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Exploring profiles of varied types of achievement goals, emotions and digital insight problem solving through cluster analysis

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ABSTRACT

Insight experience results from an interaction between the problem and the individual solver. This study aimed to identify distinctive profiles concerning varied types of achievement goals, emotions, and insight problem solving through an online system and cluster analysis. A manipulable online insight test (Digital Insight Problem Solving Test, DIPST) was developed first. Then, an online experiment was conducted. The participants were 153 college students. Four types of achievement goals, eight types of emotions, and insight problem solving performance were included in the cluster analysis. The results revealed four distinctive profiles for insight problem solving: Achieved thinkers who are with appropriate achievement goals show a high level of performance and positive emotions; satisfied thinkers who are with appropriate achievement goals show above-average performance and a medium level of positive emotions; confused thinkers who have undifferentiated achievement goals and emotions show below-average performance; and frustrated thinkers who have conflicted achievement goals show a low level of performance and intensive negative emotions. This study develops a valid and manipulable insight test and identifies the favorable profile for great performance in insight problem solving, which contributes to the understanding of cognitive processes as well as further instruction and research regarding insight problem solving.

1. Introduction

The insight process is critical to creative problem solving. Past studies of insight can be divided into three dimensions: process, task, and phenomenology (Webb et al., 2016). Process concerns the cognitive mechanisms through which insightful solutions are generated. Descriptions of an insightful problem-solving process emphasize a sudden certainty of a correct response, with little or no conscious access to the processing of the solution. The task dimension concerns the identification of tasks that elicit sudden solutions. In this dimension, insight is often described as a restructuring of ill-defined problem space, which occurs after a period of impasse. Finally, the phenomenology of insight focuses on the “aha experience” (Öllinger and Knoblich, 2009; Webb et al., 2016); recent studies have explored phenomenology using experimental designs. This study focused on the task and the phenomenology aspects of insight. Although insight problem solving has been studied for decades, there is a lack of digital or online comprehensive tasks that allow for “physical” rather than “mental” operation of objects to get answers. This study attempted to develop such comprehensive insight tasks to provide a valid instrument for insight problem solving.

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Furthermore, the phenomenology perspective in insight research suggests that the insight experience results from an interaction between the problem and the individual solver (Bilalić et al., 2019; Bowden & Grunewald, 2018; Bowden et al., 2005); motivations, emotions, and insight experience are interrelated (Skaar & Reber, 2020). This study, therefore, focused on two individual characteristics: the trait of achievement goals and the emotional states during insight problem solving. Although insight problem solving has been studied for decades, and achievement goal theory has become the predominant framework to study motivation (Yeh & Lin, 2018; Bounoua et al., 2012; Hornstra et al., 2017), no study has examined the relationship between achievement goals and online insight problem solving. On the other hand, findings regarding how different types of emotional states influence insight problem solving are inconsistent (Yeh et al., 2016; Baas et al., 2011; Orita & Hattori, 2019). Identifying the favorable profile for great performance in insight problem solving would contribute to understanding the cognitive process of insight problem solving as well as effective intervention or training of insight problem solving.

Because achievement goals and emotions all include multiple and interrelated aspects, it is difficult to get an overall profile of how these personal characteristics and insight problem performance are related through the commonly used Analysis of Variance or similar methodologies. To solve this problem, we employed cluster analysis to explore the latent subgroups of people with varied levels of insight problem performance. Cluster analysis, a person-centered analytic approach, is a popular statistical method for identifying subgroups or clusters of respondents using sets of observed variables (Ford et al., 2020; Timmerman et al., 2013; van den Bergh et al., 2017). Briefly speaking, this study aimed to develop a comprehensive digital insight problem test and, further, to identify distinctive profiles concerning achievement goals, emotions, and insight problem solving through an online system and cluster analysis.

2. Insight problem solving

Insight research has developed over several decades and mainly through a cognitive problem-solving perspective (Martinsen et al., 2016). Insight is often defined as a sudden formation of a concept, which leads to the solution of a problem; during the process, breaking an impasse is accompanied by the reinterpretation or restructuring of a problem to reveal a new solution (Lai et al., 2017, Yeh et al., 2020; Kounios & Beeman, 2014; Weller et al., 2011). Such a restructuring should lead to a non-monotonic, discontinuous problem-solving process and is often accompanied by an "aha experience" (Bilalić et al., 2019; Danek et al., 2020). Specifically, Batchelder and Alexander (2012) proposed that an insight problem is characterized by the following cognitive processes: (1) It admits several possible problem representations, each with an associated solution search space. (2) Initial representations may be inadequate to allow the possibility of discovering a problem solution. Therefore, it is necessary to find an alternative productive representation of the problem. (3) Finding a productive problem representation may be facilitated by a period of incubation or well-chosen hints. (4) Once obtained, a productive representation leads to a direct and quick solution; it is accompanied by a so-called aha experience.

Whether insight problem solving involves conscious or unconscious processes has been an issue. Some researchers (Baas et al., 2008) suggested that insight problem solving involves a sudden understanding of a correct response with little conscious access to the processing of the solution, and the process of insight problem solving is largely governed by an implicit learning mechanism (Orita & Hattori, 2019; Suzuki & Fukuda, 2013). In essence, insights are sporadic and unpredictable thinking where unwarranted assumptions must be discarded before solutions to problems can be obtained (De Dreu et al., 2008). On the other hand, some researchers support that insight problem solving involves a deliberate and systematic evaluation of the problem (Webb et al., 2016). Bilalić et al. (2019)) demonstrated that in a problem that requires restructuring of the initial mental representation, paying progressively more attention to the crucial elements of the problem often preceded the finding of the solution. Most importantly, the sooner solvers started paying attention to the crucial elements, the less sudden and surprising the solution felt to them. In this study, we defined insight problem solving as a process in which breaking an impasse is accompanied by the restructuring of a problem to reveal a new solution. Moreover, such a process involves conscious and unconscious processes as well as "aha experiences" when the problem is solved.

