# Reverse Design Strategy in Design Education: Effects on Creativity and Engagement

Chao Yang Yang
Tatung University, Taiwan

**ABSTRACT:** Student engagement—comprising emotional, behavioral, and cognitive components—is critical to learning effectiveness and academic outcomes. This study examines the potential of integrating the Reverse Design Strategy (RDS) with a Concept Triangulation Map (CTM) to support idea development in design education. A quasi experimental design compared this method with traditional teaching in innovation courses. The Self-Rated Creativity Scale (SRCS) and the Student Engagement in Schools Questionnaire (SESQ) were used for assessment. Results indicated that RDS significantly enhanced students' project scores and promoted deeper learning strategies and knowledge integration. However, students rated their creativity, particularly novelty, relatively low. No significant difference was found in overall engagement, but the experimental group showed greater cognitive investment. Some participants experienced learning pressure due to unfamiliarity with the structured process. The findings suggest that while RDS facilitates systematic ideation and learner autonomy, it may also limit perceived creative freedom. This study affirms the instructional value of RDS and recommends a phased teaching model that blends structured synthesis with opportunities for free creation and reflection, aiming to optimize both innovation quality and learning outcomes.

**Keywords:** Conceptual Blending Theory, Creative Self-perception, Design Education, Learning Effectiveness, Reverse Design Strategy, Student Engagement

## 1. Introduction

Teaching methods can be categorised on the basis of their emphasis on input, process, or outcome (Richards, 2013). Traditional teaching models typically begin with curriculum planning, proceed through methodological execution, and conclude with an evaluation of learning outcomes. With a wide range of teaching resources and materials, the majority of planning and development strategies rely on established knowledge bases rather than on the immediate responses of individual instructors. By contrast, backward design begins by defining the expected learning outcomes and operates in reverse to identify key learning activities and content input. This methodology is designed to achieve specific objectives and employs standardised evaluation methods. Teaching objectives serve as criteria for selecting materials and content, with the primary goal of guiding students towards meaningful transformation through structured planning and instructional development (McTighe & Thomas, 2003; Richards, 2013).

In design education, instructional design is typically structured following a traditional design process, characterised by an inspiration–ideation–implementation framework (Scheer et al., 2012). This approach ensures that students systematically develop innovative skills while achieving high-quality design outcomes. Despite variations in different design models regarding the interpretation of design phases (Waidelich et al., 2018), a common feature is that the output of each stage serves as the input for the next. This process is highly structured, with progressively refined deliverables, positioning the planning and execution of design courses as a sequence of standardised stages (Tessmer & Wedman, 1990; Trilling & Fadel, 2009). This structured approach is useful for beginners because it facilitates foundational skill acquisition and prepares students for advanced creative exploration; nevertheless, the approach has several limitations. Students who lack a rigorous knowledge base and logical reasoning skills may struggle to achieve expected results (Lo, 2021). Additionally, the rigid framework of the approach may limit creative divergence during the early stages of ideation (Conradie et al., 2015).

In design education, backward design focuses on final design outcomes. Its primary teaching objective is to enable students to independently produce high-quality design work. This approach fosters a deep understanding of design methods, execution frameworks, and strategic thinking strategies while helping students conduct precise problem analyses and balance divergent and convergent thinking (Yang & Fu, 2025). The reverse design strategy helps learners regulate their learning process by focusing on concrete design deliverables, ensuring that they acquire essential design competencies in settings involving limited resources. This approach not only enhances design



quality and feasibility but also aids in the evaluation of learning progress, evaluating execution capabilities and innovation skills and emphasising outcome-driven and practice-oriented learning (Dorst, 2011).

### 1.1. Reverse Design Course Strategy

Unlike conventional design processes, which follow a sequential structure of need exploration, problem definition, ideation, prototyping, testing, iteration, and implementation (Anand et al., 2015; Gloger, 2017; Scheer et al., 2012; Shapira et al., 2017), the reverse design strategy resembles case-based reasoning. By focusing on successful case studies, this approach enables the rapid construction of design concept frameworks, which in turn mitigate speculative ideation and uncertainty while enhancing design quality and learning efficiency (Riesbeck & Schank, 2013). According to the literature, the reverse design strategy accelerates the early stages of design projects, offering precise conceptual substitution options through conditional analysis, which in turn enhances creative thinking, accelerates concept development, reduces trial-and-error costs, and improves design decision-making and learning efficiency (Yang & Fu, 2025).

The concept triangulation map is presented in the form of an A0-sized poster, which delineates the ideation space into three principal components. It emphasizes the spatial representation of conceptual relationships through distance and orientation, thereby enabling the assignment of value to each concept and supporting the consideration of alternatives from multiple analytical perspectives (see *Figure 1*). Throughout the process, participants engage in iterative analogy, analytical decomposition, and comparative assessment of design concepts, which progressively facilitates the refinement and structuring of ideas. This systematic approach provides a solid foundation for subsequent development and implementation.

