



# Measurement scale of design thinking competency for Thai graduates' 21st century skills

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## Abstract

Design thinking has been applied in learning and work processes in order to comprehensively solve emerging problems and to create innovations to serve the needs of users. The aims of the study were to develop and validate a measurement scale of design thinking competency of Thai graduates. The mixed-method design employed in this study can be divided into qualitative research using the in-depth interviews and quantitative method to collect data from 623 Thai undergraduates. The qualitative data were analyzed using the content analysis method and quantitative data were analyzed using the confirmatory factor analysis in order to ensure structural measurement model. The results showed that design thinking competency has three main components: knowledge domain of three indicators; thinking ability domain of three indicators; and skill domain of two indicators. Finally, the results will provide the instrument and information for developing the essential skills of undergraduate students in the 21st century.

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## Introduction

Social and technological changes have led to the era of disruption. Over the past decade, the innovation development process has been accepted and adopted to solve complicated problems in rapidly changing technological environments, especially in terms of multidisciplinary approaches that focus on integrating

innovation into daily life in various forms. (Beckman & Barry, 2007). Innovative thinking is one of the essential skills for individuals in the 21st century. It can drive individuals to explore and create innovative inventions or processes necessary for sustainable national development (Chompabhoti & Sae-Joo, 2019; Saavedra & Opfer, 2012; Wisetsat & Nuangchalerm, 2019). Those with innovative thinking skills must possess creativity accumulated from experience, expertise, motivation, and attitudes toward the world and the environment (Oppezzo & Schwartz, 2014). The ability to find solutions to complex problems and to create new products and services can be developed through learning processes and

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practices. Integrated cooperation from related parties is required in order to develop analytical thinking skills, decision-making abilities, and innovative problem-solving ideas.

Thailand has formulated a national strategy called Thailand 4.0, which aims to transform the country's economic structure into a value-based economy in order to overcome the middle-income trap and social inequality. This strategy focuses on transformation in four dimensions: economic wealth, social well-being, human wisdom, and environmental wellness. The development of workforce potential has been promoted and supported in order to drive Thai S-Curve industries. Graduates with innovative thinking skills are considered the country's key competitiveness drivers that can perform better than machines (Chaemchoy et al., 2022). Graduates in the 21st century have to be able to create innovation to meet users' needs (Watson, 2015) and have the ability to work and think in a systematic and creative way—in other words, graduates should have design thinking competency.

Design thinking is a key competency that underlies creative solutions and innovations. Design thinking is not only about talent and inspiration; it can be developed through learning (Scheer et al., 2012). Although there are a lot of research studies on design thinking, most of them focus on studying the impacts of design thinking, measuring the success of design thinking (Schmiedgen et al., 2016), and exploring the definitions of design thinking competency in different contexts. However, the measurement of the design thinking competency of learners has not been clearly addressed (Rauth et al., 2014; Retna, 2016; Robbins, & Fu, 2022; Schmiedgen et al., 2016). Therefore, the present research aimed to study the components and indicators of design thinking competency in the context of Thai students. The developed measurement model can be used to examine the design thinking competency of students in actual situations in order to develop effective teaching and learning processes and to formulate a guideline for the development of design thinking competency in the future.

### *Design Thinking*

Those that like to seek information to support themselves in making changes and to apply new methods or technologies to optimize work efficiency and effectiveness are considered as individuals with innovative thinking (Kleysen & Street, 2001). This behaviour is partially influenced by inspirations and ideas for designing something new or for design thinking. At present, the concept of design thinking has been used in various

contexts, including teaching and learning, management systems, and work activities. It has also been applied to develop scientific processes in various areas, such as product design, drug development, service design, social development, and daily life activities. Thus, the development of students' design thinking competency is vital to the preparation of human resources for achieving competitiveness at the international level.

Design thinking is a skill that influences the advancement of innovation through the thinking process and creative ideas. Innovations of the 21st century have been created using a user-centric approach through a complex process, integrated knowledge, and perspectives on expertise. Most innovations are the integration and adaptation of existing ones to better serve the needs of users (Noweski et al., 2012). The Hasso Plattner Institute of Design (2010) divided the design thinking process into five steps; (1) empathize, which deals with observing and understanding users' needs; (2) define, which includes studying, analyzing, and synthesizing the problems and needs of users; (3) ideate, which is associated with designing and brainstorming ideas before creating a prototype; (4) prototype, which is the process of turning a set of ideas resulting from shared experience between the designer and users into a prototype; and (5) test, which is about testing the prototype with real users and getting feedback.