3. Insight problem solving and related personal traits

3.1. Insight problem solving

A major theory in academic motivation is the achievement goal theory, which focuses on the reasons that students have for engaging in achievement behavior (Dweck, 1986; Hornstra et al., 2017). Achievement goals help construct a framework for how people interpret a learning event that guides learning efforts toward competence-relevant activities (Yeh & Lin, 2018; Bounoua et al., 2012; Dweck, 1986; Elliot, 1999). To date, few studies have examined the relationship between achievement goals and insight problem solving.

The research on achievement goals has been initially divided into two main categories of goals: mastery goals and performance goals (Darnon et al., 2012; Elliot et al., 2005). A mastery goal refers to the desire to learn new knowledge and build up competence; such a goal is usually derived from a belief that ability is malleable and that errors are natural to learning (Elliot et al., 2005; Senko & Tropiano, 2016). On the other hand, a performance goal refers to the desire to demonstrate competence and to perform better relative to others (Elliot et al., 2005; Senko et al., 2011); such a goal is derived from a belief that ability is mostly fixed and that errors signal inabilities (Senko & Tropiano, 2016).

Pintrich, 2000a, 2000b) claimed that learners can have multiple goals during the learning process. He further proposed four types of achievement goals: (1) Approach-mastery goal: Focus on mastering tasks and deep understanding of tasks; use standards of self-improvement and progress. (2) Approach-performance goal: Focus on being superior and being the best at tasks in comparison with others; use of normative standards of being the top or best performer in class. (3) Avoidance-mastery goal: Focus on avoiding misunderstanding and not mastering tasks; use standards of not being wrong or not doing something incorrectly relative to tasks. (4) Avoidance-performance goal: Focus on avoiding inferiority or looking stupid in comparison to others; use normative standards of not being the lowest performer in class. This study used this construct to measure achievement goals. It has been suggested that mastery goals (both the approach-mastery goal and the avoid-mastery goal) are related to cognitive strategy use, self-regulation, as well as students' positive affect and school learning (e.g., Fokkens-Bruinsma et al., 2020; Kaplan & Maehr, 2007; Linnenbrink & Pintrich, 2002; Pekrun et al., 2009; Senko & Tropiano, 2016). On the other hand, the influence of performance goals on learning is inconsistent. While the approach-performance goal is often positively related to learning outcomes, the avoidance-performance goal is often negatively related to performance (Elliot & McGregor, 2001; Fokkens-Bruinsma et al., 2020; Pekrun et al., 2009; Wolters, 2004).

The multiple-goal perspective points out that certain combinations of achievement goals are more favorable than others regarding educational outcomes (Harackiewicz et al., 2002; Pintrich, 2000a, 2000b). Hornstra et al. (2017) found that increased mastery goals combined with decreased avoidance-performance goals resulted in positive developments in the effort; on the other hand, students with a relatively high avoidance-performance goal, below-average mastery goals, and a slightly above-average approach-performance goal showed fewer achievement gains compared with students in other profiles. A recent study (Giel et al., 2019) found that performance goal orientations (approach and avoidance) and avoidance-mastery goal orientation related positively to fear of failure, whereas approach-mastery goal orientation attenuated the fear of failure.

Although no studies have investigated the relationship between the varied types of achievement goals and online insight problem solving and the fact that the effects of achievement goals on learning are inconsistent, we support the existence of multiple goals and postulate that a high level of approach goals (especially approach-mastery goal) and a low level of avoidance goals (especially avoidance-mastery goal) would result in the best performance in insight problem solving. The process of insight problem solving can be very frustrating; such combined goal orientation may contribute to breaking the impasse of insight through facilitating the cognitive process that is critical to insight problem solving, such as mindfulness, focused attention, persistence, emotional creativity, and flexible thinking (Yeh et al., 2020, 2014).

3.2. Emotions and insight problem solving

Numerous studies have investigated the influence of emotional states on insight problem-solving or creativity (e.g., Baas et al., 2008; Jovanovic et al., 2016; Skaar & Reber, 2020). It was commonly suggested that a positive emotional state facilitates creative problem solving, whereas a negative emotional state decreases creative problem solving. Skaar and Reber (2020) found that sudden insight was highly correlated with positive affect. Similarly, in a crossword puzzle study, Friedlander and Fine (2018) found that the "aha" moment with positive emotions has an energizing effect on a participant's motivation to continue solving problems. In addition, it is suggested that positive affect is related to implicit and flexible thought whereas negative affect is associated with explicit and elaborative thought (Orita, & Hattori, 2018), suggesting that both positive and negative emotions influence insight problem solving.

Emotional states differ along some dimensions. The three-dimensional theory of emotion (Baas et al., 2008) suggests that the emotional state–insight problem solving link can be understood in terms of hedonic tone (positive vs. negative), level of activation (activating vs. deactivating), and regulatory focus (promotion vs. prevention), or some combination. In creativity studies, it was found that promotion-focused emotions (e.g., anger, happiness) expand the attentional scope and thus facilitate creative performance, whereas prevention-focused emotions (e.g., fear, relaxation) constrict attentional scope and therefore impede creative performance (Baas et al., 2008).

Only a few studies have employed the three-dimensional emotion theory in digital or online insight problem studies. Based on Baas et al. (2008) theory, Yeh et al. (2016) developed the Inventory of Three-dimensional Emotions (I3E), which includes eight types of emotions consisting of three dimensions: valence (positive vs. negative), activation (low vs. high), and regulatory focus (prevention vs. promotion) (also see Table 1). Using this three-dimensional emotion framework, Yeh et al. (2016) found that the positive-high activation-promotion emotions (happy, elated) facilitated insight problem solving, whereas the negative-high activation-promotion emotions (angry, frustrated) hindered insight problem solving during game-based learning. They suggested that a positive emotional state facilitates creativity as it enhances cognitive flexibility as well as the ability to overcome challenges and therefore enhances the player's performance in creativity game-based learning. In the same vein, it was found that creativity decreased when negative-high activation-promotion emotions were provoked (Yeh et al., 2015).

