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Abstract

Using science majors as an example, we analyzed how generative cognition, organizational culture, and personality traits affect student imagination, and examined the mediating effects of generative cognition and organizational culture. A total of 473 undergraduates enrolled in physical, chemical, mathematical, and biological science programs participated in this empirical study. The traits of openness, agreeableness, conscientiousness, extraversion, and neuroticism had various effects on student imagination. Openness proved to be the most influential factor on initiating, conceiving, and transforming imagination. Extraversion was the second best predictor of initiating imagination, and conscientiousness was the second best predictor of conceiving and transforming imagination.

Keywords: Generative cognition; imagination; organizational culture; personality traits; science education.

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Los Roles que Median la Cognición Generativa y la Cultura Organizativa entre los Rasgos de Personalidad e Imaginación de los Estudiantes

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Resumen

Basándonos en estudiantes universitarios de Ciencias como ejemplo, hemos analizado de qué manera el conocimiento generativo, la cultura de la organización y los atributos personales afectan la imaginación de los estudiantes, y logramos, así, examinar los efectos mediadores del conocimiento generativo y la cultura de la organización. Un total de 473 estudiantes no graduados se inscribieron en programas de física, química, matemática y biología y participaron de este estudio empírico. Los rasgos como sinceridad, amabilidad, concienciación, extroversión y neuroticidad tuvieron efectos diversos en la imaginación de los estudiantes. La extroversión fue el segundo predictor que más impulsa la imaginación y la concienciación resultó ser el segundo indicador que más genera imaginación y la transforma.

Palabras clave: conocimiento generativo; imaginación; cultura de la organización; rasgos personales; educación científica.

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The discovery of new facts existing in nature is the goal of the scientific imagination (Shin, 1994). However, Holton (1998) noted that little consensus exists on how the scientific imagination functions. Simonton (1988) suggested that it is impossible to fully appreciate the essence of scientific imagination without discussing its psychological dimension. Feist (2006) indicated that science involves a myriad of cognitive process and is a highly social activity, in which much work is performed cooperatively or competitively with other research teams. Feist argued that major social psychological phenomena can be easily applied to the study of science and scientists, but much of this work has not been conducted.

Generative cognition and organizational culture are two critical factors in the cognitive process and social context that have a profound effect on student imagination (Liang, Hsu, & Chang, 2013). Generative cognition is a measure of the value participants place on various ways to formulate mental representation, whereas organizational culture is a measure of the influence of organizational culture and the characteristics of its inhabitants. In addition, Feist (2006) indicated that personality traits can predict scientific interest and creative performance. Despite the separate influence of generative cognition, organizational culture, and personality traits on student imagination, little research exists on how these influences jointly affect student imagination. Using science majors as an example, we analyzed how generative cognition, organizational culture, and personality traits affect the imagination of science majors, and we examined the effects of personality traits on student imagination through generative cognition and organizational culture.

Literature Review

Kettering, inventor of the electric starter, said: "Our imagination is the only limit to what we can hope to have in the future" (Quotations Page, 2014). Numerous scholars have devoted themselves to the study of scientific imagination over the past decade. For example, Stinner (2003) reviewed the imagination of eminent scientists and encouraged science educators to use *the contexts of inquiry* approach to apply imagination to science teaching. Taylor, Jones, Broadwell, and Oppewal (2008) emphasized that teaching critical thinking to science students and inspiring creative imagination are necessary. De Cauz and de Smedt (2010) held that most scientific progress occurs as a mental journey and preserves the properties of the source domain. They suggested that we perceive science as a form of structured imagination.

Lin, Hsu, and Liang (2014) categorized the imagination into three types: initiating, transforming, and conceiving. The initiating imagination refers to exploring the unknown and productively originating novel ideas. The conceiving imagination refers to grasping the core of a concept by using personal intuition and sensibility and formulating effective ideas through concentration and dialectics to achieve a goal. The transforming imagination refers to crystallizing abstract ideas and reproducing knowledge across various domains and situations. We adopted the imagination construct proposed by Lin et al.. In this study, imagination refers to the ability of science majors to initiate, conceive, and transform their mental images into scientific experiments and discoveries.