Previous studies on design thinking competency have addressed various related theories and have provided different definitions of design thinking. In the 20th century, Buchanan (1992) indicated that design thinking competency is a problem-solving tool that leads to more complex technological designs through a systematic thinking process and logical problem-solving analysis. In the 21st century, Cross (2006) and Lawson (2006) assumed that design thinking competency focuses on practicality and emotional reference, which leads to a recursive design strategy. Kimbell (2012) suggested that good design is not just about creating something new but creating something meaningful. This concept leads to a circle process of rethinking design thinking that aims to produce products that can satisfy the needs of users.

The key principles of educational management in the age of digital disruption are developing students to have learning competency beyond academic skills and encouraging them to independently seek knowledge and create their own learning practices through creative thinking processes in order to achieve lifelong learning and employability. Similarly, Scheer et al. (2012)

indicated that learning experience associated with design thinking contributes to positive attitudes toward learning and increased skills. The design thinking process can promote students' ability to deal with problems and create solutions. At the same time, the problem-based learning model can motivate students to analyze problems and design solutions, which leads to the development of practice-based behavior. Thus, this process can be applied in a variety of professional fields.

Importantly, the measurement of students' design thinking competency has the major goal to obtain accurate information for creating an appropriate skill development plan that can improve their competency and professional readiness in an effective way.

### *Research Objective*

To develop and validate a measurement scale of design thinking competency of Thai graduates.

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## **Methodology**

The exploratory sequential mixed-method design was used to conduct the study, and began with the qualitative method. The results from this qualitative step were used to design the quantitative part of the study. All of the data from first step were analysed to design the domains of design thinking competency, and all domains were developed following not only the academic results, but also the context of Thai graduates. This study method is in line with the work of Kimbell (2012). The qualitative research was initially carried out in order to collect data on the definition and components of design thinking competency, using the in-depth interview technique. The obtained results were used to develop a questionnaire for collecting the quantitative data. The confirmatory factor analysis was used to analyze the components and indicators of design thinking competency. Therefore, this study was composed of two steps; (1) qualitative research; and (2) quantitative research.

### *Step 1: Qualitative Research Part*

#### *Participants*

Nine experts with at least five years of experience in design thinking, or qualified professionals who were recognized in academics involving innovation and in the following three disciplines: social science and the humanities, science and technology, and health science

#### *Instrument*

Semi-structured interview form, consisting of open-ended questions about the definition and components of design thinking competency

#### *Statistical analysis*

The data were analyzed using the content analysis method. The R package for qualitative data analysis (RQDA) version 4.0.0, which was applied in this study, is a computer-assisted qualitative data analysis (CAQDAS) that helps to ensure the transparency and reliability of qualitative research. The analysis process consisted of six steps: preparation, coding, data attributes, code abstraction, code plotting, and theory building (Chandra & Shang, 2017).

### *Step 2: Quantitative Research Part*

#### *Population and samples*

The sample size for the confirmatory factor analysis of the quantitative study was calculated based on the concept of Hair et al. (2010), which suggests that the sample size should be at least 5 times the number of parameters. From the result of the qualitative part, there were 19 parameters in three components with 8 indicators, so a total of 623 graduates were randomly selected, 209 of who were from social science and humanities students, 209 were from health science students, and 205 were from science and technology students.

#### *Instrument*

The questionnaire was separated into two parts. The first part comprised questions about general information, including gender, religion, and activities or experiences. The second part was a 45-items with 5-point Likert scale to measure the design thinking competency. The measurement instrument was checked for validity by using Index of Item-Objective Congruence (IOC), and reliability by using Cronbach's alpha coefficient for the quality of the appropriate tool.

#### *Statistical analysis*

Confirmatory factor analysis and the measurement invariance test were carried out to examine the structural measurement model using the M-plus 8.0 software (Muthén & Muthén, 2017). Cronbach's alpha was also used to examine the internal consistency reliability using the SPSS V-22 program.

