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The Effects of Imagination between Psychological Factors and Academic Performance: The Differences between Science and Engineering Majors*

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The current study examined the effects that psychological factors have on academic performance through imagination. The study also compared the different ways these factors affect science and engineering majors. A survey was administered at six universities across different regions of Taiwan. The participants in this study were divided into two groups. The first group consisted of 387 science majors, whereas the second group consisted of 386 engineering majors. A structural equation modeling was used to test all the hypotheses proposed. The results showed that the structural models of both majors were similar to each other, but the effects of each variable in the structures were different. Through the mediator effect of imagination, *self-efficacy* had the greatest influence on the academic performance of both groups. *Generative cognition* was identified as the second major predictors of student performance, but its effects on academic performance were slightly negative. The effects of both *intrinsic motion* and *negative emotion* on the science group were smaller than on the engineering group. The influence of *inspiration through* action on the science group was greater than on the engineering group. Finally, practical applications of the current study were suggested. Both limitations and future research were discussed.

Keywords: academic performance; engineering education; imagination; psychological factors; science education

1. Introduction

As the world constantly changes, learning cultures are necessary. Cultivating imagination should be viewed as cornerstones of learning because basic discovery requires high levels of creative thinking [1]. Classroom practices should then change to encourage imagination, inquiry, invention, implementation, and initiative [2]. Many scholars have highlighted the role imagination may play in scientific discovery and engineering invention. However, it is remarkable how little consensus has developed on how imagination functions [3].

Anyone who cares about science and engineering education will pay attention to how students learn, and how their psychological states can influence their imagination. The purpose of this study was threefold: (1) to analyze how student imagination influences academic performance; (2) to examine how psychological factors influence academic performance through their collective impact on imagination; and (3) to compare differences between the structural model of psychology-imagination-performance of science majors and that of engineering majors.

2. Literature

2.1 Psychological influences on imagination and academic performance

Imagination can be perceived as "a creative faculty of the mind" [4]. This point of view explains the close relationship between imagination and psychology. Accordingly, human imagination may be stimulated by several psychological states such as motivation, emotion, cognition, and self-efficacy [5, 6]. These states and the influences upon them were examined by many scholars of science and engineering education. For example, Taasoobshirazi and Sinatra indicated that student need for cognition and goals had a significant influence on motivation. Motivation may further influence both concepts and grades [7]. In addition, Vanasupa, Stolk, and Herter concluded that there is a need for engineering educators to strategically target student development in affective, cognitive, psychomotor, and social domains [8].

To be more specific, numerous scholars have indicated that *intrinsic motivation* is closely associated with creative behavior [9]. Gungor, Erylmaz, and Fakoglu also found that *achievement motivation* highly influenced achievement in the study of physics, whereas *motivation in physics* had a negative

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impact on achievement [10]. In addition, Jones et al. concluded that expectancy-related constructs (i.e., engineering self-efficacy and expectancy for success in engineering) predicted achievement better than the value-related constructs (i.e., identification with engineering and engineering values), whereas value-related constructs predicted career plans better [11].

Although emotions have been studied as facilitating factors in changing people's attitude, motivation, creativity and problem-solving skills [12], there are other studies that argue conversely. Some studies showed that emotions experienced during cognitive processing can be viewed as an unnecessary load, and they can have a negative effect on human reasoning [13]. In the recent research of science education, Abrahams concluded that while practical work generates short-term engagement, it is ineffective in emotionally generating longer-term personal interest in science [14].

In the geneplore model of creative cognition, Finke claimed that two aspects accounted for creative thinking, a generative phase where an individual formulates mental representations, and an exploratory phase where those structures are adopted to establish creative ideas [15]. Creative thinking at the generative phase is closely associated with *generative cognition*, while the exploratory phase is associated with *meta-cognition*. In their research, Rivet and Krajcik concluded that contextualizing instruction is good for leveraging students' experiences and prior knowledge to foster understanding of science [16]. In addition, Gupta and Elby believed that engineering students' difficulties with mathematical sense-making is possibly because of their epistemological views rather than epistemological deficits [17].

