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Development of the Tsai Design Thinking Scale

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Abstract

Design thinking is a human-centered creative problem-solving approach in the service of innovation. Design thinking involves both analytical and creative thinking; reasoning and imaging are both necessary to face design challenges of different degrees. Although a number of theories have been proposed, a lack of empirical validation of design thinking framework needs to be addressed in order to move forward. Therefore, the purpose of the current study was to create an assessment instrument that can measure the degree to which an individual can use design thinking abilities. The Tsai Design Thinking Scale (TDTS) was initially developed with the initial item pool including 36 items. Based on the results of exploratory factor analysis and confirmatory factor analysis, the 16-Item TDTS with four factors shows a reliable and valid measure. Overall, the TDTS indicates that it is suitable for assessing stable design thinking based on the perceptions of college students and that it is in line with theoretical expectations

Keywords: Design thinking, Taiwanese college students, measure development, exploratory factor analysis, confirmatory factor analysis

1. Introduction

Design thinking is a human-centered creative problem-solving approach in the service of innovation. Design thinkers utilize analytical and emotional analysis to propose rational, artistic, and innovative ideas to respond to identified customer needs (Yang, 2018). Design thinking involves both analytical and creative thinking; reasoning and imaging are both necessary to face design challenges of different degrees (Donar, 2011).

Design thinking has been identified as the key to success in the current competitive business environment (Donar, 2011). In the business field, design thinking is often described as integrative thinking, and has been used as a problem-solving apparatus and a key element of business strategy (Matthews & Wrigley, 2017). In a sense, the ultimate goal of designers is to seek promising results that are “desirable for users, viable for the client, and feasible within technical and design constraints” (Matthews & Wrigley, 2017, p. 42). In doing so, design thinking behavior can be observed throughout the design process – from defining the design problem to iterating on solutions (Wu, Chen, & Chen, 2012).

Owen (2006) argues that design thinking complements science thinking, which involves a whole range of creative characteristics and some distinct qualities of decision-making. Scientists observe facts to discover patterns and insights, whereas designers create new patterns and notions to address facts and possibilities. Compared to science, design is highly synthetic and more concerned with reality. Owen (2006) asserts that the disciples of design focus more on communications and symbolism, with symbolic and analytic components. Consequently, he contends that what distinguishes science from design is grounded in the difference in the implementation of measures of success.

Brown (2008) defines design thinking as “a methodology that imbues the full spectrum of innovation activities with a human-centered design ethos” (p. 86). Design thinking requires the designers’ sensibility and understanding to match people’s needs with a feasible technological method and a viable business strategy to create customer value and market opportunity. Brown (2008) believes that the design process could be understood metaphorically as “a system of spaces” (p. 88), and it is the consequence of “hard work augmented by a creative human-centered discovery process followed by iterative cycles of prototyping, testing, and refinement” (p. 88).

From the educational perspective, Scheer, Noweski, and Meinel (2012) claim that design thinking, as a team-based learning process, is a beneficial learning tool for tackling complicated problems, and provides practice-oriented and holistic experiences of constructivist learning. More specifically, “design thinking is a constructivist learning design, because of its qualities in training certain skills, which are predispositions for a constructive way of learning” (Scheer et al., 2012, p. 11). Scheer et al. (2012) argue that the three core elements of design thinking

- flexible space, teamwork, and design process - do not only constitute a process of learning, but also a whole mindset and atmosphere thanks to the systemic approach to problem solving.

Donar (2011) examined five Canadian post-secondary programs related to design thinking and found that the design process was always highlighted, essentially following the stages of research, ideation, implementation, and review. In terms of learning experience, Gray (2013) conducted a qualitative study through a critical pedagogy perspective on first-year design students. He found that four factors impact students' creative thinking: (a) environmental factors including physical space, resources, tools used, and pedagogy occuring within the context of the design studio; (b) social factors—the interactions among peers, professors, and design professionals; (c) formative factors—students' perceptions of the design discipline; (d) evaluative factors—common evaluation strategies within the studio including public critique, individual reflection and iteration, and peer feedback or mentoring.