## Results

### *The Results of the Qualitative Study*

Definition and components of the design thinking competency of Thai undergraduates

The results of the qualitative data showed that there were eight indicators of three components. Three indicators were from the knowledge domain, three indicators were from the thinking ability domain, and two indicators were from the skill domain as follows.

1. Knowledge Domain is accumulated by learners through different forms of learning processes. It has three indicators, comprising general, professional, and technological knowledge: (1) General knowledge is basic knowledge related to the context of what is being designed. It covers a broad range of understanding and modern information that has continuously accumulated from past to present; (2) Professional knowledge is in-depth academic knowledge unique to an area of study, discipline-specific knowledge, and understanding of design principles, theories, procedural application, and comprehensive work processes; and (3) Technological knowledge refers to available information on design-related technologies that can be used to enhance design efficiency and effectiveness and to develop products to meet users' needs according to predetermined objectives, as shown in [Table 1](#).

2. Thinking Ability Domain refers to the ability to integrate creativity, problem-solving, and critical thinking in the implementation of design in order to achieve design objectives: (1) Creativity is the imagination of ideas to create solutions to meet requirements under resource constraints and the ability to produce alternatives in a novel and original way; (2) Problem-solving refers to the assessment of a situation in order to find the most appropriate process or approach for solving a problem. The problem-solving process begins with identifying the problem, making an assumption, evaluating the assumption, implementing the solution, and improving the solution; (3) Critical or logical thinking refers to a systematic thinking process associated with the assessment of causal relationships and the ability to compare the advantages and limitations of operations in a complete and comprehensive manner, as listed in [Table 2](#).

3. Skill domain refers to the expertise resulting from repeated training over a period of time. It has two indicators, as shown in [Table 3](#): (1) The soft skill is the ability to understand, interact, and communicate with others, which leads to the development of designs that meet the needs of user as well as productive team working and seamless integration of ideas; and (2) The hard skill is the ability to perform professional tasks and specific techniques that arise from accumulated design experiences.

**Table 1** Consensus of knowledge domain

| Areas of expertise            | Consensus                                                                                                                                                                                                                             |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| General knowledge             |                                                                                                                                                                                                                                       |
| Health science                | "Designers should know what they are concerned with or have basic knowledge in related matters."                                                                                                                                      |
| Science and technology        | "Basic knowledge is required."<br>"They should have knowledge and information accumulated from researching."                                                                                                                          |
| Social science and humanities | "They should have general knowledge, such as current news and information."                                                                                                                                                           |
| Technological knowledge       |                                                                                                                                                                                                                                       |
| Health science                | "They are involved with some technologies. If they conduct research, it must be about product development."                                                                                                                           |
| Science and technology        | "They should have knowledge of current and future technology."                                                                                                                                                                        |
| Social science and humanities | "They should know about and understand today's technology."<br>"Good designers have to be creative. Nowadays, innovative technology should be used to increase efficiency and effectiveness in order to achieve the desired results." |
| Professional knowledge        |                                                                                                                                                                                                                                       |
| Health science                | "Professional knowledge and critical thinking should be used to determine a guideline or solve a problem."                                                                                                                            |
| Science and technology        | "Designers should have a basic understanding of what they will design. In this way, design thinking can be developed."<br>"Professional knowledge."                                                                                   |
| Social science and humanities | "They must have knowledge and understanding of input, the production process, related factors, and how to generate productivity."                                                                                                     |