Accordingly, recent studies by cognitive scientists of factors affecting cognition imply the need to reconsider current conceptual theories about science education [18, 19]. By asserting the situated nature of cognition, these theorists emphasize the role of context, embodied practices and narrative-based representation rather than learners' cognitive constructs. These studies identified the importance of 'inspiration through action' (i.e., mega-cognition with hands-on practice) [20].

With respect to *self-efficacy*, many studies have indicated that individuals with high self-efficacy perceive themselves as capable of taking the necessary steps to resolve problems [21]. After studying 1,387 first-year engineering majors, Hutchison, Follman, Sumpter, and Bodner found that student self-efficacy was most influenced by drive and motivation, understanding of materials, and computing abilities [22]. Self-efficacy was also identified as one of the primary dimensions of students' overall science identity [23]. Taking the aforementioned studies into account, we proposed the following hypotheses to be tested:

1. *Intrinsic motivation* influences academic performance through its effect on imagination.
2. *Positive emotion* influences academic performance through its effect on imagination.
3. *Negative emotion* influences academic performance through its effect on imagination.
4. *Generative cognition* influences academic performance through its effect on imagination.
5. *Inspiration through action* influences academic performance through its effect on imagination.
6. *Self-efficacy* influences academic performance through its effect on imagination.

In the current study, *intrinsic motivation* assessed whether participants were influenced by the desire for personal satisfaction rather than some external reward. *Positive emotion* reflected the extent to which participants reported being influenced by positive psychological states. *Negative emotion* indicated the degree to which participants were influenced by negative psychological states. *Generative cognition* measured the degree of importance participants placed upon various ways to formulate mental-representation. *Inspiration through action* examined how participants felt with regards to being influenced by meta-cognition with hands-on practice. Finally, *self-efficacy* evaluated the extent to which participants reported being influenced by the belief in their own competence.

2.2 The role of imagination in science and engineering

Science and engineering have different goals and methods. A scientist seeks to understand what is, whereas an engineer seeks to create what never was [24]. However, both scientists and engineers need an overwhelming amount of imagination and creativity in order to achieve their ends [3]. To be more exact in the distinction between science and engineering, Bybee explained that scientists plan and carry out systematic investigations that require clarifying what counts as data and experiments identifying variables. Engineering investigations are conducted to gain data essential for specifying criteria or parameters and to test the effectiveness, efficiency and durability of proposed designs. In addition, the solutions made by scientists refer to the construction of theories, which have multiple independent lines of empirical evidence, great explanatory power and a breadth of phenomena it accounts for. In contrast, engineers usually propose a systematic solution which is resulted from a process of balancing competing criteria of desired functions, feasibility, cost, safety, and compliance with legal requirements [25].

Over the past decade, many scholars have devoted themselves to the study of *scientific imagination*. For example, a study done by Maeyer and Talanquer concluded that it was very important that science students develop and apply analytical reasoning and be able to evaluate the effectiveness of intuitive heuristics in different contexts [26]. Stone also indicated that it is imagination that enables scientists to make the initial or final advance of their discoveries [27]. Although many great educators seem to agree that imagination is at the root of how human beings modify their material world, Van Eijck and Roth found that the process by which this scientific imagination in education occurs has rarely been conceptualized [28].

In contrast, *engineering* scholars seem even more enthusiastic about imagination, creativity and innovation than scientific scholars [29]. For example, Charyton and Merrill developed the Creative Engineering Design Assessment to evaluate general creativity and creative design capability of engineering majors [30]. Liang, Hsu, Chang, and Lin made an effort to establish an assessment index of imaginative capabilities for virtual experience designers [31]. In addition, Genco, Hölttä-Otto, and Seepersad experimentally investigated the innovation capabilities of undergraduate engineering students [32]. The research of Daly, Yilmaz, Christian, Seifert and Gonzalez showed that the use of design heuristics can help student effectively generate ideas, especially during the ideation stage [33].