Altogether, positive or negative emotions would have a stronger impact on insight problem solving when emotions are highly activated and promotion-focused. In other words, the valance, activation level, and regulatory focus of emotions need to be simultaneously considered to understand their relationship with insight problem solving. The three-dimensional emotion theory was therefore employed in this study.

3.3. The present study

This is a two-phase study. In phase 1, we aimed to develop the Digital Insight Problem Solving Test (DIPST) to measure the performance of insight problem solving. Two pretests were conducted. In phase 2, we aimed to picture the profiles of four types of achievement goals, eight types of emotions, and insight problem solving performance through an online system. In an exploratory manner, cluster analysis was employed to explore such profiles. Although no specific hypotheses were proposed, we postulated that a high level of approach goals (especially approach-mastery goal), a low level of avoidance goals (especially avoidance-mastery goal), strong positive-high activation-promotion emotions, and weak negative-highly activation-promotion emotions would result in a better performance in insight problem solving than the other profiles.

4. Method

4.1. Participants

In Phase 1, we first conducted a pretest using a paper-and-pencil test to make sure the test items of DIPST were valid before converging them into the digital test; participants were 22 college students (10 males and 12 females) who enrolled in the class "Instruction for Creativity." As a class activity, no extra credits or rewards were given. After revisions, we pretested the DIPST through an online system to confirm its validity again; participants were 32 college students (16 males and 16 females) who were recruited from campus internet advertisements. Approximately $7 was rewarded upon the completion of the test.

In Phase 2, we recruited 153 college students (35 males and 118 females) to explore the relationship between achievement goals, emotions, and insight problem solving as well as to reexamine the reliability and validity of DIPST. Approximately $10 was rewarded upon the completion of the test. The revised version of DIPST was then employed to analyze the profiles regarding insight problem solving, achievement goals, and emotions. Informed consent was obtained from all participants at all stages of this study.

4.2. Instruments

4.2.1. Digital insight problem solving test (DIPST)

To develop manipulable online insight tasks, we developed the DIPST. The test items were developed based on definitions and criteria of insight problem solving (Batchelder & Alexander, 2012; Wen et al., 2013). The original DIPST, 32 test items in total, includes four types of tasks: problems involving moving matchstick(s), rearranging balls, separating balls by lines or circles, and moving arrows. These test items were adapted from books, magazines, and website information. Based on the analytical results and feedback from the participants in the pretests, we deleted two items and added specific instructions for the movement of objects. The question and the solution strategies (moving matchstick(s), rearranging balls, separating balls by lines, or separating balls) for each of the insight problem tests were clearly stated at the top of the screen (see Fig. 1 for an example screen). The test items were randomly presented and participants were encouraged to solve each problem within 90 s.

For each test item, a correct answer was scored as "1″ point, and an incorrect answer was scored as "0″ points. The DIPST was developed through Tk, a GUI toolkit that is cross-platform for universal use. The advantage of this platform is that after the participants finished their problem solving by moving certain objects, they could simply click one button to submit the screenshot to the Common Gateway Interface (CGI) server. Moreover, the tasks can be shown in full-screen mode for the duration of the test so that the participants will not be disturbed by any events or elements in the monitor (Roseman, 2019). On the administrators' side, they can check the results documented by CGI using two formats: the image format that includes the exercise screenshots and the JSON format that includes text files of the administered questionnaire (see Fig. 2).

4.2.2. The multiple goals scale

The achievement goals were measured by the Multiple Goals Scale (MGS) (Liu, 2009). With a total of 30 items, the MGS included four factors: approach-mastery goal (8 items), approach-performance goal (8 items), avoidance-performance goal (7 items), and avoid-performance goal (7 items). The Cronbach's α for the MGS were 0.85, 0.89, 0.84, 0.83, and 0.84, respectively. MGS is a 6-point Likert scale with response options ranging from "very unlikely" to "very likely."

The test items included statements such as "The main drive for my learning is that I am interested in the content and I enjoy the

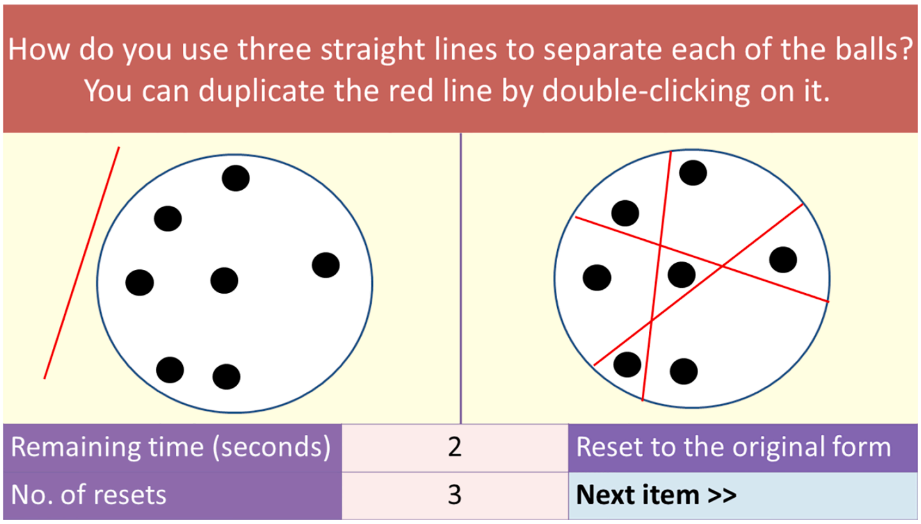

Fig. 1. An example screen of the DIPST.