**Table 2** Consensus of thinking ability domain

| Areas of expertise                    | Consensus                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Creativity                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Health science                        | <p>“They should have resources and the potential to achieve objectives or to solve a problem.”</p> <p>“Create imagination and creativity. Then look for possibilities from current situations and existing resources before planning a practical process.”</p> <p>“Creative thinking is more than just dealing with problems and routine tasks.”</p> <p>“Innovative thinking is design thinking and may be part of creative ideas.”</p>                                                                                                                                                                                                                            |
| Science and technology                | <p>“Show imagination in solving problems by posing a question for students to solve using innovative methods.”</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Social science and humanities         | <p>“Good designers have to be creative. Nowadays, innovative technology should be used to increase efficiency and effectiveness in order to achieve the desired results.”</p> <p>“Good design requires creativity.”</p>                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Problem solving                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Health science                        | <p>“Think beyond what you have done in the past. Designing is about putting the right process in place to reach goals and to solve problems.”</p> <p>“It should be different from existing or regular problem solving processes.”</p> <p>“The same method can be used but it should be revised to require less time and fewer resources.”</p>                                                                                                                                                                                                                                                                                                                      |
| Science and technology                | <p>“Show imagination in solving problems. Use different and innovative solutions.”</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Social science and humanities         | <p>“Generate ideas and create solutions to problems. Assess alternatives based on social, economic, and environmental factors. Explore various methods to solve problems.”</p> <p>“Analyze targets and preferred output based on actual situations. The innovator must be able to analyze the needs, input, and process in order to achieve goals.”</p> <p>“First, they must observe the environment, recognize the problem, and see the connections of things. They must be an observer and connector.”</p> <p>“Understand pain points and find solutions. It can be difficult because we have to use an overview of the enterprise to identify the problem.”</p> |
| Critical thinking or logical thinking |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Health science                        | <p>“Evaluate resources or possibilities to achieve goals.”</p> <p>“It’s a matter of system. During work, they can use design thinking skills to do systemic work, and plan or create innovation.”</p> <p>“Design work requires an analysis of possibilities and logical thinking on how to turn the ideas into products.”</p>                                                                                                                                                                                                                                                                                                                                      |
| Science and technology                | <p>“Thinking in a systematic way of using logic. For example, before designing something, we have to prioritize related tasks in the order of importance.”</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Social science and humanities         | <p>“The ability to think systematically through the use of concrete tools or visualizations.”</p> <p>“It is similar to the positioning technique. Pros and cons must be analyzed. It depends on what method is used to analyze the results.”</p> <p>“Those that can design innovative products must be able to analyze needs and targets and understand input and process.”</p>                                                                                                                                                                                                                                                                                    |

**Table 3** Consensus of skill domain

| Areas of expertise            | Consensus                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Soft skill                    |                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Science and technology        | <p>“Soft skills are associated with emotions and the ability to work with others and to develop one’s self in terms of teamwork, leadership, persuasion, and holistic planning.”</p> <p>“How to convince other parties to get back to the topic we want. We have to know how to persuade them.”</p> <p>“Design thinking begins with exploring what has been done and generating different ideas. It mainly depends on users’ needs.”</p> |
| Social science and humanities | <p>“In order to solve problems, you must have well-rounded knowledge.”</p>                                                                                                                                                                                                                                                                                                                                                               |
| Hard skill                    |                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Health science                | <p>“To start, you must have experience or basic skills in related matters.”</p>                                                                                                                                                                                                                                                                                                                                                          |
| Science and technology        | <p>“Hard skills are skills used in the workplace and the ability to perform professional techniques that can be taught and assessed, such as engineering knowledge, prototype development, and testing.”</p>                                                                                                                                                                                                                             |
| Social science and humanities | <p>“Searching for ideation skills mostly resulting from experience and training.”</p>                                                                                                                                                                                                                                                                                                                                                    |

The results of the consensus analysis based on data attributes are presented below. In the field of science and technology, the analysis results showed that two out of three experts agreed that professional knowledge and creativity are key components. In the field of health science, the analysis results revealed all experts placed importance on creativity and critical thinking. Two out of three experts paid attention to general knowledge. In the field of social science and humanities, the analysis results indicated that all experts placed emphasis on problem-solving and critical thinking. Two out of three experts gave priority to general knowledge, professional knowledge, and creativity.

Based on the factor loading analysis, the importance of each component differed in each field. The consensus on the components of design thinking competency is shown in Table 4. The code plotting created with the RQDA package is presented in Figure 1.

Based on the results of theory building, design thinking competency can be defined as the knowledge, thinking ability, and skill domains that are used for developing innovative products, services, or processes based on technological and economic viability in order to serve and respond to the needs of users. The study found

that three components were composed of eight indicators, as shown in Figure 1.