In this study, *generative cognition* is a measure of the value participants place on various ways to formulate mental representation. Finke (1996) indicated that the generative phase of creative thinking occurs when an individual formulates mental representations. Creative thinking at the generative phase is associated with the prior knowledge and experiences of

an individual (Hsu, Liang, & Chang, 2013). Rivet and Krajcik (2008) suggested that contextualizing instruction is vital for leveraging the experiences and prior knowledge of students to foster an understanding of science. Hsu et al. (2013) also indicated that generative cognition influenced student imagination (r = .40).

Organizational culture, in the current study, is used interchangeably with school culture. This dimension assesses the extent to which school culture and the characteristics of its inhabitants influence the imagination (American College Personnel Association, 1994). Roehrig, Kruse, and Kern (2007) showed that the beliefs of teachers about teaching and learning, and the presence of a supportive network at schools strongly influence the implementation of science curriculum reforms. Gislason (2010) also indicated that school culture is closely related to student learning. Chen, Huang, and Liang (2012) concluded that organizational culture significantly predicts the imagination of educational technology majors.

The Five-Factor model has provided researchers with a reliable psychometric instrument to assess the predictive validity of personality traits in numerous settings, including school and university (McCrae & Costa, 1991). Based on a meta-analysis of 26 studies, Feist (1998) found that high levels of introversion and openness lower the threshold for interest in or pursuit of a career in science. However, Hong and Lin (2011) indicated that the traits of agreeableness and extraversion are significant predictors of student attitudes toward science. Lounsbury et al. (2012) indicated that scientists have higher levels of openness and neuroticism than do non-scientists. Personality trait conscientiousness has been closely associated with academic achievement (O'Conner & Paunonen, 2007) but negatively related to ideation (Batey, Chamorro-Premuzic, & Furnham, 2010).

Vygotsky (2004) developed the philosophical framework that provides insightful interpretations about the cognitive tools of mediation and the notion of knowledge internalization. Internalization of acquired knowledge and experience is a crucial method of facilitating imagination (Valett, 1983).

Thus, *generative cognition* is expected to play a crucial role in mediating imagination (Finke, 1996). In addition, Vygotsky (1978) contended that human development cannot be separated from its social context, learning leads to development, and learning is mediated though interactions with cultural tools and symbol systems. Numerous studies have found that personality traits are positively related to organizational culture (Rasulzada, 2007; Shalley, Zhou, & Oldham, 2004). Based on the aforementioned studies, we proposed the following five hypotheses:

H1: Openness affects the three types of imagination through generative cognition and organizational culture.
H2: Agreeableness affects the three types of imagination through generative cognition and organizational culture.
H3: Conscientiousness affects the three types of imagination through generative cognition and organizational culture.
H4: Extraversion affects the three types of imagination through generative cognition and organizational culture.
H5: Neuroticism affects the three types of imagination through generative cognition and organizational culture.

Method

Imaginative capability. To measure imaginative capability, we used a 29-item scale based on Lin et al. (2014), that consists of three dimensions: initiating imagination, conceiving imagination, and transforming imagination (see Appendix for a list of scale items). Participants were instructed to determine the level of agreement with each item of imaginative capability. The respondents answered on a 6-point scale ranging from 1 (strongly disagree) to 6 (strongly agree).

Big-Five Mini-Markers. Personality traits were measured using the 40-item international English Big-Five mini-markers (Thompson, 2008):

extraversion (e.g., talkative, energetic, outgoing), open to experience (e.g., creative, intellectual, deep), neuroticism (e.g., emotional, anxious, moody), conscientiousness (e.g., efficient, systematic, organized), and agreeableness (e.g., sympathetic, cooperative, warm). Before setting up the survey, this scale was translated from English to Chinese and then translated back into English by three independent bilingual translators to ensure equivalency of meaning (Brislin, 1980). Respondents answered on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Generative cognition and organizational culture. Based on the psychological influence scale (Hsu et al., 2013) and the environmental influence scale (Chen et al., 2012), the subscales of generative cognition (five items) and organizational culture (six items) were adopted in this study. Example items of generative cognition include "use of immersive sensory exploration" and "use of personal experiences." Example items of organizational culture are: "schoolmate characteristics" and "common practice on campus." In the scales, respondents were asked to determine the level of influence each item had on their imagination. The respondents answered on a 6-point scale ranging from 1 (strongly disagree) to 6 (strongly agree).