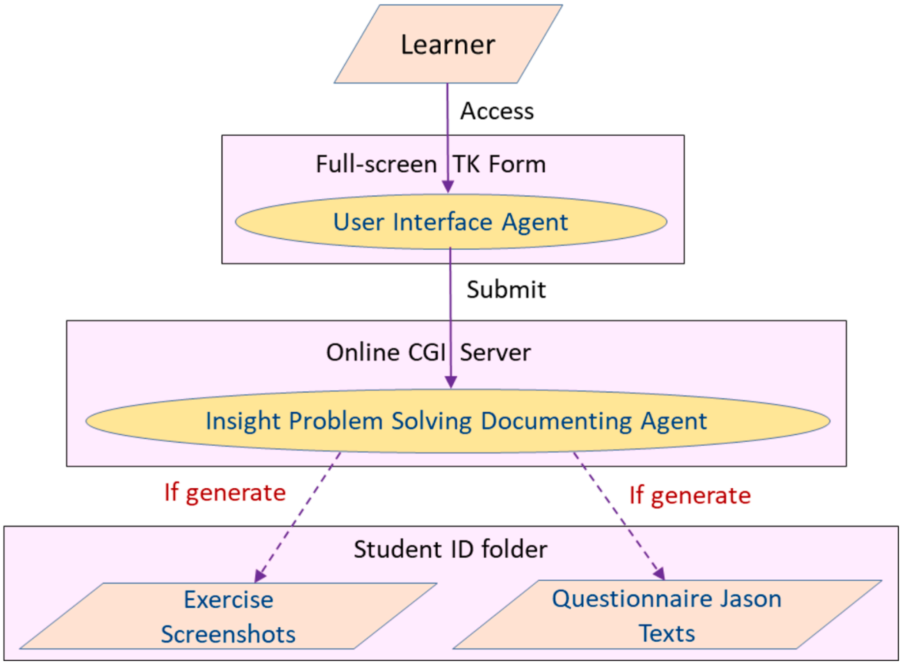

Fig. 2. The procedure and structure of the GUI platform.

learning"; "It's important to me that my performance is better than others"; "I am worried that I may not make any progress, so I strictly monitor my learning to not miss mastering any contents that the teacher has taught"; "The main drive for my learning is that I don't want to be the person who has the worst grade in class" (Liu, 2009).

4.2.3. Inventory of three-dimensional emotions

Emotions were measured by the Inventory of Three-dimensional Emotions (I3E) (Yeh et al., 2015, 2016). The I3E included three dimensions: valence (positive vs. negative), activation (low vs. high), and regulatory focus (prevention vs. promotion) (see Table 1). Sixteen items are evenly distributed in the 8 types of emotions, namely, the positive-low activation-prevention emotions (P-L-Pre), the positive-low activation-promotion emotions (P-L-Pro), the positive-high activation-prevention emotions (P-H-Pre), the positive-high activation-promotion emotions (P-H-Pro), the negative-low activation-prevention emotions (N-L-Pre), the negative-low activation--promotion emotions (N-L-Pro), the negative-high activation-prevention emotions (N—H-Pre), and the negative-high activation-promotion emotions (N—H-Pro). As a 4-point Likert-type scale, each item of the I3E item was scored from 1 to 4 points, representing "highly disagree" to "highly agree."

A confirmatory factor analysis (CFA) indicated that the positive emotion model had good construct validity: $\chi^2(17, N = 301) = 57.134$ ($p < .001$); GFI = 0.956, AGFI = 0.906, RMSEA = 0.089, RMR = 0.022. Similarly, the negative emotion model had good construct validity: $\chi^2(15, N = 301) = 29.151$ ($p = .015$); GFI = 0.976, AGFI = 0.944, RMSEA = 0.056, RMR = 0.017. As for reliability, Cronbach's α for the I3E, the positive emotions, and the negative emotions are 0.839, 0.771, and 0.842, respectively (Yeh et al., 2015) (see Table 1).

4.3. Procedures

The paper-and-pencil pretest of DIPST was administered in a classroom by the researchers. The online pretest in Phase 1 and the formal test in Phased 2 were conducted in a computer laboratory using desktop computers. For the Phase 2 study, the participants completed the inventory measuring achievement goals after they signed the consent form and received a brief introduction. Then, they proceeded to complete the DIPST; the test items of DIPST were randomly displayed. A 5-minute break was employed in the middle of

Table 1
Construct and reliability of the I3E.

Positive (α = 0.771)				Negative (α = 0.842)			
Low-activation(α = 0.686)		High-activation(α = 0.706)		Low-activation(α = 0.795)		High-activation(α = 0.723)	
Prevention (P-L-Pre)	Promotion (P-L-Pro)	Prevention (P-H-Pre)	Promotion (P-H-Pro)	Prevention (N-L-Pre)	Promotion (N-L-Pro)	Prevention (N—H-Pre)	Promotion (N—H-Pro)
Calm	Warm	Secure	Happy	Isolated	Sad	Tense	Angry
Relaxed	Lively	Trusting	Elated	Exhausted	Disappointed	Fearful	Frustrated

the DIPST. Upon the completion of the DIPST, the participants completed the inventory measuring emotions and had a debriefing session. The experiment took about 75 min.