In developing the Imaginative Capability Scale, Liang and Chia empirically categorized human imagination into three types: initiating, conceiving and transforming [34]. *Initiating imagination* refers to the capability to explore the unknown and productively originate novel ideas [35]. It consisted of three indicators, namely exploration, novelty and productivity. *Conceiving imagination* refers to the capability to mentally grasp the core of a phenomenon utilizing personal intuition and sensibility, and the capability to formulate effective ideas for achieving a goal through concentration and logical dialectics [36]. It consisted of five indicators, namely concentration, dialectics, effectiveness, intuition and sensibility. *Transforming imagination* refers to the capability to crystallize abstract ideas and reproduce what is known across different domains and in various situations [37]. It consisted of two indicators: crystallization and transformation.

On the basis of the aforementioned literature, this study took into account the decisive role of imagination and hypothesized that imagination would mediate between psychological factors and academic performance. Subsequently, the following hypotheses were proposed:

1. *Initiating imagination* influences academic performance.
2. *Conceiving imagination* influences academic performance.
3. *Transforming imagination* influences academic performance.
4. The structural model of science majors is different from that of engineering ones.

3. Method

3.1 Measurements

Imaginative Capability. Based on the study of Liang and Chia, the measure for imaginative capability was a 29-item scale which consisted of three dimensions: initiating, conceiving, and transforming imagination [34]. The participants were instructed to determine the level of agreement with each item of imaginative capability. The scale was scored on a six-point Likert scale ranging from 1 = strongly disagree to 6 = strongly agree. Some example items are: "I often have unique ideas compared to others" (from initiating imagination), "I can continue to focus on a project until the ideas are formed" (from conceiving imagination), and "I can express abstract ideas by using examples from daily life" (from transforming imagination).

Psychological Influences. The psychological influence scale proposed by Hsu et al. was slightly revised in the present study [20]. The 25-item scale consisted of six subscales, namely intrinsic motivation, positive emotion, negative emotion, generative cognition, inspiration through action, and self-efficacy. In the questionnaire, respondents were asked to determine the level of influence each psychological item had on their imagination. The respondents answered on a six-point scale ranging from 1 = strongly disagree to 6 = strongly agree. Some example items are: "Courage to present different ideas" (from intrinsic motivation), "Joyfulness from the surroundings" (from positive emotion), "Anxiety felt by individuals" (from negative emotion), "Use immersive sensory exploration to spark imagination" (from generative cognition), "Hands-on design with constantly changing concepts envisaged" (from inspiration through action), and "Be determined to achieve set standards" (from self-efficacy).

Academic Performance. For the purposes of this study, Grade Point Average (GPA) was used as a means to measure academic performance. GPA in this study is the cumulative average of grades across all subjects during the student's tenure at school in the previous academic year. Although academic performance could be measured by diverse approaches, using GPA enabled us to study large samples of students. This approach was also employed because of the acceptable results it yielded in many other studies [38, 39]. The study done by Gralewski and Karwowski indicated that the role of creative abilities for GPA was greater in larger schools and in schools located in big cities [38]. The sizes of the six universities in our study are similar, and they are all located in the urban areas.

3.2 Participants and procedures

The ten hypotheses proposed were tested with data from six universities across different regions in Taiwan. The participants in this study were divided into two groups. The first group (science majors) consisted of 387 undergrads enrolled in mathematics, physics and chemistry programs; whereas the second group (engineering majors) consisted of 386 undergrads in information, mechanical and chemical engineering programs. Participants of the science group included 252 males and 135 females; 34.1% were sophomores, 32.8% were freshmen, 19.9% were juniors, and 13.2% were seniors. Participants of the engineering group included 301 males and 85 females; 30% were sophomores, 26.2% were freshmen, 24.4% were juniors, and 19.4% were seniors.

Upon securing participants' approval in each program, the students were asked to complete a questionnaire consisting of the measurements included in this report. All participation was voluntary and anonymity was guaranteed. The survey in each university was conducted according to the same procedure and included tutorial groups who were accompanied by their class instructors. In this manner, the problems participants faced when answering the questions could be resolved directly. The survey took approximately 15 minutes to complete and was administered either during or immediately following regular class time.

