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How Does Human Aggregate Moderate the Effect of Inspiration through Action on the Imagination of Engineering Majors?*

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This study analyzes how *human aggregate* moderates the effect of *inspiration through action* on student imagination. A survey was administered at five universities across various regions of Taiwan. The participants in this study consisted of 543 engineering majors. Structural equation modeling was used to test all the proposed hypotheses. The results showed that *inspiration through action* had the strongest effect on student imagination, followed by *human aggregate* and *social climate*. Our data also indicated that student imagination levels were highest when students were also high in inspiration through action and human aggregate.

Keywords: engineering education; human aggregate; imagination; inspiration through action

1. Introduction

According to the National Society of Professional Engineers, engineering refers to the creative application of scientific principles used to plan, build, direct, guide, manage, or work on systems to maintain and improve our daily lives [1]. Bybee added that engineers are usually capable of simulating user situations and asking appropriate questions to identify constraints and determine criteria for successful solutions [2]. Competent engineers seek to innovate and thus require strong imagination to perform creatively and effectively. Numerous scholars have highlighted the role that imagination plays in scientific discovery and engineering invention [3]. However, the lack of a consensus on how imagination functions is noteworthy [4].

Creative people can typically explain their expertise and spontaneously transfer domain-specific knowledge to new settings. Their meta-cognitive knowledge is typically applicable in various situations [5, 6]. Duggan and Gott argued for increasing the amount of time devoted to procedural knowledge [7]. The rationale behind this argument is that procedural competence in the form of expert problem solving and critical thinking has become more critical at higher levels of science education. Hsu, Liang and Chang named this 'meta-cognition with hands-on practice' as *inspiration through action*, and found that it can predict student imagination [8].

In addition, Swirski indicated that imagination in learning environments frames educational activities and facilitates innovative assessments that allow students to explore, question, and understand the diversity surrounding them [9]. Prior research had shown that student perception of teaching emphasis and peer goals in science learning is heavily influenced by the school culture [10, 11]. In addition, numerous studies have shown that social climate can positively predict human creativity and imagination [12, 13]. According to the American College Personnel Association, both human aggregate (i.e., organizational culture) and social climate are the major college campus factors affecting student learning [14].

Considering the aforementioned studies, the interplay between *human aggregate*, *social climate* and *inspiration through action* becomes a critical issue in the research of engineering education. In particular, we investigate how different levels of *human aggregate* affect the influence of *inspiration through action* on the imagination of engineering majors. This study analyzes the moderator effect of *human aggregate* between *inspiration through action* and student imagination. To render the moderator effect explicit, we treated *social climate* as a controlled confounder in the moderation model.

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2. Literature

2.1 Engineering and imagination

Numerous engineering educators have devoted themselves to the areas of imagination, creativity and innovation. For example, Coeckelbergh and Wackers stated that engineers require imagination to transcend their expertise-specific perspectives to improve the robustness of their organizations and to be better prepared for crisis situations [3]. Charyton and Merrill developed the Creative Engineering Design Assessment (CEDA) to evaluate the general creativity and creative design capability of engineering majors [15]. Charyton et al. revised the CEDA and assessed the usefulness of engineering students' creativity [16]. In addition, Liang et al. (2012) established an assessment index of imaginative capabilities for virtual experience designers [17]. Genco et al. also investigated the innovative capabilities of undergraduate engineering students [18].

Daly et al. showed that the use of design heuristics can help students to effectively generate ideas, particularly during the ideation stage [19]. Farber and Pietrucha explored scenario planning for cultivating strategic imagination in the next generation of engineering systems transportation professionals [20]. In particular, they examined the use of scenario planning as a method of enabling professionals to think more creatively and thereby create a common medium for multiple stakeholders to think collaboratively and reflect upon the deeper connections among socio-technical systems. Esolen thus concluded that, at their best, engineers imagine a better future for people and then work to make it a reality [21].