5. Results

5.1. Reliability and validity of the DIPST

Descriptive statistics, item analyses, and reliability analysis were employed to examine the reliability and validity of the DIPST in both Phase 1 and Phase 2. Two indices are usually used for item analysis: item difficulty and item discrimination. Item difficulty is the average proportion of the upper group who got an item right and the proportion of the lower group who got the item right; i.e., $(\text{Correct}_{\text{High}} + \text{Correct}_{\text{Low}})/2$. A high index indicates an easy item and a low index indicates a difficult item. On the other hand, item discrimination is the difference between the proportion of the upper group who got an item right and the proportion of the lower group who got the item right ($\text{Correct}_{\text{High}}$ - $\text{Correct}_{\text{Low}}$) (Michigan State University, 2016; Stronge et al., 2017). Good items have a discrimination index of 0.40 and higher, reasonably good items from 0.30 to 0.39, marginal items from 0.20 to 0.29, and poor items less than 0.20 (McCowan & McCowan, 1999). However, the application of these criteria depends on the purpose of measurement (Stronge et al., 2017). In this study, we employed the upper 30% and the lower 30% as the cut-off points for grouping.

Based on the analytical results from Phase 1 and Phase 2, we screened out the best 20 test items (see Fig. 3). A T-test was performed to further examine the item discrimination of each test item. The results showed that the upper group outperformed the lower group on all test items. On average, the item difficulty was 0.482, and the item discrimination was 0.405. These findings suggest that the 20 items have appropriate item difficulty and discrimination. Moreover, Cronbach α was 0.637 for the 20 items. Because this is a true and false test, and varied types of problems are included, internal consistency is acceptable.

5.2. Relationship between achievement goals, emotions, and insight problem solving

5.2.1. Preliminary analysis

To ensure the DIPST was not gender-biased, we used gender as a between variable and the total score of insight problem solving as the dependent variable to conduct an Analysis of Variance (ANOVA). The results showed no gender difference on insight problem solving, $F(1151) = 0.838$, $p = .361$, $\eta_p^2 = 0.006$. The mean time for each insight problem solving was 61.18 ($SD = 8.37$). Accordingly, we used all the samples to do the following analyses.

5.2.2. Cluster analysis

Cluster analysis was employed to explore the patterns of achievement goals, emotions, and insight problem solving. In this study, we employed k-means clustering, which gives a formal definition as an optimization problem: find the k cluster centers and assign the objects to the nearest cluster center so that the squared distances from the cluster are minimized (Cutillo, 2019). Four types of achievement goals (approach-mastery, approach-performance, avoidance-mastery, and avoidance-performance), 8 types of emotions (P-L-Pre, P-L-Pro, P-H-Pre, P-H-Pro, N-L-Pre, N-L-Pro, N—H-Pre, N—H-Pro), and insight problem solving were included in the cluster analysis. Overall, the variables formed four significant clusters (C1, C2, C3, and C4), $F(3148) = 13.307$, $p < .001$, $\eta_p^2 = 0.558$. The mean

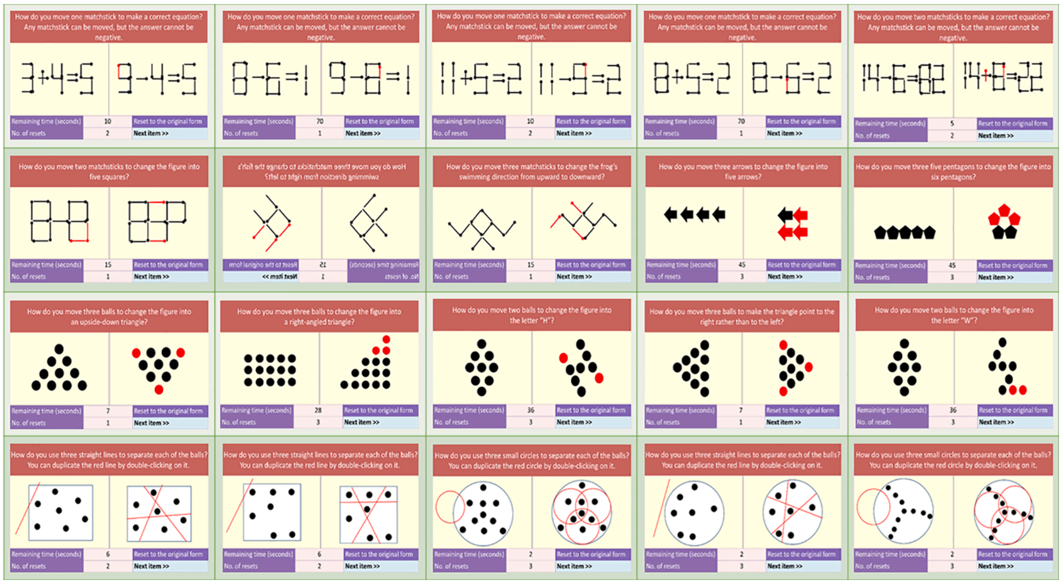

Fig. 3. Test items of the DIPST.

scores of the final center for each of the variables are shown in Fig. 4(a). Because the score of insight problem solving was far beyond the other mean scores, we excluded the score of insight problem in Fig. 4(b) to make the differences between clusters clear. The results revealed that, except for the approach-mastery goal, approach-performance goal, positive-low activation-promotion emotions, and positive-high activation-prevention emotions, all variables were significant in predicting cluster membership (see Table 2).

We then conducted a multivariate analysis of variance (MANOVA) to further examine cluster differences in all variables. The results showed that C1 had a higher level of avoidance-mastery goal, N—H-Pre emotions (tense, fearful), and N—H-Pro-emotions (angry, frustrated) than C2, C3, or C4 ($ps < 0.001$). Moreover, C1 had a higher level of avoidance-performance goal than C3 or C4 ($p = .014$). Finally, C1 had a higher level of N-L-Pre emotions (isolated, exhausted) than C3 ($p = .013$) and had a higher level of N-L-Pro-emotions (sad, disappointed) than C4 ($p = .007$). On the other hand, C1 had a lower level of P-L-Pre emotions (calm, relaxed) than C2, C3, or C4 ($p = .001$) and a lower level of P-H-Pro-emotions (happy, elated) than C4 ($p = .001$). Regarding the scores of insight problems solving, the results indicated C2 > C4 > C3 > C1 (see Table 2).