Moreover, CTM underscores the significance of individual cognitive contributions and intra-team communicative agreements, aiming to mitigate value-based discrepancies and to sustain team cohesion. Empirical studies have demonstrated that CTM maintains creative performance within teams, significantly enhances the practical realization of innovative ideas, and exerts positive effects on communication, conceptual concretization, and evaluative judgment (Yang & Fu, 2022). By enhancing team-level effectiveness, CTM contributes to the overall improvement of collaborative outcomes (DeFranco et al., 2011).

In contrast to conventional design approaches, the reverse strategy embedded within CTM offers a more structured problem-solving process and facilitates task-oriented communication, which has been shown to significantly improve interdisciplinary collaboration efficiency (Yang & Fu, 2025). Applied in this context, the CTM-based reverse design strategy enables teams to analytically deconstruct the conceptual structure, design logic, and critical innovation attributes of successful products. This approach deepens problem exploration, reinforces collaborative efficacy, and fosters the development of students' creative thinking and problem-solving capacities, rendering the design process more systematic and practically feasible (Yang & Fu, 2025). The CTM-based reverse design strategy comprises three sequential stages (see ***Figure 2***):

#### *1.1.1. Reverse Analysis Stage*

Learners articulate their design focus through the formulation of a design statement, initiating from key problems, proposed solutions, or intended design outcomes. Subsequently, they conduct analogical reasoning with validated award-winning design cases, deconstructing each in terms of contextual issues (What), user characteristics

(Who), and design carriers (Carrier), thereby establishing a foundational conceptual framework "WWC(1)".

#### *1.1.2. Concept Blending Stage*



Anchored in the core innovative elements identified within award-winning cases "WWC(1)", this stage involves the associative expansion of potential contextual problems, user needs, and design carriers. Through the application of CTM's positional logic, concepts are categorized and analyzed based on their relational coherence. A value assessment process, often operationalized via group-based voting, is employed to evaluate the novelty and feasibility of conceptual alternatives, which are subsequently synthesized, substituted, or transformed into a new conceptual constellation "WWC(2)" in relation to "WWC(1)".

#### *1.1.3. Test and Iteration Stage*

Drawing upon iterative design discourse and formative feedback, selected conceptual combinations are refined and consolidated into implementable design proposals.

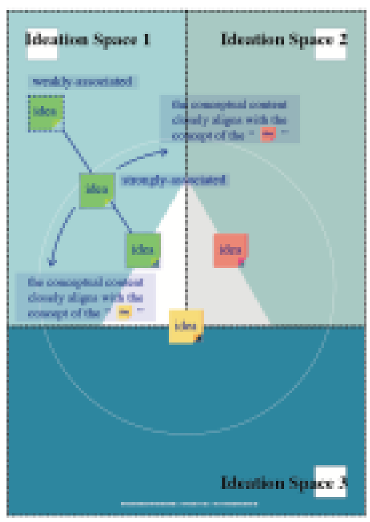


*Figure 1.* Operational Framework and Positioning Logic of CTM

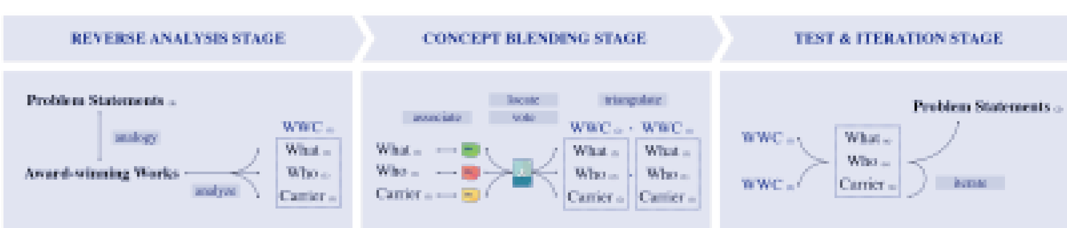


*Figure 2.* The CTM reverse strategy consists of three stages.

### 1.2. Learning Outcomes in Design Courses: Creativity and Student Engagement

In design courses, innovation cannot be measured using a single approach. Creativity performance must be comprehensively evaluated, with multiple factors considered in both the process and outcomes. Creativity may exhibit complex interactions with an individual's knowledge, cognitive skills, intrinsic motivation, and personality traits and may even be influenced by external environmental factors (Sternberg, 1999). Self-reported creativity is often used as an indicator of individual creativity because self-reported creativity is somewhat impervious to external factors such as social expectations. This indicator is correlated with personality traits, fluency, and divergent thinking (Carson et al., 2005; Reiter-Palmon et al., 2012).