In developing the imaginative capability scale, Liang et al. empirically categorized human imagination into three types: initiating, conceiving, and transforming [22]. *Initiating imagination* refers to the capability to explore the unknown and productively originate novel ideas [23, 24]. It consists of three indicators: exploration, novelty, and productivity. *Conceiving imagination* refers to 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 [25, 26]. It consists of five indicators: 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 various situations [27, 28]. It consists of the two indicators of crystallization and transformation.

For example, information engineers use initiating imagination to create fresh, original ideas for application software to make lives easier. Information engineers exercise conceptual modeling by using conceiving imagination to clarify ambiguous concepts and ensure that problems involving multiple interpretations of the concepts cannot occur. In addition, information engineers frequently do not know how to write manuals that enable users to easily and successfully use their products or services. Unless engineers use transforming imagination to empathize with users, the manuals they write may leave numerous questions unanswered.

2.2 Relationships between imagination and inspiration through action/human aggregate/social climate

Imagination can be perceived as 'a creative faculty of the mind' [29]. This perspective explains the close relationship between imagination and cognition [30]. Recent studies by cognitive scientists of factors affecting cognition indicate the need to reconsider current theories regarding science and engineering education. These studies have emphasized the role of context and embodied practices rather than learners' cognitive constructs [31, 32]. These studies highlighted the importance of *inspiration through action* (i.e., to examine how participants felt with regards to being influenced by meta-cognition with hands-on practice). El-Sakran et al. indicated that contextualizing communication skills through multidisciplinary engineering projects improved student understanding of team-role behavior and facilitated project success [31]. Liang et al. determined that *inspiration through action* had direct effects on both creative imagination ($r = 0.24$) and reproductive imagination ($r = 0.18$) [33].

Human aggregate assesses the extent to which participants report being influenced by organizational culture and the characteristics of its inhabitants. In this study, this factor is used interchangeably with school culture. Human aggregate not only creates features in an environment that reflect varying degrees of consistency [34], but also affects the students' performance, restricts their behavior, creates campus culture, and produces a stable impression of the school [35]. Paretti et al. studied capstone engineering design teams and suggested that departmental cultures should be examined and improved if faculty members seek to cultivate student imagination and enhance student performance [10]. Chen et al. concluded that human aggregate significantly predicted the creative imagination capabilities of educational technology majors [36].

In this study, *social climate* reflects the extent to which participants report being influenced by the climate of the class. This factor typically has an intrinsic influence (i.e., member motivation) and an external impact (i.e., control over the members) [35].

Studying student collaboration, Oliveira and Sadler indicated that social context, interactive patterns, and group approaches to conceptual conflicts were crucial aspects of productive group learning [37]. Marquez et al. integrated teams into multidisciplinary project-based learning groups and found that both participants' enthusiasm and well-distributed work facilitated the development of positive team climate and enhanced overall performance [13]. Chen et al. determined that students who perceived that the social climate was positive participated in school activities more actively and received higher scores in schoolwork than those who did not [38].

Taking the aforementioned studies into account, the following hypotheses were proposed to be tested: (a) *inspiration through action* can predict three types of imagination; (b) *human aggregate* can predict three types of imagination; and (c) *social climate* can predict three types of imagination.

2.3 Relationships between inspiration through action and human aggregate

Regarding the relationship between *inspiration through action* and *human aggregate*, Phelps and Graham stated that the development of a school-wide meta-cognitive approach to professional development changed several aspects of school culture, including institutional attitude and support for professional learning [39]. Momeni indicated that the effective use of meta-cognitive strategies for problem solving can facilitate the enhancement of student performance and promote a school culture of deep learning [40]. Fouché supported that a meta-cognitive strategy effectively improved student academic performance [41]. A developing proficiency culture of school improvement, which had a focus on data-driven instruction and best practices, was thus implemented.

Walczyk et al. contended that school culture is the major obstacle to the use of learner-centered instruction in college classrooms. This results in negative effects on undergraduate learning and creativity [42]. Demir suggested that collaborative school culture had a moderating effect on collective teacher efficacy, that was closely associated with student cognitive development and academic achievement [43]. Tarnoff used interdisciplinary teams to develop an assessment system and change organizational culture to focus on assurance of learning [11]. The change of organizational culture was the foundation for designing the assessment process, which applied to diverse departments and satisfied the requirements of multiple engineering accreditors.