Integrating analysis of mean scores and the results of MANOVA, we identified four clusters of participants with distinctive features as follows: "Achieved thinkers" (C2) who are with appropriate achievement goals show a high level of performance and positive emotions; "satisfied thinkers" (C4) who are with appropriate achievement goals show above-average performance and a medium level of positive emotions; "confused thinkers" (C3) who have undifferentiated achievement goals and emotions show below-average performance; and "frustrated thinkers" (C1) who have conflicted achievement goals (high approach and high avoidance goals) show a low level of performance and intensive negative emotions. More specifically, "achieved thinkers" are characterized by "high" insight problem solving ability with medium approach-mastery goal and approach-performance goal, low avoidance-mastery goal, high P-L-Pre emotions (calm, relaxed), low negative emotions (especially N—H-Pre and N—H-Pro; i.e., tense, fearful, angry, and frustrated). "Satisfied thinkers" feature "upper medium" insight problem solving ability with a medium avoidance-mastery goal, high P-H-Pro-emotions (happy, elated), and low negative emotions. "Confused thinkers" are characterized by "lower medium" insight problem solving ability with low avoidance goals, high P-L-Pre emotions, and medium negative emotions. Finally, "frustrated thinkers" feature "low" insight problem solving ability with high avoidance goals, low P-L-Pre emotions, low P-H-Pro-emotions, and high negative emotions (especially N—H-Pre and N—H-Pro) (see Fig. 5).

6. Discussion

Past studies of insight focused on three dimensions: process, task, and phenomenology (Öllinger and Knoblich, 2009; Webb et al., 2016). This study focuses on task and phenomenology dimensions. We first developed the DIPS, which integrates different types of insight tasks. Then, we identified the profiles of insight problem solving regarding achievement goals and emotions through cluster analysis.

Most traditional insight tasks request the learner to "mentally" solve the problem (e.g. matchstick problem); few digital insight tasks have been developed to allow the learner to "actually manipulate" objects to solve the problems. Such digital tasks not only help participants visualize problem solving process but also help participants monitor their remaining time." The DIPST developed in this study includes four types of tasks: moving matchstick(s), rearranging balls, separating balls by lines or circles, and moving arrows. In developing the DIPST, we conducted one paper-and-pencil pretest, one online pretest, and one online formal test. After continuous analyses and revisions, the final 20 test items have good reliability and validity. Notably, a major difficulty in insight problems is the

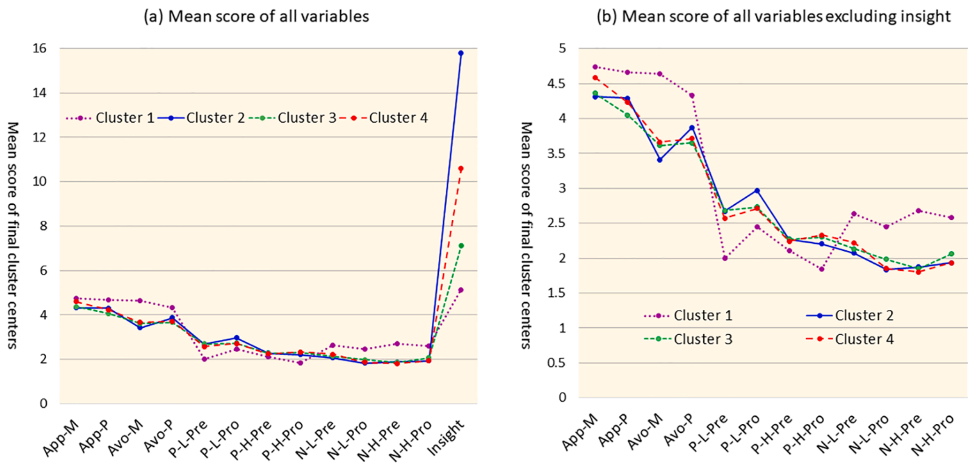

Fig. 4. Mean scores of the final center for achievement goals, emotions, and insight problem solving

Note. Four cluster groups: C1, C2, C3, and C4. Number of participants in each cluster: G1 = 35; G2 = 19; G3 = 76, G4 = 23. Four achievement goals: approach-mastery (App-M), approach-performance (App-P), avoidance-mastery (Avo-M), and avoidance-performance (Avo-p). Eight emotions: positive-low activation-prevention (P-L-Pre), positive-low activation-promotion (P-L-Pro), positive-high activation-prevention (P-H-Pre), positive-high activation-promotion (P-H-Pro), negative-low activation-prevention (N-L-Pre), negative-low activation-promotion (N-L-Pro), negative-high activation-prevention (N—H-Pre), and negative-high activation-promotion (N—H-Pro).

Table 2
Final cluster centers and ANOVA.

	Cluster				ANOVA			
	1	2	3	4	*F*(1, 3)	Sig.	η_p^2	Scheffé
App-M	4.74	4.31	4.36	4.59	2.297	.080	.044	
App-P	4.66	4.29	4.05	4.23	2.528	.060	.049	
Avo-M	4.64	3.41	3.61	3.66	10.764***	.000	.179	C1 > C2, C3, C4
Avo-P	4.33	3.87	3.65	3.71	3.650*	.014	.069	C1 > C3, C4
P-L-Pre	2.00	2.67	2.68	2.57	5.763***	.001	.105	C2, C3, C4 > C1
P-L-Pro	2.45	2.97	2.73	2.71	2.175	.093	.042	
P-H-Pre	2.11	2.27	2.27	2.24	.396	.756	.008	
P-H-Pro	1.84	2.20	2.30	2.33	2.791*	.043	.054	C4 > C1
N-L-Pre	2.63	2.07	2.13	2.22	3.691*	.013	.070	C1 > C3
N-L-Pro	2.45	1.83	1.98	1.85	4.240**	.007	.079	C1 > C4
N—H-Pre	2.68	1.87	1.85	1.80	11.038***	.000	.183	C1 > C2, C3, C4
N-H-Pro	2.58	1.93	2.06	1.93	6.415***	.000	.115	C1 > C2, C3, C4
Insight	5.11	15.80	7.11	10.59	285.818***	.000	.853	C2, C3, C4 > C1
								C2 > C1, C3, C4
								C4 > C3