The proposed hypotheses were tested using data from four universities across Taiwan. Data were collected between March 2013 and April 2013. A total of 473 undergraduates enrolled in physical, chemical, mathematical, and biological science programs participated in the study. The samples consisted of 308 men and 165 women; 31.5% were freshmen, 31.3% were sophomores, 24.3% were juniors, and 12.9% were seniors.

Prior to the investigation, all participants were given a letter containing a brief explanation of the purpose of this study and a statement ensuring the confidentiality of their individual survey results. Immediately after this explanation, the participants were asked to complete a questionnaire consisting of the measurements included in this report. The survey in each university was conducted according to the same procedure. Tutorial groups

were accompanied by their class instructors. In this manner, the problems participants faced when answering questions were resolved immediately.

Results

Confirmatory factor analysis

Confirmatory factor analysis (CFA) with maximum likelihood estimator was conducted using LISREL 8.80 to test the factor structures of the scales. The indicators recommended by Hu and Bentler were used to assess goodness of model fit (Hu & Bentler, 1999). The composite reliability estimates should be .60 or higher (Fornell & Larcker, 1981). The standardized factor loadings should be .50 or higher to achieve convergent validity (Hair et al., 2006). Discriminant validity in this study was examined using a confidence interval test. The confidence intervals for the estimates of inter-factor correlations should not include one (Bagozzi & Phillips, 1982).

According to these quality criteria, the three-factor structure of imaginative capability yielded an acceptable fit for this study (X^2 = 1433.44, df = 374, p < .005, RMSEA = .079, SRMR = .070, CFI = .96, NFI = .95, TLI = .96). The results of CFA also showed a good fit to match the hypothesis that the five personality traits and two constructs of generative cognition and organizational culture, X^2 = 1014.69, df = 384, p < .005, RMSEA = .059, SRMR = .060, CFI = .95, NFI = .92, TLI = .94. Our results showed that all the constructs used in this study had strong internal consistency. Both convergent and discriminant validity were also assured.

Structural model

Structural equation modeling (SEM) with maximum likelihood estimation was continually employed to test the hypotheses. We examined the mediating effects based on the steps provided by MacKinnon et al. (2002).

Our results showed that the relationships between all predictive variables and student imagination were significantly reduced when the mediators (generative cognition and organizational culture) were included in the model. Therefore, the mediation models were initially supported. We removed the insignificant paths, and then revised the structural model as shown in Figure 1. The revised model showed a model fit comparable to that of the initial model (X^2 = 4736.76, df = 1623, p < .005, RMSEA = .068, SRMR = .070, CFI = .95, NFI = .95, TLI = .94). It accounted for substantial variance in generative cognition (38%), organizational culture (7%), initiating imagination (65%), conceiving imagination (61%) and transforming imagination (60%).

Openness directly and indirectly predicted the three types of imagination through both mediators; H1 was supported. Agreeableness indirectly predicted the three types of imagination through both mediators, but only directly predicted initiating imagination; H2 was partially supported. Conscientiousness directly predicted conceiving and transforming imagination, and indirectly predicted conceiving imagination through organizational culture; H3 was partially supported. Extraversion only directly predicted initiating imagination; H4 was disproved. Neuroticism directly predicted initiating and conceiving imagination, and indirectly predicted the three types of imagination through generative cognition; H5 was partially supported.