Based on the aforementioned studies, *inspiration through action* and *human aggregate* have an interactive relationship. Recent studies in the field of organizational behavior have revealed that organizational culture moderates the effect of motivation and cognition on work performance [44, 45]. Therefore, the fourth hypothesis is proposed: *Human aggregate* moderates the effect of *inspiration through action* on three types of imagination. Because the temporary nature of *social climate* was not the focus of this study and might confound the model testing the harmful effects concerning *human aggregate*, *social climate* was thus treated as a controlled confounder in the moderation model.

3. Method

3.1 Measurements

Imaginative capability. The 29-item imaginative capability scale was used to measure student imagination [22]. 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' (refers to *initiating imagination*), 'I can express abstract ideas by using examples from daily life' (refers to *transforming imagination*), and 'I can continue to focus on a project until the ideas are formed' (refers to *conceiving imagination*).

Inspiration through action, *human aggregate*, and *social climate*. Based on the environmental influence scale proposed by Chen et al. [36] and Hsu et al. [8], the subscales of inspiration through action (5 items), human aggregate (5 items), and social climate (6 items) were adopted in this study. In the scales, respondents were asked to determine the level of influence each item had on their imagination. The respondents answered on a six-point scale ranging from 1 = strongly disagree to 6 = strongly agree. Example items of *inspiration through action* include 'Hands-on design with constantly changing concepts envisaged in mind,' 'Inspiration kindled during the design process,' and 'Intuitive responses to design assignments.' Example items of *human aggregate* include 'Schoolmate characteristics,' 'Common practice on campus,' and 'School culture.' Example items of *social climate* include 'Pleasant learning climate,' 'Mutual support among classmates,' and 'Communication and discussion with classmates.'

3.2 Participants and procedures

The four proposed hypotheses were tested using data from five universities across various regions of Taiwan. A total of 543 undergraduates enrolled in electrical, chemical, mechanical and computer engineering programs participated in the study. The samples consisted of 420 men and 123 women; 27.1% were freshmen, 24.9% were sophomores, 27.8% were juniors, and 20.2% were seniors. The participants 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. The survey was administered either during or immediately following regular class time.

4. Results

4.1 Mode testing

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 moderator effects based on the suggestions of Frazier et al. [46]. According to the results, the moderator models were initially supported, but not all variables were significantly associated with three types of imagination. We removed the paths that were less significant and subsequently revised the structural model.

The trimmed model showed a model fit comparable to that of the initial model, $\chi^2 = 5890.46$, $df = 2273$, $p < 0.005$, RMSEA = 0.058, SRMR = 0.078, CFI = 0.96, NFI = 0.96, TLI = 0.96. It accounted for substantial variance in *initiating imagination* ($R^2 = 0.36$), *conceiving imagination* ($R^2 = 0.39$), and *transforming imagination* ($R^2 = 0.44$). Both *inspiration through action* and *human aggregate* predicted three types of imagination. *Social climate* only predicted *transforming imagination* ($r = 0.12$). In other words, Hypotheses 1 and 2 were supported, and Hypothesis 3 was partially supported.

4.2 Moderator effects

Our data showed that the interaction of *human aggregate* and *inspiration through action* exerted a significant effect on three types of imagination (see Fig. 1). Therefore, Hypothesis 4 was also supported. To further examine the form of interaction for interpreting the moderator effects, we calculated simple slopes and regression lines for each level of the moderator [47]. As recommended by Cohen et al., regression lines were plotted for high (1 *SD* above the mean), average, and low (1 *SD* below the mean) influence levels of *human aggregate* (HA) [48]. In this study, high HA refers to student imagination that is highly (+1 *SD*) influenced by human aggregate, whereas average HA represents the average level of HA influence, and low HA represents a low level (–1 *SD*) of HA influence.