Note. Four cluster groups: C1, C2, C3, and C4. Number of participants in each cluster: G1 = 35; G2 = 19; G3 = 76, G4 = 23. Four achievement goals: approach-mastery (App-M), approach-performance (App-P), avoidance-mastery (Avo-M), and avoidance-performance (Avo-p). Eight emotions: positive-low activation-prevention (P-L-Pre), positive-low activation-promotion (P-L-Pro), positive-high activation-prevention (P-H-Pre), positive-high activation-promotion (P-H-Pro), negative-low activation-prevention (N-L-Pre), negative-low activation-promotion (N-L-Pro), negative-high activation-prevention (N—H-Pre), and negative-high activation-promotion (N—H-Pro).

Cluster / Variables	**Cluster 2 (Achieved thinkers)** High insight problem solving ability with medium approach goals, low avoidance-mastery goal, high P-L-Pre emotions, and low negative emotions (especially N-H-Pre and N-H-Pro)	**Cluster 4 (Satisfied thinkers)** Medium insight problem solving ability with medium avoidance-mastery goal, high P-H-Pro emotions, and low negative emotions	**Cluster 3 (Confused thinkers)** Medium insight problem solving ability with low avoidance goals, high P-L-Pre emotions, and medium negative emotions	**Cluster 1 (Frustrated thinkers)** Low insight problem solving ability with high avoidance goals, low P-L-Pre emotions, low P-H-Pro emotions, and high negative emotions (especially N-H-Pre and N-H-Pro)
Insight ability	**High**	**Upper medium**	**Lower medium**	**Low**
Approach goals	Medium approach-mastery goal and approach-performance goal	Medium approach-mastery goal and approach-performance goal	medium approach-mastery goal and low approach-performance goal	High approach-mastery goal and approach-performance goal
Avoidance Goals	Low avoidance-mastery goal and medium avoidance-performance goal	Medium avoidance-mastery goal and low avoidance-performance goal	Medium avoidance-mastery goal and low avoidance-performance goal	High avoidance-mastery goal and avoidance-performance goal
Positive emotions	High positive emotions, especially P-L-Pre emotions	Medium positive emotions with higher P-H-Pro emotions	Medium positive emotions with higher P-L-Pre emotions	Low positive emotions
Negative emotions	Low negative emotions, especially N-H-Pre and N-H-Pro emotions	Low negative emotions with higher N-L-Pre emotions	Medium negative emotions	High negative emotions, especially N-H-Pre and N-H-Pro emotions

Fig. 5. Key features of each cluster
Note. Four achievement goals: approach-mastery (App-M), approach-performance (App-P), avoidance-mastery (Avo-M), and avoidance-performance (Avo-p). Eight emotions: positive-low activation-prevention (P-L-Pre), positive-low activation-promotion (P-L-Pro), positive-high activation-prevention (P-H-Pre), positive-high activation-promotion (P-H-Pro), negative-low activation-prevention (N-L-Pre), negative-low activation-promotion (N-L-Pro), negative-high activation-prevention (N—H-Pre), and negative-high activation-promotion (N—H-Pro).

need for extensive search processes in large problem spaces (Martinsen et al., 2016); a search constraint (e.g., solution hints) may reduce search in large problem spaces and therefore facilitate finding a solution (Hattori et al., 2013; Martinsen et al., 2016). We, therefore, give specific constraints (e.g. "move two matchsticks" or "move three dots") to each test item in DIPST. Furthermore, based on our paper-and-pencil pretest, we set up 90 s for each online insight task. The online test results showed that the mean time for solving an insight problem was 61.18 s (SD = 8.37 s), suggesting that hands-on manipulation facilitates the efficiency of insight problem solving.

Phenomenology approach of insight studies found that sudden insight increases fluency, positive affect, and subjective certainty (Skaar & Reber, 2020; Tobin, 2018), and such metacognitive feelings mediate the effect of sudden insight on the immediate sense of motivation and coping (Skaar & Reber, 2020). Accordingly, emotions, motivation, and insight are interconnected. To identify the profiles of these variables, we included four types of achievement goals and eight types of emotions, together with insight problem solving, to perform a cluster analysis. Cluster analysis aims to partition a large dataset into meaningful subgroups of subjects; it is a common technique for pattern recognition (Cutillo, 2019). Four distinctive types of profiles merged in the cluster analysis, suggesting personal traits of achievement goals and emotional state during problem solving are closely related to the performance of insight problem solving. The best profile for great performance in insight problem solving (i.e., the achieved thinkers) was a combination of a medium level of approach achievement goals, a low level of the avoidance-mastery achievement goal, strong positive-low activation-prevention emotions (calm, relaxed), and weak negative emotions (especially the highly activated emotions, i.e., tense, fearful, angry, frustrated). This finding supports the multiple-goal perspective (Pintrich, 2000a, 2000b) and provides a favorable profile for effective insight problem solving.

Among the variables included in cluster analysis, an avoidance-mastery achievement goal, as well as positive-low activation-prevention emotions (calm, relaxed), negative-high activation-prevention emotions (tense, fearful), and negative-high activation-promotion emotions (angry, frustrated) could best demonstrate the difference between high performance and low performance in insight problem solving (see Table 2). Across the groups, however, the avoidance-mastery goal and negative emotions (especially the highly activated emotions, i.e., tense, fearful, angry, frustrated) could best predict the performance of insight problem solving. In other words, college students with a lower level of avoidance-mastery achievement goal and weaker negative emotions (especially the highly activated negative emotions) performed better in insight problem solving than their counterparts. These results lend support to the findings that negative-high activation-promotion emotions can decrease insight problem solving performance (Yeh et al., 2016), but they are inconsistent with the finding that negative emotions encourage people to intensively focus on solving the insight task (Orita & Hattori, 2019) and therefore lead to successful insight problem solving (Baas et al., 2011).