2. Design Thinking Models

Tim Brown is the CEO and President of IDEO, which is an innovation and design firm. Brown (2008) argues that ordinary people without professional background have a natural aptitude for design thinking, which can be developed and unlocked. He profiles design thinkers' personality traits with five characteristics: (a) *empathy*—by using people-oriented approach, design thinkers can imagine solutions from multiple views, which meets latent needs; (b) *integrative thinking*—design thinkers demonstrate the ability to see through all the salient aspects of a confounding problem and generate original working solutions; (c) *optimism*—design thinkers assume that at least one potential solution is better than the existing alternatives; (d) *experimentalism*—design thinkers ask questions and explore constraints and opportunities in creative ways; (e) *collaboration*—due to the complex nature of products, services, and experiences, design thinkers need to work in teams of various experts from different fields. With regard to the design process, Brown (2008) notes three major stages: (a) *inspiration*—the circumstances that motivate the search for solutions; (b) *ideation*—the process of generating, developing, and testing ideas; (c) *implementation*—the charting of a path to market.

Stanford d.school purposes the design thinking approach to help students deal with actual problems related to products, services, and consumers. They condense the process of design thinking into five steps: (a) *empathy*—seeking to understand and be non-judgmental; (b) *define*—finding out role objectives, decisions, and challenges; (c) *ideate*—sharing and prioritizing ideas; (d) *prototype*—building mockups and storyboards to keep it simple; (e) *test*—understanding impediments (Yang, 2018). Basically, in their view, design thinking is conceptualized as a specific approach of assessing and exercising design methods by non-designers (Matthews & Wrigley, 2017). Namely, everyone can be a design thinker with the appropriate training and support.

In a similar fashion, Scheer et al. (2012) believe that the heartbeat of design thinking process follows six cyclical and iterative phases that fosters several competencies in different phases. The first and second phases are to understand and to observe, building up empathy and understanding of the people and the context, with the goal of identifying the relations between the problem and needs. The third phase is to synthesize, interpreting and condensing necessary information into meaningful insights to generate feasible solutions. The fourth is to ideate, searching for alternatives through being imaginative and generating various possible ideas. The fifth is prototype, experimenting with tangible, actionable, and testable ideas. The last phase is to test, taking the prototypes out into the real world to obtain feedback from experts, novices, and potential users.

Tschimmel (2012) proposes the Double-Diamond method, which is based on the divergent and convergent stages of the design process. This model includes four components: (a) *discover*—insight into the problem; (b) *define*—the area of the problem to focus on; (c) *develop*—potential solutions to be tested; (d) *deliver*—solution that satisfies customer needs. He believes that this process can enable all team members to be on the same page during design and development.

Owen (2006) argues that creativity is a major component of design thinking. Apart from that, he has identified several important characteristics of design thinking: (a) *conditioned inventiveness*—creative thinking for designers is directed toward inventing; (b) *human-centered focus*—design is client-directed; (c) *environment-centered concern*—sustainable design is a noticeable interest; (d) *ability to visualize*—all designers work visually; (e) *tempered optimism*—designers should be able to turn on enthusiasm on demand; (f) *bias for adaptivity*—the design of adaptive products that are able to fit user needs uniquely; (g) *predisposition toward multifunctionality*—designers routinely look for multiple dividends for solutions to problems; (h) *systemic vision*—design thinking is holistic; (i) *view of the generalist*—design thinking is highly generalist in preparation and execution; (j) *ability to use language as a tool*—visual language is used in design thinking to abstract concepts, reveal and explain patterns, and simplify complex phenomena; (k) *affinity for teamwork*—designers routinely work closely with other designers and experts from other fields; (l) *facility for avoiding the necessity of choice*—the optimistic and adaptive designer searches the competing alternative for their essential characteristics and finds ways to reformulate them in a new configuration; (m) *self-governing practicality*—design thinkers learn to govern flights of fantasy with a latent sense of the practical; (n) *ability to work systematically with qualitative information*—as design research progressed, design processes with component methods and tools have been developed and refined (pp. 24-25).

A significant number of theories have been discussed, it seems that several similar elements have been highlighted. However, the biggest drawback of these frameworks is that they are not supported by empirical evidence. In other words, in this field, including more observable data is necessary to validate design thinking theory and expand our understanding of design thinking.