This study hypothesized that *human aggregate* moderates the effect of *inspiration through action* on three types of imagination. Our data showed that the moderator effects on three types of imagination were similar to each other, but the power of each individual effect was different. The results of simple slope analysis revealed that *inspiration through action* was more closely associated with *imagination* for high HA than with those at average and low levels. In addition, when *inspiration through action* was low, high HA had a greater effect on imagina-

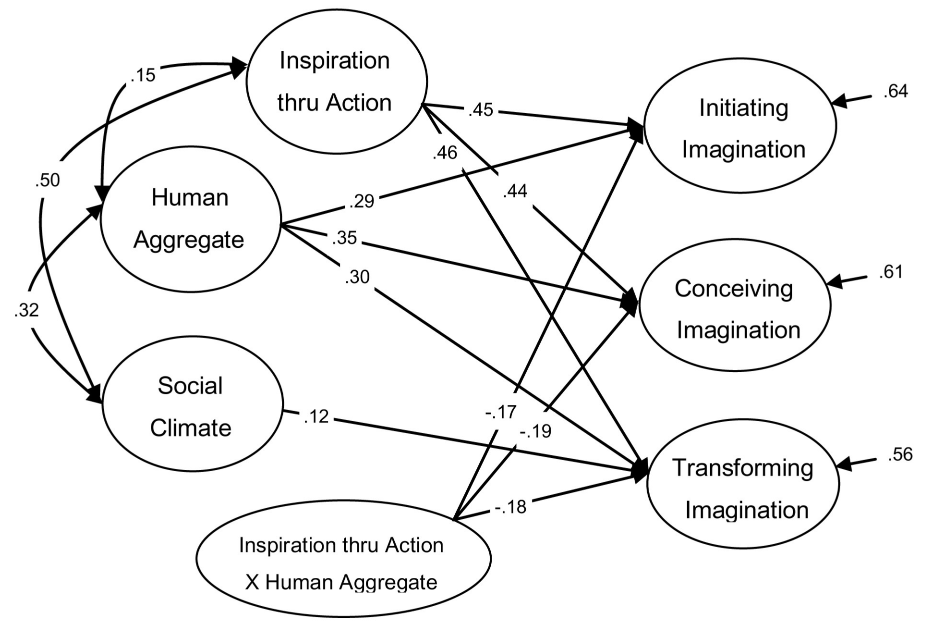

Fig. 1. The moderation model of the engineering majors ($n = 543$).

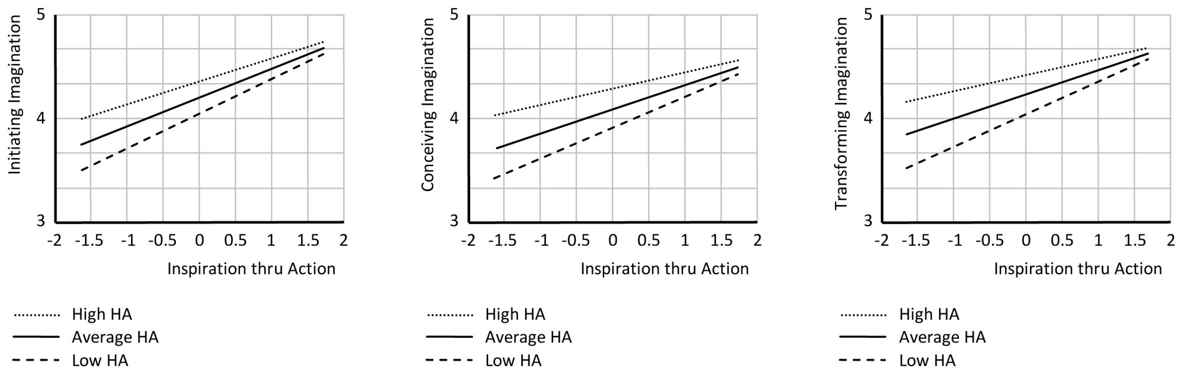

Fig. 2. Plot of inspiration through action × human aggregate on three types of imagination.

tion. The slope of low HA was steeper than that of high HA; when *inspiration through action* was high, the moderator effects between different levels of HA influence on imagination narrowed (see Fig. 2). This implies that the moderator effect of *inspiration through action by human aggregate* for low HA was stronger than for high HA.