Creative self-efficacy is a key prerequisite for creativity performance that can mediate the relationship between personal and environmental factors (Choi, 2004; Mathisen & Bronnick, 2009). Enhancing self-efficacy necessitates a cognitive evaluation of personal successes or failures, through which individuals can develop an understanding of



their own capabilities (Bandura, 1997). Creative self-efficacy enables students to believe in their ability to generate creative outcomes, which in turn increases their engagement in creative activities (Locke et al., 1984; Tierney & Farmer, 2011). When students have greater confidence in their creative behaviour, they tend to exhibit higher creativity performance (Mathisen & Bronnick, 2009). Research has confirmed a positive correlation between students' creative self-efficacy and teachers' evaluations of their creativity (Choi, 2004).

Individuals tend to perceive themselves as creative, particularly in environments where innovation is highly valued. Self-reports are typically associated with a high risk of score distortion as a result of honesty concerns and social expectations (Heidemeier & Moser, 2009). Additionally, research has identified gaps between domain-specific creative performance and actual creative abilities (Reiter-Palmon et al., 2012), which do not diminish the usefulness or practical value of self-reports despite limiting their measurement validity.

In empirical research, accessible data often involve learners' emotional and cognitive feedback during the learning process. Emotional behaviours refer to students' positive or negative psychological reactions to external stimuli. Cognitive behaviours involve knowledge acquisition, principle application, and problem-solving abilities (Yang & Hsu, 2020). This study focuses on evaluating learners' intrinsic motivation and cognitive skills by using creativity and student engagement as key indicators of the learning effectiveness of innovative courses. Creativity is the ability to generate novel and valuable ideas and is essential for solving complex problems and driving innovation (Runco & Jaeger, 2012). Student engagement has emotional, behavioural, and cognitive dimensions (Fredricks et al., 2004) and reflects students' involvement in learning and the influence of this involvement on their creative thinking and problem-solving abilities (Henriksen et al., 2014).

## 2. Method

### 2.1. Participants

This study recruited 65 third-year students enrolled in a compulsory product development course at the Department of Industrial Design. The course, categorized as an advanced professional design subject, is part of the core third year curriculum. All students shared similar learning motivations and academic goals. The study was reviewed by the Ministry of Education, which required informed consent but not IRB approval. All participants signed consent forms prior to the course, with confidentiality and voluntary participation ensured. The initial sample included 25 male and 41 female students.

Participants S1–S32 were assigned to the experimental group, which received instruction based on the reverse design strategy. Participants S33–S65 were assigned to the control group, which received traditional design instruction. Participant S46 was excluded from our analysis because they withdrew for personal reasons.

### 2.2. Measures

#### *2.2.1. Self-Rated Creativity Scale*

Reiter-Palmon et al. (2012) developed the 13-item Self-Rated Creativity Scale (SRCS) to evaluate individual creativity. This scale has high internal consistency (Cronbach's $\alpha = .96$). Each item is rated on a 5-point Likert scale. Tan and Ong (2019) identified the optimal factor model as a 12-item structure, excluding item 9. This refined model includes a general creativity factor, reflecting each individual's overall perception of their creative thinking ability, along with two specific factors, namely practicality (items 1–4) and novelty (items 5–13). This two-factor model provides a precise representation of the data structure of the SRCS.

#### *2.2.2. Student Engagement in Schools Questionnaire*

Lam and Jimerson (2008) developed the 109-item Student Engagement in Schools Questionnaire (SESQ) to comprehensively evaluate student engagement in learning. This paper-and-pencil self-report questionnaire has high reliability (α = .92) and is used to evaluate four main dimensions: school engagement, motivational beliefs, social



relationships, and student outcomes. To address sampling limitations in the original scale, Hart et al. (2011) developed a 33-item shortened version, referred to as the SESQ-ENG.

The SESQ-ENG consists of three subdimensions: emotional engagement (Q1–Q9), including learning enjoyment (Q1–Q5) and school affinity (Q6–Q9); behavioural engagement (Q10–Q21), including effort and persistence (Q10–Q18) and participation in extracurricular activities (Q19–Q21); and cognitive engagement (Q22–Q33). This questionnaire has high internal consistency, with Cronbach's α values ranging from .65 to .95. Although the majority of subscales meet the acceptable reliability threshold (α > .70), the attribution domain has a lower α value of .65, suggesting potential measurement inconsistencies. Therefore, researchers recommend removing or modifying items in the attribution domain to ensure measurement clarity.

Research indicates that SESQ-ENG scores exhibit significant correlations with teacher ratings, confirming the construct validity of the questionnaire. As a concise and effective assessment tool, the SESQ-ENG offers practical applications for both academic research and educational practice.