4. Results

In the current study, Structural Equation Modeling (SEM) with maximum likelihood estimation using LISREL 8.80 was employed to test the proposed hypotheses. We examined the mediator effects of imagination based on the four steps provided by MacKinnon, Lockwood, Hoffman, West, and Sheets [40]. According to our data, the relationships between all predictive variables and academic performance in both the science and engineering groups were significantly reduced when the mediator (imagination) was included in the model. Therefore, the mediation models were initially supported. Although the initial models showed a good fit to the present data, not all variables were significantly associated with academic performance. We removed the less significant variable (*positive emotion*) and paths, and then revised the structural models of both groups.

In regards to the *science* group, the revised model showed a model fit comparable to that of the initial model, $X^2 = 2541.58$, $df = 1249$, $p < 0.005$, RMSEA = 0.051, SRMR = 0.060, CFI = 0.97, NFI = 0.95, TLI = 0.97. The results showed that, through the mediator of imagination, *self-efficacy* had the strongest indirect effect on academic performance, followed by *generative cognition*, *inspiration through action*, *intrinsic motivation*, and *negative emotion* (but insignificant). In other words, hypotheses 1,

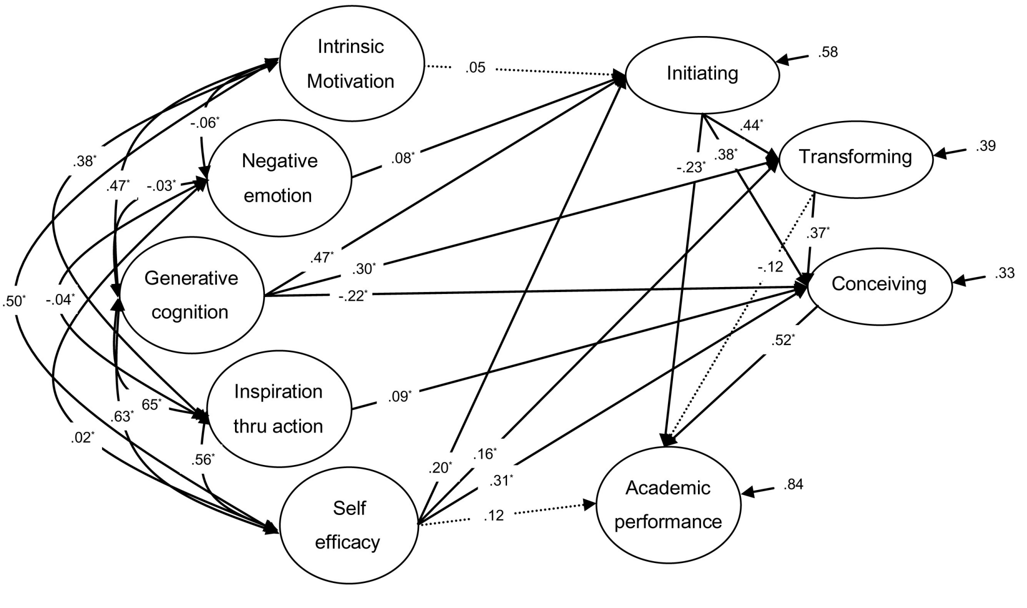

Fig. 1. The Imagination-Mediated Model of the *Science* Group ($n = 387$).