### The Results of the Quantitative Study

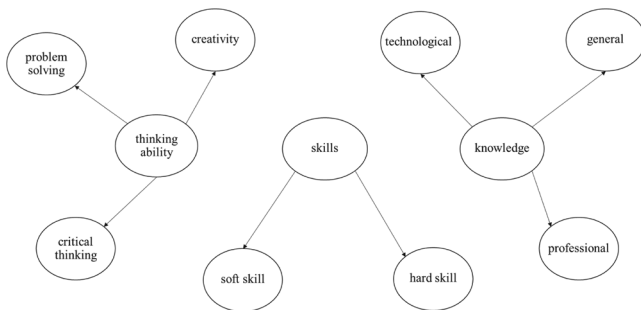
#### The measurement model of design thinking competency

The results of the quantitative data showed that the majority were Buddhist (89.06%) and female (58.54%). Based on the 10-point self-assessment scale, their mean scores for experience were 4.98 ( $SD = 2.51$ ) doing activities with their peers from different faculties and 6.67 ( $SD = 2.47$ ) using online media.

The mean scores for design thinking competency were at a moderately high level and the total mean score of all disciplines was at 3.67 ( $SD = 0.45$ ). The results showed that all three components were mostly close, as shown in Table 5.

The correlation coefficients of eight indicators, comprising general knowledge, professional knowledge, technological knowledge, creativity, problem solving, critical thinking, soft skill, and hard skill, were analyzed using Pearson's correlation coefficient method. Each pair of indicators was correlated at a statistical significance level of .05 and the coefficients ranged from 0.40 to 0.71, as shown in Table 6.

Regarding the results of the second order confirmatory factor analysis, it was found that the measurement model for design thinking competency was consistent with the empirical data, considering chi-squared statistic ( $\chi^2 = 20.23$ ,  $df = 15$ ,  $p = .14$ , CFI = 0.99, and SRMR = 0.01). This result concluded that the structural validity of the model was confirmed with three components and eight indicators. When considering each component, the standardized factor loadings of the measurement model were positive and significant at a statistical significance level of .05.



**Figure 1** Framework of three components

**Table 4** Consensus on experts' ranking components

| Component                      | Numbers of experts' ranking components |               |               |                  |
|--------------------------------|----------------------------------------|---------------|---------------|------------------|
|                                | HS<br>(n = 3)                          | ST<br>(n = 3) | SH<br>(n = 3) | Total<br>(n = 9) |
| <b>Knowledge Domain</b>        |                                        |               |               |                  |
| 1.1 General knowledge          | 2 (1)                                  | 1 (3)         | 2 (1)         | 5 (1)            |
| 1.2 Professional knowledge     | 1 (3)                                  | 2 (1)         | 2 (1)         | 5 (1)            |
| 1.3 Technological knowledge    | 1 (3)                                  | 1 (3)         | 1 (3)         | 3 (3)            |
| <b>Thinking ability Domain</b> |                                        |               |               |                  |
| 2.1 Creativity                 | 3 (1)                                  | 2 (1)         | 2 (3)         | 7 (1)            |
| 2.2 Problem solving            | 1 (3)                                  | 1 (3)         | 3 (1)         | 5 (3)            |
| 2.3 Critical thinking          | 3 (1)                                  | 1 (3)         | 3 (1)         | 7 (1)            |
| <b>Skill Domain</b>            |                                        |               |               |                  |
| 3.1 Soft skill                 | 1 (1)                                  | 3 (1)         | 1 (2)         | 5 (1)            |
| 3.2 Hard skill                 | 1 (2)                                  | 2 (2)         | 1 (2)         | 4 (2)            |

Note: Health science (HS); Science and technology (ST); Social science and humanity (SH).