3. Proposed Design Thinking Models

Based on the reviewed literature, a common theme emerges in the process of design thinking, which can be broken down into three phases: identification, generation, and actualization. The goal of the first phase, *identification*, is to observe, gather, and reflect necessary facts, data, and problems. For designers, the first phase will be more focused on analytical thinking to untangle the complicated relationship between issues, people, and the context. Therefore, caring, systematic reasoning, critical reflection are three major characteristics in this phase of design thinking. The second phase is the *generation* of possible ideas, and includes creating, imaging, and visualizing all alternatives, potentials, and opportunities. Creative thinking will be the prime characteristic of the second phase; and ideation, imagination, and attitudes toward ambiguity will be more salient traits. The final phase is to conclude the options through *actualization*; it involves prototyping, testing, and determining the designers' ideas, solutions, and action plan. Critical thinking will play the key role in this phase to ensure the quality of the products or services. Consequently, designers with perseverance, collaboration, execution have more chance to succeed in the third phase of the design thinking process.

4. Purpose of the Study

The purpose of the current study was to create an assessment instrument that can measure the degree to which an individual can use design thinking abilities. It is hoped that this design thinking scale could provide awareness of the strengths and weaknesses of individuals or designers. Most importantly, the design thinking scale will help designers discover their capabilities and untapped skills so that they can better meet their goals.

5. Method

5.1 Participants

Convenience sampling was used to recruit 200 Chinese college students in Taiwan. Of these, 19 (9.5%) were male and 181 (90.5%) female. The average age was 19.34 (*SD* = 1.72). They were all fashion design department students, out of which 88 were first-year undergraduate students (44%), 23 second-year undergraduate students (11.5%), 73 third-year undergraduate students (36.5%), and 16 fourth-year undergraduate students (8%).

5.2 Measurement

Based on the preceding literature review of design thinking, the Tsai Design Thinking Scale (TDTS) was initially developed in Chinese, and I later translated it into English (see Table 1). The initial item pool included 36 items reflecting nine components, with responses recorded on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). Data collection took place at the first class of the Introduction of Design. Each participant completed the questionnaire, which included three demographic questions, in approximately ten minutes.

6. Results

6.1 Item Analysis and Internal Reliability

Table 1 shows the means, standard deviations, and corrected item-total correlations of the 36 items of the TDTS. The instrument's overall Cronbach's alpha was .873, which indicates excellent internal reliability. Corrected item-total correlations of some items were less than .30, which indicates the item is measuring something different from the scale. Pallant (2013) suggests that if scale's overall Cronbach alpha is too low (less than .70), we may need to remove items with low item-total correlations. As a result, we decide to retain these items for further analysis.

6.2 Exploratory Factor Analysis

Using SPSS version 22.0, the 36 items of the TDTS were subjected to principal components analysis with varimax rotation. The Kaiser-Meyer-Olkin value was .842 and Bartlett's test of sphericity reached statistical significance, supporting the factorability of the correlation matrix. The results show the presence of nine components with eigenvalues exceeding 1, explaining 24.12%, 9.56%, 6.38%, 6.17%, 4.79%, 3.45%, 3.34%, 3.09%, 2.85% of the variance, respectively. For the purpose of this study, a factor loading of .45 (20% overlapping variance) was used as the cut-off point (Tabachnick & Fidell, 2007). Furthermore, variables with communalities greater than .50 should be retained in the analysis (Hair, Black, Babin, Anderson, & Tatham, 2006). As shown in Table 2, the factor loading of item 3, 18, and 36 was less than .45 and the communalities of item 18 was less than .50. In addition, the factor loadings of item 11, 17, 30, and 35 had more than one significant loading. Therefore, these items were candidates for deletion.

After conducting a series of principal components factor analysis based on three criteria (factor loading > .45, communalities > .50, without cross loading), I finally obtain the 18-Item TDTS with five factors (Factor 1 = Reasoning and Reflection; Factor 2 = Ideation; Factor 3 = Collaboration; Factor 4 = Execution; Factor 5 = Tolerance of Ambiguity), which suggest a good model for further confirmatory factor analysis.