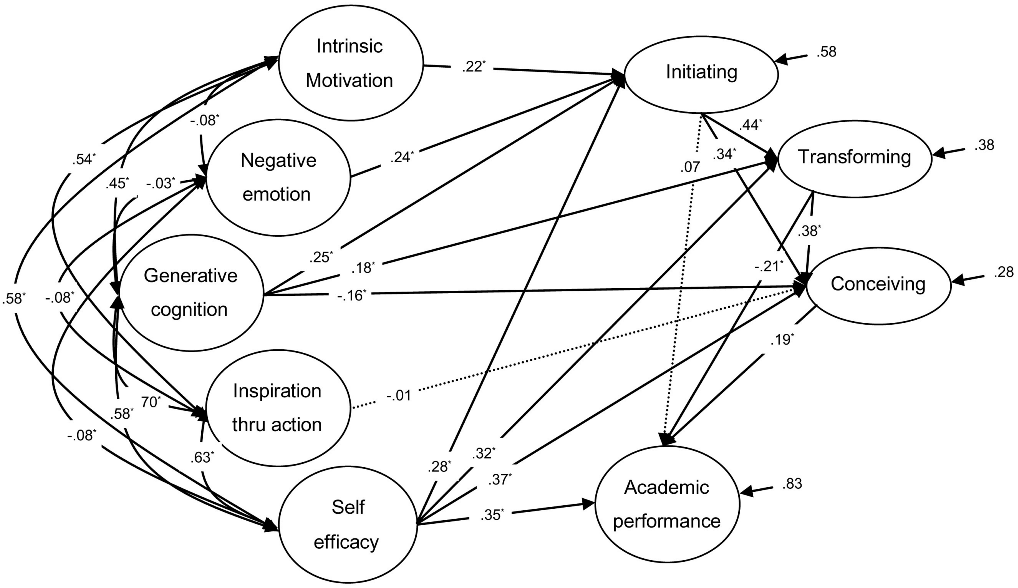

Fig. 2. The Imagination-Mediated Model of the *Engineering* Group (n = 386).

4, 5 and 6 were supported, but hypothesis 2 and 3 were disproved. *Self-efficacy* was found to be the only variable which had a direct effect on academic performance (0.12).

Our data also showed that, the SEM accounted for substantial variance in *conceiving imagination* (R^2 = 0.67), *transforming imagination* (R^2 = 0.61), *initiating imagination* (R^2 = 0.42) and academic performance (R^2 = 0.16). The standardized path coefficient of *conceiving imagination* to academic performance was 0.52, whereas that of *initiating imagination* to academic performance was –0.23. *Transforming imagination* influenced academic performance through its effect on *conceiving imagination*. In other words, hypotheses 7, 8 and 9 were supported. The structural model of the *science* group is illustrated in Fig. 1. In the following figures, the solid line refers to a significant effect, whereas the dotted line refers to an insignificant effect.

With respect to the *engineering* group, the trimmed model showed a model fit comparable to that of the initial model, X^2 = 2143.64, df = 1249, p < 0.005, RMSEA = 0.044, SRMR = 0.057, CFI = 0.98, NFI = 0.96, TLI = 0.98. Our data showed that, through the mediator of imagination, *generative cognition* had the strongest indirect effect on academic performance, followed by *self-efficacy*, *intrinsic motivation*, *negative emotion*, and *inspiration through action* (but insignificant). In other words, hypotheses 1, 3, 4 and 6 were supported, but hypothesis 2 and 5 were disproved. *Self-efficacy* was found to be the only variable which had a direct effect on academic performance (0.35).

The SEM results also showed that, the SEM accounted for substantial variance in *conceiving imagination* (R^2 = 0.72), *transforming imagination* (R^2 = 0.62), *initiating imagination* (R^2 = 0.42) and academic performance (R^2 = 0.17). The standardized path coefficient of *conceiving imagination* to academic performance was 0.19. Both *initiating imagination* and *transforming imagination* influenced academic performance through their effects on *conceiving imagination*. In other words, hypotheses 7, 8 and 9 were supported. The structural model of the engineering group is illustrated in Fig. 2.

The current study hypothesized that the psychology-imagination-performance structures between science and engineering majors would be different. The SEM analyses found that these two structures were similar to each other, but the effects of each variable in the structures were different. The results showed that *self-efficacy* and *generative cognition* were the two most influential psychological variables on both the science and engineering groups. The direct and indirect effects resulting from all the latent predictor variables on academic performance are reported in Table 1. According to the data, hypothesis 10 was supported.