In addition, the findings support that the avoidance-performance goal, associated with negative emotions, disengagement following obstacles, and low achievement, is harmful to learning outcomes (Elliot & McGregor, 2001; Hornstra et al., 2017; Urdan & Kaplan, 2020; Wolters, 2004). Moreover, the observation that the avoidance-mastery goal is the most detrimental goal orientation to insight problem solving is also in line with past findings (Giel et al., 2019; Lee & Anderman, 2020). However, the approach-mastery goal, which has been found to be related to challenge seeking, the use of effective learning strategies, persistence in the face of difficulty, and positive emotions (Chung et al., 2020; Elliott & Dweck, 1988), was not predictive to the performance of insight problem solving, contrary to our expectations. One possible explanation is that most participants in this study had a medium level of approach-mastery goal, which decreases the variation and leads to insignificant effects.

Notably, the influence of negative emotions on insight problem solving seems to be stronger than that of approach-mastery goal and approach-performance goal, and the influence of negative emotions on insight problem solving is stronger than that of positive emotions. The results of cluster analysis indicated that when college students had strong negative emotions, even when they had a high level of approach achievement goals, they still performed the worst (C1, the frustrated thinkers). However, the cluster profiles reveal that achievement goals and emotions can be compensatory. For example, positive-high activation-promotion emotions (happy, elated) may help decrease the negative influence of the avoidance-mastery goal on insight problem solving (C4, the satisfied thinkers). Accordingly, although positive emotions were not so influential in insight problem solving, they play a role as a buffer and moderator.

7. Conclusion

This study investigated the task and the phenomenology aspects of insight problem solving. Owing to the lack of comprehensive and valid online tests of insight problem solving, we developed and validated the DIPST through two pretests and one formal test. The results suggest that the DIPST has appropriate item difficulty and good item discrimination. Then, we employed the DIPST to explore the profiles of four types of achievement goals, eight types of emotions, and creative insight problem solving among college students through online tests and cluster analysis. Cluster analysis is a great vehicle for identifying the profile of people with varied levels of insight problem solving when a set of important personal characteristics are considered. Yet, few studies have employed this technique to conduct empirical insight studies. We employed this technique and found four distinctive insight profiles (achieved thinkers, satisfied thinkers, confused thinkers, and frustrated thinkers). The findings suggest that a combination of a medium level of approach achievement goals, a low level of avoidance-mastery achievement goal, strong positive-low activation-prevention emotions, and weak highly-activated negative emotions results in the best performance in insight problem solving. To conclude, this study develops a valid and manipulable insight test and identifies the favorable profile for great performance in insight problem solving, which contributes to the theoretical understanding of cognitive processes as well as further instruction and research regarding insight problem solving.

8. Limitations and implications

Complex dynamic system theory provides an attractive paradigm (Kaplan et al., 2012); it describes emergent phenomena in which elements continuously and reciprocally influence each other to manifest in the system's behavior (Urdan & Kaplan, 2020). In this study, we did not measure achievement goals, emotions, and insight problem solving at different time points, and therefore we cannot explore the dynamic relationship between these variables. Future studies can employ a dynamic assessment design to explore the complex dynamic system of insight problem solving.

Furthermore, the mean time for solving each insight problem online was 61.18 s in this study, suggesting that the given time of 90 s can be shortened. The results also suggest that online hands-on manipulation facilitates the efficiency of insight problem solving; more hands-on activities should be employed in classroom teaching. Moreover, this study did not trace and record all the cognitive processes. Future studies using online insight tasks can include such a design. Moreover, developing more online or digital insight tests is encouraged to provide adequate instruments for dynamic assessment of insight problem solving and to enhance learners' problem solving ability.

More recent studies have suggested that insight problem solving, although largely governed by an implicit learning mechanism, involves both conscious and unconscious cognitive processes (Yeh et al., 2020). Similarly, in an eye movement study, Yeh et al. (2014) suggested that insight problem solving involves a top-down process that deliberately directs attention to pertinent information for solving insight problems and a bottom-up process that unconsciously leads to the association of insight thoughts. This study did not request the participants to report their cognitive processes. Future studies can employ questionnaires or a think-aloud technique to obtain such information.

Finally, the findings of this study revealed that the avoidance-mastery goal combined with highly activated negative emotions is the most detrimental factor to the performance of insight problem solving. However, positive-high activation-promotion and positive-low activation-prevention emotions may buffer such negative influences on insight problem solving. Instructions or software design endeavoring to improve the ability of insight problem solving should build a positive environment to support the development of these positive emotions in order to decrease learners' avoidance-mastery goal orientation and the detrimental negative emotions. Additioanlly, the findings of this study suggest that a medium level of approach goals combined with a low level of avoidance-mastery goals help set appropriate expectations and therefore bring about positive emotions and great performance during insight problem solving. On the other hand, a high level of approach and avoidance goals may bring about great pressure and intensive negative emotions, which hinders the performance of insight problem solving. Accordingly, guiding students to set goals with appropriate challenges is important for facilitating the cognitive process that is critical to insight problem solving, such as mindfulness, persistence, positive emotions, and flexible thinking.

CRediT authorship contribution statement

Yu-chu Yeh: Conceptualization, Instrument development, Formal analysis, Funding acquisition, Methodology, Validation, Visualization, Writing original draft, Review & editing. **Hsiao-an Wu:** Data curation, Instrument development, Writing part of the literature review. **Frank Huang:** Programming for the insight tasks.

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Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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