5. Discussion

5.1 Direct effects on imagination

According to our data, *inspiration through action* significantly predicted three types of imagination. This finding lends additional support to recent studies of cognitive science regarding an emphasis on the learning context and embodied practices [5, 31, 32]. Our results also show that *inspiration through action* is positively associated with *social climate*. This is likely because most engineering design projects are team-based tasks. These findings suggest that further research on *inspiration through action* should be conducted in engineering education. Engineering curricula should be reformed to provide each course with a collaborative element. Engineering educators should also focus on issues related to *inspiration through action*, such as monitoring and problem-solving strategies, multidisciplinary projects, situated learning, real-life workplace examples, and collaboration with the outside community.

In this study, *human aggregate* also exerted direct influences on three types of imagination. This implies that organizational culture could help engineering students to generate new ideas, continuously revise ideas, and apply knowledge to various domains. Taking *human aggregate* into account, Grindstaff and Richmond claimed that, unless the campus culture recognizes the role of creativity, students are not encouraged to discuss their ideas or value outside perspectives [49]. Lichtenstein et al. indicated that 'programmatic' is critical to differentiating engineering students from non-engineering students [50]. The present study indicates that organizational culture and diverse student subcultures must be considered when aiding students in developing practical and marketable skills and participating in edifying activities.

Our results show that *social climate* can only positively influence transforming imagination. This implies that peer relationships could help engineering students to make associations between concepts that had previously seemed unconnected and to apply experience to various situations. Educators have pursued effectiveness in large college courses by using specific approaches such as peer-led guided inquiry [51] and collaborative learning [13]. This study indicates that engineering instructors should focus on effective instructional approaches and improving student relationships, particularly during the ideation stage of engineering design.

5.2 Moderator effects on imagination

According to our results, the effects of *human aggregate by inspiration through action* on three types of imagination were significant and similar. The *inspiration through action* of high HA exhibited stronger effects on imagination than that of average and low HAs. However, the slope of low HA was steeper than that of high HA. The imagination of engineering majors was strongest for students with high *inspiration through action* and *human aggregate*. This implies that this moderator effect is particularly helpful in stimulating the imagination of students influenced weakly by *human aggregate* or *inspiration through action*. To be more specific, it implies that cultural change can facilitate the imagination of those whose meta-cognition was underdeveloped. It also implies that development of meta-cognition can facilitate the imagination of those who were situated in culturally discouraged organizations.

Although most engineering design projects are team-based tasks, the present study suggests that engineering educators may still need to pay attention to individual needs. Both good peer relationships and instructional strategies to develop meta-cognition would be helpful for those students who are unaware of the socio-cultural environment. Numerous studies have been devoted to the issues of cultural change [52, 53] and meta-cognition development [54, 55] in the field of engineering education. Schraw et al. suggested that socio-cultural models of learning, such as situated learning theory and cognitive apprenticeships could play a prominent role in developing student meta-cognition and changing school culture [6]. This study uniquely contributes to the understanding of interaction between *inspiration through action* and *human aggregate* on the imagination of engineering majors. These findings are sufficiently promising to warrant further inquiry.

Although this study expands on the findings of previous research, it is not without certain limitations. First, we have not attempted to examine the differences in the opinions of instructors. The potential influences of instructors have not yet been explored. Second, the type of imagination on which this study focused was limited to self-perceived capabilities. The research tools were chosen based on the preliminary nature of imagination research. Following Chan's discussion of self-reporting measures [56], the samples of our study were sufficiently large to allow us to generalize our findings to a larger population.

6. Conclusions

The present study provides empirical evidence and contributes to the structural view regarding how different levels of *human aggregate* influence the impact of *inspiration through action* on student imagination. In particular, identifying the joint effects of *human aggregate* and *inspiration through action* on imagination opens various possibilities to develop intervention packages. Cultivating imagination should be viewed as a cornerstone of learning because basic discovery requires high levels of creative thinking. Classroom practices should therefore change to encourage imagination, inquiry, invention, implementation and initiative. These results should be appreciated and intervention packages should be developed based on the premise that imagination and creativity are valuable to engineering students.

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