6.3 Confirmatory Factor Analysis

To further confirm the validity of the TDTS, confirmatory factor analysis (CFA) with maximum likelihood estimation procedure was used to check the 18-Item TDTS (see Table 3). I followed the guidelines suggested by Hair et al. (2006) for establishing an acceptable model fit to test my measurement theory, where significant p values can be expected, of comparative fit index (CFI) > .90, goodness-of-fit index (GFI) > .90, root mean square error of approximation (RMSEA) < .08, and standard root mean residual (SRMR) < .08. Figure 1 shows the final 16 measured indicator variables and four latent constructs. Overall model fit and construct validity were also examined. Results showed that chi square (χ^2) = 166.37, degrees of freedom (df) = 95, $p < .001$, χ^2/df = 1.75, CFI = .929, GFI = .913, RMSEA = .061, SRMR = .072. Taking into account my sample size of 200 and the number of observed variables (i.e., 16), CFA results suggest that the TDTS measurement model provided a reasonably good fit.

In terms of construct validity, Hair et al. (2006) suggest that factor loading should be .50 or higher, average variance extracted should be .50 or higher, and construct reliability should be .60 or higher. Table 4 shows that all loadings were over .50 and that variance-extracted measures were about 50%; that is, my model had adequate convergent validity. In addition, the estimates of construct reliability were over .70, indicating adequate internal consistency.

7. Discussion

The TDTS was developed primarily as a research tool, and the results suggest that it has major potential for use in research conducted in educational settings. This typology of design thinking could become an important tool for students' self-assessment and may help to improve theoretical understanding of the influence of students' design thinking. The TDTS may also prove useful in predicting a wide range of attitudes and behaviors.

The TDTS demonstrated high internal consistency (> .70) and a robust four-dimensional factor solution. On the basis of the factor loading results, the instrument converges well with measures for four possible design thinking attitudes: (a) *reasoning and reflection*—using logical and systematic thinking to understand the problems and issues, and also reflecting on their context; (b) *ideation*—using imagination and creativity to generate possible solutions; (c) *collaboration*—working with team members and being open-minded to others' thoughts; (d) *execution*—going through the tasks and completing them on time. Overall, my initial work on the TDTS indicates that it is suitable for assessing stable design thinking based on the perceptions of college students and that it is in line with theoretical expectations.

In summary, my development of the TDTS based on design thinking literature seems to warrant its validity. Most importantly, the unique contribution of this study is that I have gone beyond theoretical frameworks, and developed a valid measure for design thinking.

8. Limitations

In spite of the potential contributions, limitations to this study should also be recognized. First, design thinking was assessed through students' perceptions, rather than objective measurement; thus, my results do not provide any evidence of causality. Second, the sample used was relatively homogeneous, comprising Chinese students from one institution in Taiwan. Further research could recruit participants of different ages, gender, and ethnic groups for further validation of the TDTS. Lastly, the examination of external validity was not included in the present study, and future research is needed to address this limitation.

9. Conclusions

The TDTS enables researchers and educators to study students' design thinking in an economical way. As it consists of only 16 items (see Appendix), it can be implemented quickly and easily in larger test batteries, and can also be used for practical applications. The results suggest that the TDTS is reliable and valid, and I believe that its development will be especially beneficial for educators seeking to identify their students' design thinking attitudes. For further research directions, it is suggested that researcher could employ this instrument in different ethnic groups. Furthermore, for educators, it is suggested that this instrument could be used in the learning environment through serving as an impetus to further discuss design thinking.

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Appendix

TDTS Items (*means reverse coding)

Reasoning and Reflection:

I will analyze things with logical thinking.

I will view things from both positive and negative sides.
While doing something, I imagine the process and end results.
I will deliberately think about the steps of task.
When faced with a problem, I will carefully consider its context.
When faced with problems, I will think about the causes and effects.

Ideation:
I have lots of ideas to do things.
My imagination is very rich.
My friends often think that my ideas are creative.

Collaboration:
I enjoy teamwork.
While dealing with things, I am open-minded.
I am a patient person.

During teamwork, I get along with my team members very well.

Execution:
I will follow through on my tasks.
*I hardly ever finish tasks on time.
*I give upon things halfway.

