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Predicting scientific imagination from the joint influences of intrinsic motivation, self-efficacy, agreeableness, and extraversion

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ABSTRACT

Previous research has indicated that intrinsic motivation and self-efficacy influence the human imagination, and the personality traits of agreeableness and extraversion are significant predictors of students' attitudes toward science. The purpose of this study was to analyze the impacts of intrinsic motivation, self-efficacy, agreeableness, and extraversion on the imagination of science majors. The moderating roles of agreeableness and extraversion were also examined, and the mediating influence of self-efficacy was subsequently tested. A total of 402 science majors from 6 universities across Taiwan participated in the study. Structural equation modeling was used to test all the proposed hypotheses. The results showed that self-efficacy, agreeableness, and extraversion directly affected student imagination. Both intrinsic motivation and agreeableness indirectly affected student imagination through self-efficacy. In addition, both agreeableness and extraversion moderated the influence of intrinsic motivation on the self-efficacy of science majors, and these moderating effects continually influenced student imagination through self-efficacy.

1. Introduction

Increasing numbers of scientific problems are solved in teams. The personality traits of agreeableness and extraversion have been determined to be reliable predictors of team-based work performance (Barrick, Mount, & Judge, 2001) and the most substantial predictors of a student's attitude toward science (Hong & Lin, 2011). In addition, previous research has suggested that both intrinsic motivation and self-efficacy contribute to student performance and persistence in scientific learning (Sawtelle, Brewe, & Kramer, 2012; Wilde, Hußmann, Lorenzen, Meyer, & Randler, 2012). Therefore, it has been recommended that future research on science education investigate the relationships among student self-efficacy, intrinsic motivation, agreeableness, and extraversion.

Without appreciating the scientific imagination, "the origins of science, the emergence of new ideas about natural phenomena, must escape our grasp" (Simonton, 1988, p. 200). However, little research has been conducted to explicitly discuss scientific imagination, and much less has examined the joint influences of intrinsic motivation, self-efficacy, agreeableness, and extraversion on scientific imagination. Because of this gap in the literature, a mediated moderation model was tested to observe how agreeableness and extraversion moderate the influences of intrinsic motivation on the imagination of science majors, and identify the mediating effects of self-efficacy between the predictive variables and the imagination. In this study, *imagination* refers to the capability of science majors to initiate, conceive and transform their mental images of what is not present into scientific discoveries or related actions.

1.1. Imagination and scientific imagination

Imagination is a creative faculty of the mind; it can be viewed as a vital cognitive capacity for learning because "it permits us to give credence to alternative realities" (Heath, 2008; Perdue, 2003). Lin, Hsu, and Liang (2013) categorized the imagination into three types: initiating, conceiving, and transforming. The initiating imagination is the capability to explore the unknown and productively originate novel ideas. The conceiving imagination is the capability to mentally grasp the core of a phenomenon by using personal intuition and sensibility, and the capability to formulate effective ideas through concentration and logical dialectics to achieve a goal. The transforming imagination is the capability to crystallize abstract ideas and reproduce what is known across various domains and situations. This study adopted the construct proposed by Lin et al. (2013).

Horgan (1996) asserted that regardless of the extent of empirical science, the human imagination can always exceed it (p. 30). Numerous scholars have devoted themselves to the study of scientific imagination over the past decade. For example, Stinner (2003) reviewed

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the imagination of eminent scientists and encouraged science educators to use the contexts of inquiry approach to apply imagination to science teaching. Feist (2006) studied the scientific mind and concluded that grasping the scientific imagination and behavior could advance our understanding of what humans can achieve at their best. After interviewing 58 scientists and science educators, Taylor, Jones, Broadwell, and Oppewal (2008) emphasized that teaching critical thinking to science students, and inspiring creative imagination, is required.

Al-Balushi (2009) argued that a reliable mental model of the atom is required to conduct advanced cognitive processes for the mental exploration of chemical phenomena. Imagination, attention mode, and images in the memory shape students' mental images. De Cauz and de Smedt (2010) held that most scientific progress occurs as a mental journey and preserves the properties of the source domain. Thus, they suggested that we should perceive science as a form of structured imagination. Maeyer and Talanquer (2010) stressed that science students should develop and apply analytical methods of reasoning and evaluate the effectiveness of intuitive heuristics in various contexts. Stone (2010) concluded that imagination enables a scientist to make the initial or final advance, as well as the most exemplified breakthroughs.

1.2. Construct imagination in relation to intrinsic motivation, self-efficacy, agreeableness, and extraversion

Curiosity, flexible and insightful thinking, and creativity are the major indicators of the intrinsic motivation of learning (Well & Skoog, 2010), and are closely associated with human imagination. Regarding science education, Pugh, Linnenbrink-Garcia, Koskey, Stewart, and Manzey (2010) observed that students who strongly identify with science are more likely to report engagement in higher levels of transformative experience. Taasoobshirazi and Sinatra (2011) suggested that student motivation positively affects conceptual change and course grade in physics. Liang, Hsu, and Chang (2013) showed that intrinsic motivation can reliably predict both creative imagination ($r = .20$) and reproductive imagination ($r = .26$).