5. Discussion

5.1 The differences direct effects of imagination between the two groups

The results showed that, no matter what their major, the participants' initiating and transforming imagination influenced academic performance through their combined impact on conceiving imagination. The main differences between science and engineering students are the direct effects of initiat-

Table 1. The Direct and Indirect Effects of Both the *Science* and *Engineering* Groups

	Science (n = 387)			**Engineering (n = 386)**		
Latent predictor variables	**Indirect**	**Direct**	**Total**	**Indirect**	**Direct**	**Total**
Intrinsic motivation	0.00718	–	0.00718	0.02768	–	0.02768
Negative emotion	–0.00004	–	–0.00004	0.01775	–	0.01775
Generative cognition	–0.09294	–	–0.09294	–0.03671	–	–0.03671
Inspiration through action	0.04680	–	0.04680	–0.00190	–	–0.00190
Self-efficacy	0.11568	0.12000	0.23568	0.03549	0.35000	0.38549

ing and conceiving imagination. The initiating imagination of science majors had significant and negative effect on their academic performance, whereas that of engineering majors had an insignificant influence. In addition, the effect of conceiving imagination on science majors was greater than on engineering majors.

These findings suggested that a different educational approach may need to be taken if exploring the unknown is valued in scientific discovery or if originating novel ideas is cherished in science education. This approach should be assured to achieve a wider aim of science education in order to bring the world of science closer to students and general people. Thanks to the recent work of Van Eijck and Roth, they argued for a ‘novelization’ approach because it is a better way compared to ‘epicization’ [28]. The novelization approach can decrease the distance between students and today’s scientific enterprises. ‘Novelization’ is a continuous renewal of narratives that derives from dialogical interaction, whereas ‘epicization’ represents a past of scientific heroes and peak discoveries.

These findings also suggested that making hands-on practice as integral to classroom experiences will enable students to conceive of engineering design as intrinsic elements of the profession. Doing so should help engineering students to imagine a better future for the world and then creatively work to bring it into reality, because engineers oftentimes need to cope with contextual constraints in the sophisticated reality [41]. Several researchers have focused on this direction. For example, Pomales-Garcia and Liu called for real-life workplace projects in enhancing the quality of engineering education [42]; Turns, Eliot, Neal, and Linse stressed on professional problem-solving and value innovation [43]; and Dunsmore, Turns, and Yellin described engineering as an inherently collaborative practice [44].

5.2 The effects of psychological influences on the science group

The results showed that, through the mediator of imagination, *self-efficacy* (0.236) had the greatest influence on the academic performance of the science students, followed by *generative cognition* (–0.093), *inspiration through action* (0.047), *intrinsic motivation* (0.007), and *negative emotion* (–0.00004). *Self-efficacy* had strong and direct influence on three types of imagination and academic performance. This implies that self-efficacy in the subject matter and learning resources could help science students stimulate novel ideas, crystallize abstract concepts, improve logical thinking, and eventually enhance their academic performance. This finding is seconded by several studies in science education. For example, Taasoobshirazi and Glynn concluded that the students’ problem conceptualization and self-efficacy influenced their strategy use, which, in turn, influenced their problem-solving success [45]. The present study suggested that science instructors need to pay attention to the levels of student confidence to the subject matter and the competence of operating laboratory facility and analytical tools.

Generative cognition had strong and direct influences on initiating and transforming imagination, but negatively influenced conceiving imagination. This implies that students good at formulating mental-representations would also be capable of initiating novel ideas and using extant ideas in other tasks, which, in turn, may decrease academic performance. It also implied that this type of students may not like to invest prolonged time on one project or deliberately reason the contradictions of a problem. There are few studies in science education focusing on this particular issue. Although we recognized the argument made by Tytler and Prain regarding the correlation between the process of conceptual change and the use of mental representations, we tend to believe that the nature of conceptual change is not necessary lined to academic performance [19]. The present study suggested that students’ experiences and the way they generate ideas may hinder their scientific performance.