## 3. Results

A total of 65 questionnaires were distributed, of which 64 were returned. After data preprocessing and validation (e.g., missing value detection and outlier screening), all returned questionnaires were found to meet the criteria for analysis, with no invalid or incomplete responses. Thus, the final valid sample size was 64.

In the SRCS with item Q9 excluded (Tan & Ong, 2019), the overall internal consistency (Cronbach's α) was 0.87, indicating high reliability. The practicality dimension (Q1–Q4) had a Cronbach's α of 0.703, indicating moderate reliability, and the novelty dimension (Q5–Q8, Q10–Q13) had a Cronbach's α of 0.871, indicating high reliability. Overall, the SRCS exhibited high reliability across both the total scale and specific subdimensions, with particularly high performance in the novelty dimension.

In the SESQ-ENG (Q1–Q33), the overall internal consistency (Cronbach's α) was 0.84, indicating high reliability. The emotional engagement dimension (Q1–Q9) had a Cronbach's α of 0.76, indicating high internal consistency; the behavioural engagement dimension (Q10–Q21) had a Cronbach's α of 0.73, indicating moderate reliability; and the cognitive engagement dimension (Q22–Q33) had a Cronbach's α of 0.86, indicating very high reliability. Overall, the SESQ-ENG exhibited high reliability, particularly in the cognitive engagement dimension, which had the highest reliability.

### 3.1. Comparison of Learning Outcomes in Reverse and Traditional Innovation Course

**Strategies** ***3.1.1. Project Scores***

Project scores were evaluated by six experienced design educators, and the final score was calculated as the average rating. The experimental group (S1–S32) had an average project score of 79.13 (standard deviation [SD] = 6.33), and the control group (S33–S65) had an average project score of 75.74 (SD = 4.88).

An independent-samples *t* test revealed a significant difference, $t = 2.40$, $p = .0196$ ($\alpha = 0.05$ significance level). These results indicated that the experimental group had significantly higher scores compared with the control group, indicating the effectiveness of the concept integration tool in enhancing design outcomes.

***Table 1.*** **SCRS Score Analysis**

| | Experimental | Control | p |
|---|---|---|---|
| Creativity total score (mean) | 44.16 | 46.78 | 0.0623 |
| Creativity total score (SD) | 6.09 | 4.94 | |
| Usefulness (mean) | 3.93 | 3.94 | 0.9492 |
| Usefulness (SD) | 0.54 | 0.43 | |
| Novelty (mean) | 3.55 | 3.88 | 0.0194* |
| Novelty (SD) | 0.57 | 0.51 | |



Gender-related differences were not significant in the overall results of both scales (total scores for learning engagement and self-rated creativity) or in any of the subdimensions (emotional engagement, cognitive engagement, behavioural engagement, novelty, and practicality; $p > .05$). These results indicated that gender did not significantly affect learning engagement or creativity across any of the evaluated indicators. Both male and female participants exhibited similar performance levels in both the total and subdimension scores. Overall, these findings suggest that learning engagement and creativity performance are primarily influenced by factors other than gender itself.

### *3.1.2. Total Self-Rated Creativity Score*

As shown in Table 1, The experimental group had an average self-rated creativity score of 44.16 (SD = 6.09), and the control group had an average self-rated creativity score of 46.78 (SD = 4.94). An independent-samples t test yielded a result of $t = -1.89$ and $p = .063$ (i.e., an almost significant result), suggesting the need for further investigation.

### *3.1.3. Analysis of Practicality and Novelty*

For the practicality dimension (Q1–Q4), the experimental group scored 3.93 (SD = 0.54) and the control group scored 3.94 (SD = 0.43). The *t* test results ($t = -0.064$, $p = .9492$) indicated no significant difference between the two groups, suggesting that the participants had a similar standard for evaluating their own practicality traits.

For the novelty dimension (Q5–Q8, Q10–Q13), the experimental group scored 3.55 (SD = 0.57) and the control group scored 3.88 (SD = 0.51). The average score of the control group was significantly higher than that of the experimental group, with $t = -2.408$ and $p = .0191$. These results indicated that the control group perceived themselves as having stronger innovative traits than did the experimental group.

### *3.1.4. Significant Differences in Specific Items*

- Q8: 'Whenever I have the opportunity, I express creativity in my work'.
  Experimental group: 3.81, control group: 4.16, $t = -2.08$, $p = 0.043$
- Q11: 'I propose creative problem-solving solutions'.
  Experimental group: 3.53, control group: 4.00, $t = -2.69$, $p = .009$

A correlation analysis was conducted to examine the relationship between self-assessed creativity and project scores, revealing a significant positive correlation for both Q8 ($r = 0.332$, $p = .0078$) and Q11 ($r = 0.350$, $p = .0049$). These results indicated that participants who rated themselves higher in workplace creativity (Q8) and creative problem solving (Q11) achieved higher project performance, as reflected by the consistency between their self-assessments and actual project scores.