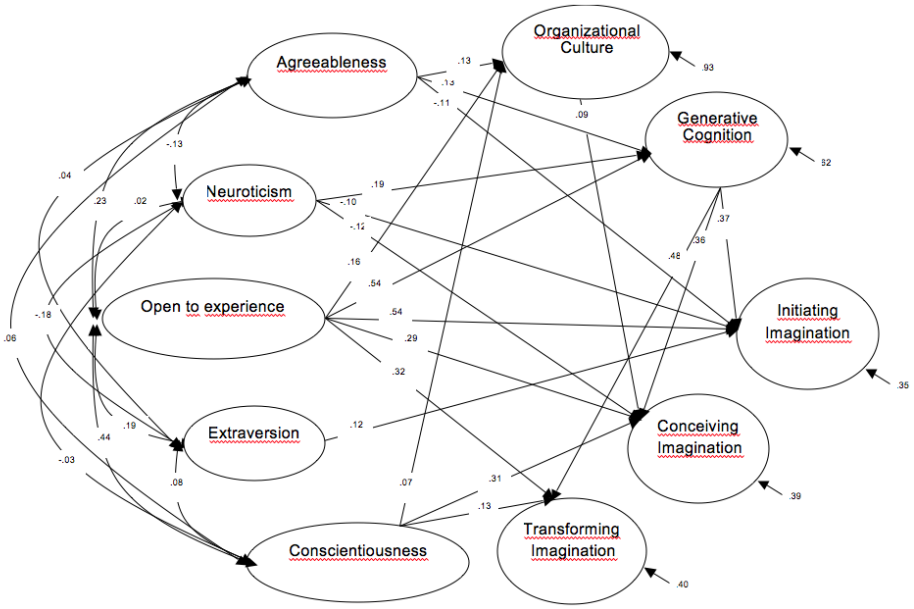

Figure 1. The mediation model of the imagination (n = 473)

Our results show that, in addition to the mediators, openness proved to be the most influential factor, which affected the three types of imagination. Extraversion was the second most influential predictor of initiating imagination, whereas conscientiousness was the second most influential predictor of both conceiving and transforming imagination. The direct and indirect effects resulting from all the latent predictor variables on the three types of imagination are reported in Table 1.

Table 1

The direct and indirect effects of the mediation model (n = 473)

Latent Predictor Variables	Initiating Imagination			Conceiving Imagination			Transforming Imagination		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Extraversion	.12	--	.12	--	--	--	--	--	--
Openness	.54	.20	.74	.29	.21	.50	.32	.26	.58
Neuroticism	-.10	.07	-.03	-.12	.07	-.05	--	.09	.09
Conscientiousness	--	--	--	.31	.01	.32	.13	--	.13
Agreeableness	-.11	.05	-.06	--	.06	.06	--	.06	.06
Generative cognition	.37	--	.37	.36	--	.36	.48	--	.48
Organizational culture	--	--	--	.09	--	.09	--	--	--

Discussion

Direct effects of personality traits

Our results show that the trait of *openness* strongly predicted the three types of imagination. This finding is consistent with those of previous research (Feist, 1998; McCrae & Costa, 1991), which indicated that open people are curious and apt to entertaining new ideas. This study contributes to the understanding that openness could be best used in generating novel ideas and could be most valuable during the ideation stage of scientific discoveries.

The personality trait of *extraversion* only affects initiating imagination. This implies that extraversion helps science students explore the unknown and generate unusual ideas (Batey et al., 2010). Extraversion has insignificant effects on conceiving and transforming imagination, probably because these types of imagination rely on personal concentration to formulate ideas (Zafar & Meenakshi, 2012).

The personality trait of *conscientiousness* significantly predicts conceiving and transforming imagination. This implies that

conscientiousness is particularly beneficial for formulating ideas to achieve goals and applying knowledge to various situations. The results support the finding that conscientiousness is useful for task-related endeavors (O'Conner & Paunonen, 2007) indicating that conscientiousness is applied during the stages of experiment implementation.

The personality trait of *agreeableness* exerts a negative effect on initiating imagination, whereas *neuroticism* negatively predicts both initiating and conceiving imagination. Agreeable people are typically cooperative and considerate, which explains their negative influence on generating unusual ideas. Neurotic people are typically anxious and easily disturbed, which explains their negative influence on ideation and concentration. The total effects reveal that both agreeableness and neuroticism are likely to be critical in the implementation process of scientific discoveries.