Although *inspiration through action* had an insignificant effect on conceiving imagination, its cumulative effect on academic performance was still noticeable. This implies that students’ conceiving capabilities would benefit from engaging their meta-cognition with hands-on practice. Many science educators have shared their research results on this topic. For example, after studying meta-cognitive engagement during field-trip experiences, Nielsen, Nashon, and Anderson concluded that individual students' deep understandings, which manifested through students' cognitive and social behaviors, demonstrated the invocation of metacognition to varying degrees [46]. Swarat, Ortony, and Revelle argued for a closer link between the form of activity, the learning goal and student metacognition. The current study suggested that science instructors may need to refocus on the effectiveness of hands-on practice [47].

Both *intrinsic motivation* and *negative emotion* had only slight effects on the students' initiating imagination. This finding is indirectly supported by previous studies. For example, the research of Pugh, Linnenbrink-Garcia, Koskey, Stewart, and Manzey showed that students who strongly identified with science and who endorsed a mastery goal orientation were more likely to report engagement in higher levels of scientific discovery [48]. Abrahams studied the affective value of students and concluded that practical work is helpful in initiating short-term engagement [14]. However, prior research had also shown that students' motivation toward science learning tends to decrease during adolescence [49, 50]. Our findings in the current study seem consistent with this global phenomenon of motivational decline.

5.3 The effects of psychological influences on the engineering group

In contrast, *self-efficacy* (0.386) was identified as the most influential psychological variable among engineering students, followed by *generative cognition* (–0.037), *intrinsic motivation* (0.028), *negative emotion* (0.0178), and *inspiration through action* (–0.002). Similar to the science group, *self-efficacy* also had strong and direct impact on three types of imagination and academic performance of the *engineering* group. This implies that self-efficacy in the content topic and learning resources could help engineering students to confront new realities, improve logical thinking, focus on learning activities, and eventually enhance their academic performance. Taking the team-based nature of engineering education into account, recent studies have focused on individual self-efficacy and achievement in teams. For example, Purzer's study indicated there was a positive correlation between post self-efficacy and the extent to which a student engaged in support-oriented discourse [51]. The present study suggested that helping students build their belief in their own competence is a critical task for engineering instructors, especially in terms of their problem-solving capabilities.

Similar to the science group, *generative cognition* had direct effects on initiating and transforming imagination, but negatively influenced conceiving imagination in the *engineering* group. It also implied that students capable of formulating mental-representations would also be good at generating unusual ideas and using extant ideas in other tasks, which may actually decrease academic performance. This type of student may regard contemplating the contradictions of a problem as waste of time. In other words, students' previous experiences and the way they generate ideas may hinder their academic performance. This finding is consistent with some recent cognitive studies. For example, Gupta and Elby recognized that engineering students' difficulties with mathematical sense-making is possibly because of their epistemological views rather than epistemological deficits [17]. The present study suggested that engineering instructors need to pay attention to how students use their experiences and the way they generate ideas.

Both *intrinsic motivation* and *negative emotion* had adequate effects on initiating imagination. This implies that *intrinsic motivation* and *negative emotion* can stimulate novel ideas among students. In terms of student motivation, Jones et al. concluded that expectancy-related constructs (i.e., engineering self-efficacy and expectancy for success in engineering) predicted achievement better than the value-related constructs (i.e., identification with engineering and engineering values), whereas value-related constructs predicted career plans better [11]. In addition, Lin, Hong, and Huang found that students with high levels of emotional factors outperform their medium- and low-level counterparts in scientific literacy [52]. The present study suggested that engineering instructors may need to focus on student motivation and emotion, especially in engineering design classes.

The effect of *inspiration through action* was found to be insignificant in this study. Taking the practical aim of engineering into account, we still make a discussion about this possible influence. Pomales-Garcia and Liu studied students' views of excellence in engineering education and concluded that real-life workplace experience can enhance quality of education [42]. Gerstner and Bogner also indicated that hands-on instruction can inspire students through practices and result in better learning outcomes [53]. This finding is probably to the fact that most projects assigned in schools are not reality-based but simulative. These projects are small in scale and not sophisticated like ones in the real world. The participants in the current study may not have perceived *inspiration through action* as critical due to this difference between in-school projects and real-world cases. It is not surprised that, comparing engineering students, expert engineers spent more time on problem scoping and gathered more information covering more categories [54].