***Table 2.*** **SESQ-ENG Score Analysis**

| | Experimental | Control | ***p*** |
|---|---|---|---|
| Total score (mean) | 119.06 | 119.13 | 0.9787 |
| Total score (SD) | 10.60 | 7.87 | |
| Emotional engagement (mean) | 3.46 | 3.41 | 0.6437 |
| Emotional engagement (SD) | 0.46 | 0.44 | |
| Behavioural engagement (mean) | 3.40 | 3.33 | 0.4236 |
| Behavioural engagement (SD) | 0.40 | 0.35 | |
| Cognitive engagement (mean) | 3.93 | 4.05 | 0.2093 |
| Cognitive engagement (SD) | 0.42 | 0.33 | |



### *3.1.5. Total Score Comparison*

As shown in Table 2, The experimental group had an average SESQ-ENG total score of 119.06 (SD = 10.60), and the control group had an average SESQ-ENG total score of 120.69 (SD = 9.63), with both groups having highly similar mean values. An independent-samples *t* test yielded a result of $t = -0.64$ and $p = .523$ (i.e., a nonsignificant difference). Similarly, comparison of the subdimension mean scores revealed no significant differences, with the results detailed as follows:

- Emotional engagement:
  Learning enjoyment (Q1–Q5): experimental group = 3.71, control group = 3.66, $p = .6679$
  School affinity (Q6–Q9): experimental group = 3.14, control group = 3.09, $p = .7445$
- Behavioural engagement:
  Effort and persistence (Q10–Q18): experimental group = 3.70, control group = 3.72, $p = .8959$
  Participation in extracurricular activities (Q19–Q21): experimental group = 2.50, control group = 2.68, $p = .4512$
- Cognitive engagement:
  Cognitive engagement (Q22–Q33): experimental group = 3.93, control group = 4.05, $p = .2093$

### *3.1.6. Analysis of Emotional, Behavioural, and Cognitive Engagement*

The mean scores for each engagement dimension were as follows:
- Emotional engagement: experimental group = 3.46, control group = 3.41 ($t = 0.465$, $p = .6437$)
- Behavioural engagement: experimental group = 3.40, control group = 3.46 ($t = -0.502$, $p = .6175$)
- Cognitive engagement: experimental group = 3.93, control group = 4.05 ($t = -1.269$, $p = .2093$)

Multivariate analysis of variance confirmed that the composite differences in emotional, behavioural, and cognitive engagement between the experimental and control groups were not significant (Wilks' lambda = 0.397, $F(3, 60) = 1.004$). These findings indicated that the experimental treatment had no significant effect on the learning engagement indicators.

### *3.1.7. Significant Differences in Specific Items*

- Q14: 'In class, I only pretend to be learning'.
  Experimental group: 3.93, control group: 3.50, $t = 2.239$, $p = .029$
- Q17: 'If I encounter something I do not understand, I repeatedly study it until I grasp it'.
  Experimental group: 3.47, control group: 3.81, $t = -2.016$, $p = .048$

In terms of effort and persistence in behavioural engagement, the experimental group was more likely than the control group to perceive themselves as pretending to learn in class. In cases involving difficulties, the experimental group was less likely than the control group to actively seek understanding. Further correlation analysis between these two items and project scores revealed a positive correlation for Q14 ($r = 0.218$, $p = .083$) and a negative correlation for Q17 ($r = -0.152$, $p = .232$). Neither correlation reached significance, indicating a limited association between these items and actual project performance.

### 3.2. Correlation Analysis

#### *3.2.1. Correlation Between Total Scores*

Our analysis results indicated that the correlation coefficient between the total self-rated creativity score and total learning engagement score was 0.39, indicating a moderate positive correlation. Additionally, the correlation coefficient between project scores and self-rated creativity was −0.017, whereas the correlation coefficient between project scores and total learning engagement was 0.053. These results indicated that the scores of both scales exhibited minimal or no correlation with project scores.

#### *3.2.2. Correlation Between Scale Subdimensions and Total Scores*



According to the SRCS scores, practicality exhibited a moderate-to-strong correlation with the total self-rated creativity score ($r = 0.719$), and novelty exhibited a strong positive correlation with the total self-rated creativity score ($r = 0.953$). According to the SESQ-ENG scores, cognitive engagement exhibited a moderate-to-strong correlation with the total learning engagement score ($r = 0.641$), and emotional engagement ($r = 0.713$) and behavioural engagement ($r = 0.827$) exhibited a strong positive correlation with the total learning engagement score. Overall, novelty and behavioural engagement are the most influential factors within their respective scales in determining the total score.