Table 1. Descriptive Analysis of the 36-Item Tsai Design Thinking Scale

Item	*M*	*SD*	Corrected item-total correlation
TDTS01: I often observe people and things around me.	4.33	.66	.472
TDTS02: I can systematically think about things.	3.62	.75	.388
TDTS03: I often reflect on my actions.	4.04	.73	.413
TDTS04: I have lots of ideas on how to do things.	3.78	.75	.491
TDTS05: My imagination is very rich.	3.85	.82	.381
TDTS06: I am not comfortable with ambiguity.	3.19	.99	.128
TDTS07: I will follow through on my tasks.	3.84	.78	.422
TDTS08: I enjoy teamwork.	3.39	.98	.318
TDTS09: I am an action-driven person.	3.54	.80	.537
TDTS10: If others are in trouble, I will do my best to help them.	4.07	.73	.458
TDTS11: I will analyze things with logical thinking.	3.78	.77	.424
TDTS12: I will view things from both positive and negative sides.	4.06	.73	.505
TDTS13: My friends often think that my ideas are creative.	3.56	.74	.526
TDTS14: While doing something, I imagine the process and end results.	4.00	.75	.514
TDTS15: I feel comfortable in environments of uncertainty.	3.13	.90	.304
TDTS16: I hardly ever finish tasks on time.	3.20	.98	.187
TDTS17: I go my own way in team environments.	3.46	1.06	.242
TDTS18: I will complete a task as soon as possible while being assigned by others.	3.90	.76	.328
TDTS19: I often observe things from others' viewpoints.	3.76	.77	.539
TDTS20: I will deliberately think about the steps of task.	3.85	.76	.510
TDTS21: When faced with a problem, I will carefully consider its context.	3.89	.75	.603
TDTS22: I am inspired by doing things.	3.63	.75	.573

TDTS23: I will present things by visualizing them.	3.58	.82	.398
TDTS24: I feel panic when there is no correct answer.	2.87	.90	-.029
TDTS25: I give up on things halfway.	3.51	.88	.376
TDTS26: I do not like completing things alone.	2.78	1.01	-.070
TDTS27: I will set a future goal and try hard to achieve it.	3.73	.84	.521
TDTS28: I have great sympathy.	4.26	.81	.500
TDTS29: When faced with problems, I will think about the causes and effects.	4.11	.68	.592
TDTS30: I often learn a lot from my past experiences.	4.14	.72	.677
TDTS31: I often think of a solution if I am in trouble.	3.40	.95	.064
TDTS32: I do not like ideas that are beyond my imagination.	3.84	.99	.146
TDTS33: While dealing with things, I am open-minded.	3.92	.79	.446
TDTS34: I am a patient person.	3.45	.97	.292
TDTS35: During teamwork, I get along with my team members very well.	3.92	.78	.538
TDTS36: My friends think that I am good at dealing with things.	3.59	.75	.529

Table 2. Varimax-Rotated Principle Components Factor Analysis of the 36-Item TDTS

	Factor loading									
Item	1	2	3	4	5	6	7	8	9	h^2
TDTS01			.604							.604
TDTS02						.445				.722
TDTS04		.786								.711
TDTS05		.790								.730
TDTS06								.686		.606
TDTS07				.498						.573
TDTS08					.761					.715
TDTS09						.576				.675
TDTS10			.554							.591
TDTS11	.586					.483				.721

TDTS12	.700									.651
TDTS13		.701								.676
TDTS14	.698									.572
TDTS15						.615				.558
TDTS16				.748						.629
TDTS17				.452	.607					.696
TDTS19							.502			.608
TDTS20	.698									.547
TDTS21	.773									.694
TDTS22		.638								.706
TDTS23		.625								.606
TDTS24								.600		.587
TDTS25				.762						.744
TDTS26					.718					.672
TDTS27			.563							.541
TDTS28			.724							.689
TDTS29	.652									.626
TDTS30	.498		.518							.642
TDTS31									.763	.702
TDTS32								.608		.606
TDTS33			.459							.654
TDTS34							.733			.669
TDTS35					.500		.449			.679
Note. *Only the factor loadings > .45 are presented*; h^2 = *communality*.										