Mediating effects of generative cognition and organizational culture

Our data shows that the personality traits of openness, neuroticism, and agreeableness predict the three types of imagination through generative cognition. This means that the methods of formulating mental representation help science students generate novel ideas, use their cognitive abilities, and apply knowledge in various situations. The results are particularly favorable for students who are open-minded, agreeable, and neurotic. Because contextualizing instruction is crucial for leveraging student experience and prior knowledge (Rivet & Krajcik, 2008), we suggest that science educators focus on critical issues, such as innovation, professional problem-solving, situated learning, and real-life workplace examples, to improve mental representation formulation in students. In addition, scientific problems are increasingly being solved in teams, and more research into group thinking and the relationship between specific personalities (such as openness,

neuroticism, and agreeableness) and the social networks they belong to is required.

Our results also indicate that the personality traits of openness, agreeableness, and conscientiousness predict conceiving imagination through organizational culture. This means that school culture and the characteristics of its inhabitants help science students grasp the core of a concept, use their cognitive abilities, and formulate ideas to achieve goals. This result is particularly favorable for students who are agreeable, conscientious, and open to experience. The organizational culture usually determines the ideas that are effective, establishing an invisible boundary for its inhabitants in which social context, interactive patterns, and group approaches to conceptual development are crucial. Further research is necessary to determine whether students with specific traits ignore contextual feedback and school culture, which indicates a need for adaptation, and how this influences the development of their imagination and creative performance. We contributed to the first step in understanding the facilitative role that cultural tools and symbol systems can play in scientific imagination.

Limitations and Conclusion

This study expands on the findings of previous research, but exhibits the following limitations. First, the imaginative capabilities and influential variables in our inquiry were self-perceived. Self-reporting measures were chosen because of the preliminary nature of imagination research. This type of research tool allowed us to generalize our findings to a larger population. Second, we did not attempt to examine the differences in the opinions of instructors and their potential influences on the scientific imagination of students.

In summary, we found that the personality traits of openness and agreeableness indirectly predict the three types of imagination through both

mediators of generative cognition and organizational culture. Conscientiousness predicts conceiving imagination through the organizational culture, whereas neuroticism predicts the three types of imagination through generative cognition. Extraversion only directly predicts initiating imagination. Openness is the most powerful trait for predicting the imagination of engineering majors. Extraversion is the second most influential predictor of initiating imagination, whereas conscientiousness is the second most influential predictor of both conceiving and transforming imagination.

Little research has been conducted to explicitly discuss scientific imagination, much less examine the effects of personality traits on student imagination through specific cognitive and contextual variables. Our study uniquely contributes to the structural view regarding how personality traits predict the imagination development of science majors through generative cognition and organizational culture. We suggest that the imagination of science majors who exhibit various personality traits can be stimulated by improving their generative cognition. We also suggest that the organizational culture plays a pivotal role in science conceptualization and the development of logic. These findings have practical implications in various situations of science learning, and are sufficiently promising to warrant further inquiry.

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Appendix: The Items of the Imaginative Capability Scale

Dimension/item
Initiating Imagination
I often have unique ideas compared to others.
I can develop ideas by examining different perspectives.
I often try untraditional approaches in a project.
I often have a rich diversity of ideas.
I often use a variety of ways to express ideas.
I can constantly come up with various ways to do a project.
I often challenge existing ideas.
I often analyze numerous possibilities on how a problem may develop.
I like to explore the unknown through a variety of experiences.
Conceiving Imagination
I am often emotionally involved in a project.
I can quickly sort out complicated messages.
I can quickly grasp the big picture.
I know how to concentrate on imagination and prevent myself from distraction.
I can continue to focus on a project until the ideas are formed.
I often invest prolonged time on the project until a resolution is found.
I can come up with an approach to meet the teacher's requirements.
I often set goals in accordance with my ability.
I constantly revise my ideas to reach satisfactory results.
I can deliberately think through the contradictions of a problem.
I can make a connection between seemingly unrelated matters.
I can ruminate on an assigned project and put forward different ideas.
Transforming Imagination
I often express my feelings by using concrete ideas.
I can express abstract ideas by using examples from daily life.
I can illustrate difficult ideas with some key concepts.
I can explain unfamiliar concepts with examples common to a target audience.
I can integrate different points of view into my way of thinking.
I often apply my experiences in daily life to class projects.
I can flexibly reproduce my ideas to multiple fields.
I can transfer similar ideas to various situations.

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