#### *3.2.3. Cross-Scale Comparison*

Correlation analysis between the three subdimensions of learning engagement and the two dimensions of self-rated creativity revealed distinct patterns.

For the practicality dimension of self-rated creativity, the strongest correlation was that with behavioural engagement ($r = 0.414$), followed by cognitive engagement ($r = 0.371$), with the weakest correlation being that with emotional engagement ($r = 0.192$). For the novelty dimension of self-rated creativity, the strongest correlation was that with cognitive engagement ($r = 0.298$), followed by behavioural engagement ($r = 0.241$), with the weakest correlation being that with emotional engagement ($r = 0.092$). These findings indicated that each subdimension of learning engagement had a unique effect on self-rated creativity. Specifically, behavioural engagement had the most significant effect on practicality, whereas cognitive engagement was slightly more influential in novelty. Taken together, these findings provide valuable insights for further exploration of the relationship between learning engagement and creativity.

#### *3.2.4. Correlation Between Scale Items and Other Factors*

##### *3.2.4.1. Strong Correlation (r > 0.70) Between SRCS Items and Total Scores*

- Q5 ('I am a good source of creative ideas'): $r = 0.798$
- Q11 ('I propose creative problem-solving solutions'): $r = 0.728$
- Q12 ('I often develop new ways to solve problems'): $r = 0.777$
- Q13 ('I propose new methods for executing tasks'): $r = 0.742$

##### *3.2.4.2. Strong Correlation Between SRCS Items*

- Q5 ('I am a good source of creative ideas') and Q10 ('I often have new and innovative ideas'): r = 0.711

These findings indicate a strong relationship between the source of creative ideas and the generation of innovative thoughts, suggesting that creativity origin and innovation are interrelated and mutually reinforcing in thinking processes.

#### *3.2.4.3. Strong Correlation Between SESQ-ENG Items and Total Scores*

According to the SESQ-ENG scores, no individual item exhibited a strong correlation ($r > 0.70$) with total learning engagement scores.All item-to-total correlations fell within the moderate range ($0.7 > r > 0.5$).

#### *3.2.4.4. Strong Correlation Between SESQ-ENG Items*

• Emotional engagement:

Q2 ('I find what we learn in school interesting') and Q3 ('I enjoy learning the content taught in school'): $r = 0.741$.
This finding suggests a strong link between learning interest and enjoyment, highlighting the crucial role of emotional engagement in learning motivation.

• Cognitive engagement:



Q24 ('When learning new information, I try to explain it in my own words') and Q25 ('When I learn, I try to connect what I learn to my own experiences'): $r = 0.740$.
This finding reflects the participants' ability to integrate new knowledge through verbal expression and experiential connections.
Q26 ('I create my own examples to help me understand important concepts learned at school') and Q27 ('When learning school content, I try to see how it connects with what I already know'): $r = 0.708$. This finding indicates a complementary relationship between example application and knowledge integration.
Q30 ('I try to understand how the knowledge I learn in school is interrelated') and Q31 ('I attempt to match what I already know with what I am learning in school'): $r = 0.746$.
This finding suggests that the participants exhibit strong systematic thinking in connecting knowledge structures.

Correlation analysis revealed a significant relationship between self-rated creativity and learning engagement, particularly in terms of the effect of cognitive engagement and novelty on total scores. The concentration of highly correlated items reflected the core characteristics of creativity and learning engagement, namely the interaction between creativity sources and innovative thinking and the emotional connection driven by learning interest and cognitive strategies for knowledge integration. Overall, these findings emphasise the close interaction between creative design and learning engagement, and they provide valuable insights for design education and creative learning.

## 4. Discussion

### 4.1. The Reverse Design Strategy Enhances Teaching Effectiveness But Limits Novelty Performance

Although the experimental group scored slightly lower than the control group in both self-rated creativity (44.16 vs. 46.78) and total learning engagement (119.06 vs. 120.69), the experimental group outperformed the control group in project scores (79.13 vs. 75.74, $p = .0196$). Nevertheless, the associations of project scores with self-rated creativity
and total learning engagement were negligible, suggesting that the self-perception of creativity had a limited effect on actual creative outcomes. Other intrinsic and extrinsic factors, such as core traits, instructional style, creative strategies, or teamwork, may play a greater role in influencing creativity outcomes (Karwowski et al., 2016; Qian et al., 2010).

#### *4.1.1. Effect of Teaching Models on Novelty and Creative Freedom*

The reverse strategy improved overall design outcomes but somewhat limited creative freedom. This limitation resulted in significantly lower novelty self-assessments in the experimental group than in the control group (3.55 vs. 3.88, $p = .0194$).