Table 3. Varimax-Rotated Principle Components Factor Analysis of the 18-Item TDTS

	Factor loading					
Item	1	2	3	4	5	h^2
TDTS04		.821				.761
TDTS05		.875				.790
TDTS06					.834	.710
TDTS07				.539		.549
TDTS08			.733			.555
TDTS11	.715					.556
TDTS12	.763					.626
TDTS13		.718				.672
TDTS14	.671					.529
TDTS16				.718		.543
TDTS20	.718					.542
TDTS21	.790					.681
TDTS25				.810		.758
TDTS29	.685					.536
TDTS32					.691	.669
TDTS33			.502			.530
TDTS34			.701			.565
TDTS35			.810			.725

Note. *Only the factor loadings > .45 are presented*; h^2 = *communality*.

Table 4. Tsai Design Thingking Scale (TDTS) Standardized Factor Loadings, Variance Extracted, and Reliability Estimates

	Factor			
Variable	Reasoning and reflection	Ideation	Collaboration	Execution
TDTS11	.593			
TDTS12	.701			
TDTS14	.684			
TDTS20	.588			
TDTS21	.754			
TDTS29	.699			
TDTS04		.827		
TDTS05		.745		
TDTS13		.741		
TDTS08			.570	
TDTS33			.465	
TDTS34			.513	
TDTS35			.896	
TDTS07				.787
TDTS16				.677
TDTS25				.565
Variance extracted	45.2%	59.6%	40.2%	46.1%
Construct reliability	.83	.82	.71	.72

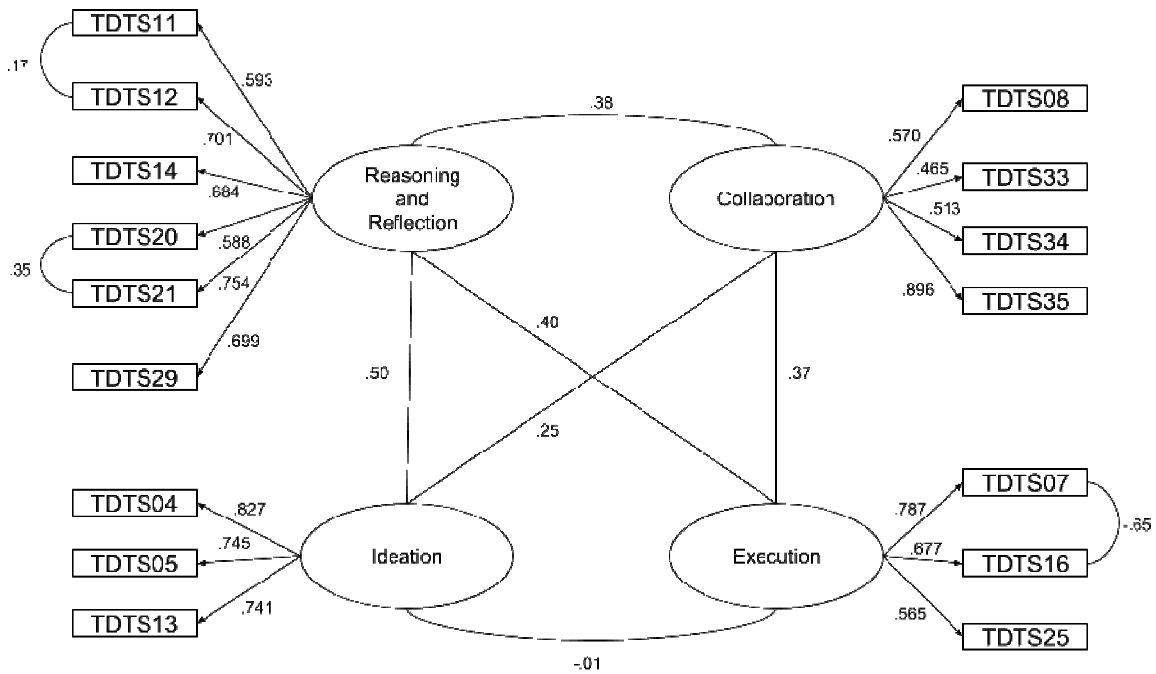

Figure 1. Measurement model of the Tsai Design Thinking Scale (TDTS).