5.4 The differences of psychological influences between the two groups

The results of this study showed that both psychology-imagination-performance structures of the science and engineering groups were similar, but each variable had different effects. The major differences between these two groups were the direct effects resulting from *self-efficacy*, *inspiration through action*, *intrinsic motivation*, and *negative emotion*. The effect of *self-efficacy* on the performance of science majors' was significantly smaller than on engineering majors. The effect of *inspiration through action* on the conceiving imagination of science majors was significantly greater than on engineering majors. Both *intrinsic motivation* and *negative emotion* had a slight, insignificant effect on the initiating imagination of science majors, as opposed to the strong influence these two variables had on engineering majors.

Three important observations can be made based on these findings. First, since *self-efficacy* was the most influential psychological factor on the academic performance of the science students, science educators may need to optimize students' self-efficacy in content topics, laboratory facilities and analytical tools. The improvement of self-efficacy may benefit from inquiries into the relationships between self-efficacy and other psychological, behavioral, ability and contextual variables. Psychological factors were introduced in this study. Behavioral variables to be studied can include: engagement, persistence, commitments, retention, etc. Ability variables to be studied may include: interpretation, reasoning, argumentation, explanation, conceptual change, problem solving, etc.

Contextual variables to be studied can include: physical environment, learning resources, instructional measure, team/class climate, organizational culture, etc.

Second, these findings also suggested that more research on *inspiration through action* needs to be carried out in engineering education. Recent perspectives of cognitive science have implications for engineering education. These studies stressed the role of context and embodied practices other than learners' cognitive constructs [18, 20]. Engineering curriculum may need to be reformed to make each course into a collaborative element. In addition, engineering educators may also need to pay more attention to some critical issues such as the adoption of innovation, professional problem-solving, situated learning, real-life workplace examples, and collaboration with the outside community.

Third, our findings suggested that science/engineering instructors should be adept at recognizing different emotions while encouraging and intervening to change students' affective states whenever possible. In terms of motivation, the recent works of Gungor et al. and Pugh et al. provided inspiring approaches which were fruitful enough to warrant further research [10, 48]. In addition, the global trend of decline in motivation in science learning deserves special attention. The studies done by Vedder-Weiss and Fortus indicated that students' perceptions of teaching emphases and peers' goals, and their self-efficacy in science learning are heavily influenced by the school culture [55, 56]. In other words, contextual influences should be taken into account in future research.

6. Limitations

The present study proposed the initial models of psychology-imagination-performance structures for science and engineering education. However, the limitations should also be acknowledged. First, imagination this study inquired about "self-perceived" imaginative capabilities. The choice of research tools was due to the preliminary nature of imagination research. Self-reporting measures allow us to generalize our findings to a larger population. Second, GPA is but one kind of measure of academic performance. Other measures should be taken into account in the future. Third, although the structural models fit the data well, the predictive validity could be stronger. Individual psychology is but one variable influencing student imagination and academic performance. Additional variables such as personality traits and learning environments should be taken into account in future studies.

7. Conclusions

The current study concluded that the initiating and transforming imagination of both engineering and science majors influenced academic performance through their combined impact on conceiving imagination. This study also concluded that both psychology-imagination-performance structures of the science and engineering groups were similar, but each variable had different effects. The major differences between these two groups were the direct effects resulting from *self-efficacy*, *inspiration through action*, *intrinsic motivation*, and *negative emotion*. Through the mediator of imagination, *self-efficacy* had a strong influence on the academic performance of both science and engineering majors. Although *generative cognition* was identified as the second major predictor of student performance, its effects were slightly negative. The influence of *inspiration through action* on the science group was greater than on the engineering group. The effects of *intrinsic motion* and *negative emotion* were smaller on the science group than on the engineering group.

The current study contributes intriguing insights into the complexities of the psychology-imagination-performance structure of science and engineering students. Particularly, the identification of imagination as a crucial mediator between psychological factors and academic performance opens various possibilities to develop intervention packages. These results will be appreciated and the packages will be developed under the premise that imagination and creativity are valuable to science and engineering students.

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