaction between them determine what approaches would be chosen to generate new ideas and what original and practical creations would be developed. Such results have a few implications for understanding the creativity of people. To begin, it seems reasonable that not only knowledge provides the substance for one's creative thought, but also the creative thought is shaped by the knowledge one possesses. Second, in order to develop more novel and original creations, people should possess abundant domain knowledge, especially schematic knowledge, and retrieve such knowledge in creative idea generation deliberately. However, an important caveat must be noted that the results of the present study probably can not be arbitrarily extended to the situation of performing the highest level creative tasks (e.g., creating products which have big leaps from what was known or can change our lives or the ways we view the world), because the nature of task and the constraints embedded in the task might influence the role of domain knowledge in creative idea generation.

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