For Q8 and Q11, the experimental group scored significantly lower than did the control group ($p < .05$), indicating differences between the two instructional models in this dimension. For example, S22 stated, 'I feel that this strategy helps me finalise ideas quickly, but sometimes I feel constrained by it, making it hard to break away from thinking only in terms of the three W-W-C elements'. This finding indicates that the structured framework of the reverse strategy may limit students' creative freedom and reduce the diversity of their creative thinking (Smith & Linsey, 2011). This effect may be attributable to the reverse strategy's emphasis on analysing a large number of award winning projects and following a systematic design process through the concept triangulation map instead of enabling free creation. Consequently, students may not fully recognise their own creative potential throughout the process.

The reverse strategy encouraged students to engage in a broader and deeper exploration of the topic before attempting to identify an optimal solution. This approach helped them establish a solid foundation for innovation. For instance, S23 argued, 'This strategy forces me to break things down step by step instead of simply thinking about how to apply it or what problems it might solve. By structuring it into W-W-C, we have to analyse deeper and investigate more to understand its feasibility'. Similarly, S30 stated, 'The advantage is that it helps us find keywords



we like and then build ideas from there. It forces us to combine seemingly unrelated words, leading to solutions no one else would have thought of'.

#### *4.1.2. Effect of Teaching Models on Learning Engagement*

Analysis of learning engagement revealed no significant differences between the experimental and control groups in total scores (119.06 vs. 120.69) or in the subdimensions of emotional, behavioural, and cognitive engagement. However, item-level analysis revealed notable variations. The experimental group scored significantly higher than the control group in Q14 (3.93 vs. 3.50, $p = .029$), indicating that certain students in the reverse strategy curriculum may have experienced greater pressure or engaged in tasks more passively compared with others. Additionally, the experimental group scored significantly lower than the control group in Q17 (3.47 vs. 3.81, $p = .048$), indicating a lower level of learning initiative and persistence, with students investing less time in overcoming challenges.

Several participants in the experimental group reported feeling confused at the beginning of the reverse strategy. For instance, S24 stated, 'I kind of understand, but at the same time, I don't quite get why we need to do it this way'. S30 mentioned, 'At first, I didn't really know what to do or what exactly I was supposed to write'. Similarly, S25 noted, 'Maybe it's because it was my first time doing this, so I wasn't very familiar with it. But I still learned something, and in the end, I came up with ideas I wouldn't have thought of otherwise'.

Overall, our findings suggest that the operational characteristics of the reverse strategy require students to familiarise themselves with and adapt to the approach and that certain students may feel uneasy or lack motivation because of their unfamiliarity with the tool. Additionally, the structured instructional framework may reinforce a task-oriented learning approach, which, despite leading to more favourable innovation outcomes, may not sufficiently encourage students to exhibit proactive learning attitudes and autonomy throughout the process.

#### *4.1.3. Advantages and Challenges of Structured Instruction*

The reverse strategy has limitations in novelty and learning engagement but also major advantages in improving design outcomes. The significant difference observed in project scores suggests that the reverse strategy helps students conduct deeper analyses of design problems and fosters a uniform team thinking model during the problem exploration and concept development stages, ultimately enhancing design outcomes.

Overall, the structured framework effectively promotes a goal-oriented design process, enabling students to focus on producing practical and feasible design solutions in scenarios involving limited resources and time. The framework also introduces constraints on creative freedom (Finke et al., 1996), which may hinder divergent thinking and creative exploration in the early design stages. This limitation is particularly challenging for students who are not yet proficient with the tool, particularly because it may increase learning pressure, affecting their engagement and confidence.

### 4.2. Effects of Different Strategies on Creativity and Learning Engagement

In this study, a moderate positive correlation was observed between self-rated creativity and total learning engagement (�� = 0.39). Students were likely to evaluate their creativity on the basis of novelty rather than on usefulness. However, this self-assessment did not fully align with their final scores, indicating a disparity between Mini-c (personal creative cognition) and Pro-c (creative performance; Kaufman & Beghetto, 2009). (Kaufman & Beghetto, 2009) This gap may arise because students can generate creative ideas but their final outcomes are limited by technical constraints, time pressure, or grading criteria, preventing their creative self-perception from fully translating into practical results. Moreover, a structured learning environment may lead students to prioritise design feasibility over creative exploration, further influencing their self-evaluation of creativity.

Our results indicated that usefulness was moderately correlated with behavioural engagement (�� = 0.414) and cognitive engagement (�� = 0.371), indicating a link between learning engagement dimensions and creativity. When students perceive creativity as valuable in practice, they tend to engage in active learning and apply higher-order thinking skills. Therefore, educators should emphasise the practical application of creativity and consider adjusting learning models on the basis of different creative requirements to balance feasibility and innovation, thereby enhancing overall student engagement and learning effectiveness.