Hong and Lin (2011) indicated that the traits of agreeableness and extraversion are reliable predictors of student attitudes toward science. According to McCrae and Costa (1999), people who score highly on agreeableness are altruistic, considerate, trusting, and soft hearted, whereas those who score highly on extraversion are active, assertive, sociable, and enthusiastic. Pattersson, Kerrin, and Gatto-Roissard (2009) suggested that agreeableness is critical in the implementation process of innovation but not for idea generation, and the association between extraversion and innovation is context dependent. Liang, Chang, and Hsu (in press) indicated that agreeableness can predict reproductive imagination, whereas extraversion can predict creative imagination.

Well and Skoog (2010) indicated that the intrinsic motivation of learning is primarily a function of the basic need to be competent and to exercise personal control, which is closely related to personality traits. Regarding the relationship between agreeableness and intrinsic motivation, Barrick, Stewart, and Piotrowski (2002) suggested that people who score highly on agreeableness are predicted to have cognitive motivations. Jang (2012) emphasized that individuals with high agreeableness are likely to be driven by affective motives. Furthermore, Ariani (2013) confirmed that agreeableness has a positive effect on intrinsic motivation in challenge and curiosity. Therefore, the following hypothesis was proposed:

H1. *Agreeableness* moderates the influences of intrinsic motivation on the three types of imagination.

Regarding the relationship between extraversion and intrinsic motivation, Barrick et al. (2002) claimed that people who score highly on extraversion are predicted to have the motivational intention to enhance their status. Hart, Stasson, Mahoney, and Story (2007) and Fatemi, Pishghadam, and Asghari (2012) have shown that extraversion contributes to the intrinsic motivation of learning. Ariani (2013) suggested that extraversion is a robust predictor of intrinsic motivation, and exerts diverse influences on all dimensions of intrinsic motivation, namely the will to succeed, the need to master challenging tasks, and appreciation of the meaningfulness of academic performance. Knežević (2013) identified that extraversion affects the intrinsic motivation to experience stimulation. Therefore, the following hypothesis was proposed:

H2. *Extraversion* moderates the influences of intrinsic motivation on the three types of imagination.

Komarraju, Karau, and Schmeck (2009) observed that agreeableness predicts the intrinsic motivation to know and to accomplish, whereas extraversion predicts the intrinsic motivation to know and to experience stimulation. Numerous studies have shown that both agreeableness and extraversion are closely related to social and enterprising self-efficacy (Nauta, 2004; Rottinghaus, Lindley, Green, & Borgen, 2002). An increasing number of scientific problems are solved in teams (Feist, 2006), and both agreeableness and extraversion are accurate predictors of team-based performance and student attitudes toward science (Barrick et al., 2001; Hong & Lin, 2011). Therefore, it is reasonable to assume that people who are highly motivated toward developing scientific imagination tend to be agreeable and extraverted, and intrinsic motivation, agreeableness, and extraversion might interact to affect student self-efficacy. Consequently, the following two hypotheses were proposed:

H3. *Agreeableness* moderates the influences of intrinsic motivation on self-efficacy.

H4. *Extraversion* moderates the influences of intrinsic motivation on self-efficacy.

Regarding the relationship between self-efficacy and imagination, numerous studies have indicated that individuals with high levels of self-efficacy perceive themselves as capable of taking the necessary steps to resolve problems (e.g. Bandura, 2000, 2012). Purzer (2011) confirmed Bandura's theory, and determined that low self-efficacy is evident in students' grades and in the conversations of team members. Yueh, Chang, and Liang (2013) indicated that student self-efficacy can positively contribute to the initiating, conceiving, and transforming imaginations of science majors.

Previous studies have shown that self-efficacy is closely associated with the intrinsic motivation of science students (Glynn, Taasoobshirazi, & Brickman, 2009; Gungor, Eryılmaz, & Fakıoglu, 2007). In a study by Hutchison, Follman, Sumpter, and Bodner (2006), students ranked motivation to succeed as the most influential factor affecting their self-efficacy beliefs. Chyung, Moll, and Berg (2010) indicated that self-efficacy and intrinsic motivation interact to affect student learning. Liao, Ferdenzi, and Edlin (2012) further suggested that intrinsic motivation predicts student self-efficacy, and in particular, contributes to the academic performance of international students through the mediation of self-efficacy.

Previous research has shown that both agreeableness and extraversion are closely related to social and enterprising self-efficacy (e.g., Rottinghaus et al., 2002). Tams (2008) determined that agreeableness and extraversion strongly predict self-efficacy, and people whose self-efficacy is grounded in extraverted or agreeable traits might ignore feedback and social referents that indicate a need for adaptation. Numerous studies have indicated that both agreeableness and extraversion reliably predict self-efficacy, and self-efficacy plays a mediating role between personality and social interest or perceived stress (Caprara, Alessandri, & Eisenberg, 2012; Nauta, 2004). Therefore, the following two hypotheses were proposed:

H5. *Self-efficacy* mediates the influences of intrinsic motivation, agreeableness, and extraversion on the three types of imagination.