**Table 5** Mean scores of the design thinking competency

| Indicators                   | Disciplines |           |          |           |          |           |          |           |
|------------------------------|-------------|-----------|----------|-----------|----------|-----------|----------|-----------|
|                              | HS          |           | ST       |           | SH       |           | Total    |           |
|                              | <i>M</i>    | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Total mean scores            | 3.67        | 0.47      | 3.60     | 0.43      | 3.73     | 0.44      | 3.67     | 0.45      |
| Knowledge domain             | 3.67        | 0.50      | 3.57     | 0.46      | 3.72     | 0.47      | 3.65     | 0.48      |
| General knowledge            | 3.74        | 0.55      | 3.64     | 0.48      | 3.72     | 0.51      | 3.70     | 0.51      |
| Professional knowledge       | 3.78        | 0.64      | 3.74     | 0.59      | 3.84     | 0.59      | 3.79     | 0.61      |
| Technological knowledge      | 3.49        | 0.64      | 3.33     | 0.64      | 3.60     | 0.58      | 3.47     | 0.63      |
| Thinking ability domain      | 3.64        | 0.54      | 3.61     | 0.49      | 3.72     | 0.49      | 3.66     | 0.51      |
| Creativity                   | 3.58        | 0.60      | 3.53     | 0.62      | 3.68     | 0.56      | 3.59     | 0.59      |
| Problem-solving              | 3.71        | 0.58      | 3.67     | 0.53      | 3.77     | 0.57      | 3.72     | 0.56      |
| Critical or logical thinking | 3.64        | 0.61      | 3.64     | 0.56      | 3.73     | 0.53      | 3.67     | 0.57      |
| Skill domain                 | 3.69        | 0.52      | 3.62     | 0.49      | 3.75     | 0.49      | 3.69     | 0.50      |
| Soft skill                   | 3.81        | 0.55      | 3.71     | 0.54      | 3.85     | 0.55      | 3.79     | 0.55      |
| Hard skill                   | 3.57        | 0.60      | 3.54     | 0.56      | 3.66     | 0.55      | 3.59     | 0.57      |

Note: Health science (HS); Science and technology (ST); Social science and humanity (SH).

**Table 6** Correlation coefficients between indicators

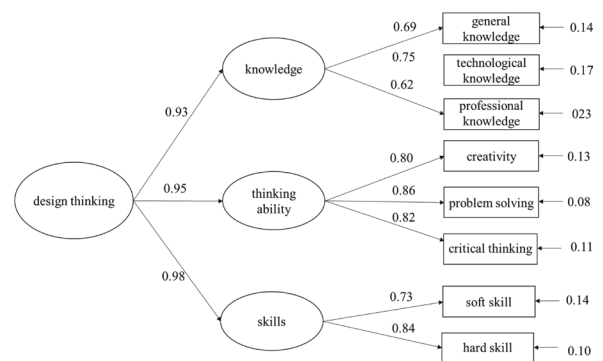
| Variables                   | K1    | K2    | K3    | T1    | T2    | T3    | S1    | S2   |
|-----------------------------|-------|-------|-------|-------|-------|-------|-------|------|
| General knowledge (K1)      | 1     |       |       |       |       |       |       |      |
| Professional knowledge (K2) | 0.56* | 1     |       |       |       |       |       |      |
| Technological knowledge(K3) | 0.52* | 0.49* | 1     |       |       |       |       |      |
| Creativity(T1)              | 0.49* | 0.40* | 0.55* | 1     |       |       |       |      |
| Problem solving(T2)         | 0.55* | 0.46* | 0.55* | 0.70* | 1     |       |       |      |
| Critical thinking(T3)       | 0.51* | 0.43* | 0.55* | 0.61* | 0.71* | 1     |       |      |
| Soft skill(S1)              | 0.46* | 0.41* | 0.47* | 0.54* | 0.63* | 0.58* | 1     |      |
| Hard skill(S2)              | 0.53* | 0.49* | 0.61* | 0.60* | 0.67* | 0.65* | 0.61* | 1    |
| <i>M</i>                    | 3.70  | 3.79  | 3.47  | 3.59  | 3.72  | 3.67  | 3.79  | 3.59 |
| <i>SD</i>                   | 0.51  | 0.61  | 0.63  | 0.59  | 0.56  | 0.57  | 0.55  | 0.57 |

Note: \*  $p < .05$ .

In the knowledge domain ( $\beta = 0.93$ ), it was found that technological knowledge had the highest loading ( $\beta = 0.75$ ). In the thinking ability domain ( $\beta = 0.95$ ), problem-solving was the indicator with the highest loading ( $\beta = 0.86$ ). In the skills component, the loading for the soft skill ( $\beta = 0.84$ ) was higher than that of the hard skill ( $\beta = 0.73$ ), as shown in Figure 2.

#### The test of the invariance measurement model of design thinking competency across the three disciplines

The test of the invariance measurement model of the design thinking competency across the three disciplines—health science, science and technology, and social science and humanities—was considered by using chi-squared statistics and goodness of fit indices composed of: (1) the difference of the comparative fit index between a and b ( $\Delta CFI_{a-b}$ ), lower or equal to .010; (2) the difference of the root mean square error of approximation between a and b ( $\Delta RMSEA_{a-b}$ ), lower or equal to 0.01 (Chen, 2007; Wang & Wang, 2020); and (3) the relative chi-squared ( $\chi^2/df$ ), lower or equal to 2.0 (Kline, 2015). There were four steps in testing the invariance measurement model of the design thinking competency across the three disciplines as follows.