#### *4.2.1. Effect of Different Strategies on Creativity*

This study discovered that the key factors influencing creativity assessments in the experimental group were creativity sources (Q5, �� = 0.84), work quality enhancement (Q4, �� = 0.75), and innovative method execution (Q13, �� = 0.71). These results indicate that the reverse strategy helps students develop a more systematic approach to creative thinking, focusing on the application of creativity to concrete design solutions. Because this strategy guides students to learn from a large number of award-winning cases and systematically extract key concepts, students may be inclined to recognise the practical value of their creativity rather than emphasising novelty.

Compared with the experimental group, the control group placed a greater emphasis on the frequency of generating innovations (Q10, �� = 0.81) and problem-solving abilities (Q11 and Q12, �� = 0.77–0.78). These results indicate that students in traditional learning environments tend to generate creativity through repeated attempts and to validate their innovation through problem-solving. Hence, free exploration and iterative experimentation may lead students to perceive creativity as a frequent output process rather than as an assessment of its application value.

#### *4.2.2. Effect of Different Strategies on Learning Engagement*

Compared with the control group, the experimental group tended to rely to a greater extent on self-created learning strategies (Q26, �� = 0.80) and knowledge matching (Q31, �� = 0.70), indicating that this strategy required students to actively integrate knowledge and identify appropriate application methods. By contrast, the control group demonstrated correlations with meeting minimum standards (Q15, �� = 0.79), learning interest (Q4, �� = 0.77), and classroom performance (Q14, �� = 0.73). These results suggest that traditional design processes encourage students to follow standard requirements and focus on completing a full project rather than engage in self-directed exploration.

In summary, the reverse strategy promotes autonomy in creative sources and learning strategies, whereas the traditional design process strengthens innovative thinking and problem-solving abilities. The relationship between creativity and learning engagement is influenced by interactions between dimensions. Future studies should explore cross-dimensional mediation or moderation mechanisms and adjust instructional strategies depending on different learning requirements to optimise learning models, ultimately enhancing students' creativity and engagement (Amabile et al., 2018; Ryan & Deci, 2000).

A structured framework can enhance project quality and problem-solving abilities but can also restrict students' recognition of novelty (Barr, 2018; Hennessey, 2019). Autonomous learning and strengthened creative sources can enhance the self-affirmation of creativity (Runco & Jaeger, 2012). In terms of learning engagement, a structured approach may increase learning pressure, affecting engagement perception, but can also promote learning strategies and knowledge integration abilities (Zimmerman, 2002). By contrast, traditional design processes can sustain learning interest and classroom engagement but may lead students to only aim for minimum standards (Pintrich, 2004). Future studies should explore dynamic instructional strategies to enhance learning autonomy and strategy application. This approach can help balance creative development and learning investment while optimising the relationship between creativity and learning engagement.

## 5. Conclusion

This study examined the application and effectiveness of the reverse design strategy in relation to traditional design processes in design courses and explored its effect on student creativity and learning engagement. Our results indicated that although the reverse strategy significantly improved final project scores ($p$ = .0196), students assigned low scores to their own creativity, particularly in terms of novelty ($p$ = .0194). This finding suggests that while a structured design framework can enhance project quality and problem-solving abilities, it may simultaneously constrain creative freedom, potentially resulting in reduced confidence in generating innovative outcomes (Beghetto, 2019). It also underscores the high risk of score distortion in self-assessments of creativity (Heidemeier & Moser, 2009). This may be because people tend to evaluate their own creativity more based on their everyday engagement in creative activities than on actual achievements or awards (Benedek et al., 2025).



In terms of learning engagement, no significant difference was observed between the reverse strategy and the traditional design process. However, item-level analysis revealed that some students felt confused or exhibited low learning initiative ($p$ = .048) during the initial stages because of their unfamiliarity with the reverse strategy.

Nevertheless, the strategy encouraged deeper conceptual integration and application, with students demonstrating high levels of knowledge matching and strategic thinking throughout the learning process. These findings suggest that the reverse strategy fosters autonomy in creative ideation and learning strategies (Childre et al., 2009; Srikongchan et al., 2021) and that the traditional design process supports stable innovation thinking and problem solving skills.

Overall, this study confirms the potential advantages of the reverse design strategy in structured ideation, knowledge integration, and project quality enhancement, which makes it suitable for enhancing goal-oriented design capabilities (Childre et al., 2009). Future studies should adjust the implementation of the proposed strategy by providing gradual guidance, incorporating free creation time, or adding reflective exercises to balance innovation and practical application (Liu et al., 2025). Studies should also explore the effects of the proposed strategy across different academic disciplines, learning styles, or long-term learning outcomes to gain a deeper understanding of the long-term effects of the reverse design strategy on creativity development and learning engagement.

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