**Figure 2** Measurement model of design thinking competency  
Note: All factor loadings are statistically significant at .05.

**Hypothesis test I:** The step of testing configural equivalence was to examine the configural invariance of the indicators of design thinking competency. The results revealed that the model approach to the empirical data by considering to chi-squared statistic ( $\chi^2 = 66.65$  degree of freedom ( $df = 57$   $p$  value ( $p = .18$  comparative fit index ( $CFI = 0.99$  root mean square error of approximation ( $RMSEA = 0.04$ ). Therefore, the structural model of the

indicators of the design thinking competency was invariant across the three disciplines.

*Hypothesis test II:* The step of testing the metric equivalence was to examine the metric invariance or loading invariance. The results revealed that the model approach to the empirical data by considering the chi-squared statistic ( $\chi^2 = 85.20$ ,  $df = 71$ ,  $p = .11$ , CFI = 0.99, RMSEA = 0.04,  $\Delta df = 71$ ,  $\Delta CFI_{a-b} = 0.00$ ,  $RMSEA_{a-b} = 0.00$ ,  $\chi^2/df = 1.30$ ). Therefore, the factor loadings were equal across the three groups.

*Hypothesis test III:* The step of testing scalar equivalence was to examine scalar invariance or intercept invariance. The results revealed that the model approach to the empirical data by considering chi-squared statistic ( $\chi^2 = 77.40$ ,  $df = 65$ ,  $p = .14$ , CFI = 0.99, RMSEA = 0.04,  $\Delta df = 65$ ,  $\Delta CFI_{a-b} = 0.00$ ,  $RMSEA_{a-b} = 0.10$ ,  $\chi^2/df = 1.19$ ). Therefore, the factor loadings and equal indicator intercepts were equal across the three groups.

*Hypothesis test IV:* The step of testing residual equivalence was to examine residual variance invariance or error invariance. The results revealed that the model approach to the empirical data by considering chi-squared statistic ( $\chi^2 = 74.47$ ,  $df = 64$ ,  $p = .17$ , CFI = 0.99, RMSEA = 0.04,  $\Delta df = 64$ ,  $\Delta CFI_{a-b} = 0.00$ ,  $RMSEA_{a-b} = 0.00$ ,  $\chi^2/df = 1.16$ ). Therefore, there were equal factor loadings, equal indicator intercepts, and equal item uniquenesses across the three groups.

The results of the four testing steps concluded that the measurement model of the design thinking competency was invariant across the three disciplines, as shown in Table 7.

The analysis of the standardized factor loading scores of the model of the design thinking competency across the three disciplines indicated that all of the factor loading scores of the three aspects were met at significance level of .05, as shown in Table 8.

## Discussion

The analysis results obtained through the use of RQDA and CFA showed that design thinking competency consists of the following three components.

Knowledge is composed of three indicators. The first indicator is general knowledge, which is in line with the

work of Thompson and Schonthal (2020), who suggested that design thinking basically begins with understanding the context of what is being designed and further developing the ideas in order to increase design efficiency and serve the needs of users in the best possible way. The second indicator is professional knowledge, which is consistent with the notions of Poth and Riel (2020), who indicated that knowledge is essential to design and ideation methods that can be appropriately recommended and considered. Knowledge is a foundation for the development of the thinking and analyzing process and for innovative initiatives. A certain level of professional knowledge is initially required to engage in an imaginative and innovative process (Hokanson & Kenny, 2020). The third indicator is technological knowledge, which is vital to creating integrated technological processes. This is similar to the findings of Lynch et al. (2019) and Kurokawa (2013), which suggested that technology is one of the key components of the design thinking process. Currently, advanced technology has been used to create innovations to serve the needs of people and to facilitate everyday life and work. Automated machines that can operate without human intervention will play a more important role in the near future. Thus, one of the most indispensable skills of human resources is the ability to design and create work processes for machines.

Thinking ability comprises three indicators. The first one is creativity. Hokanson and Kenny (2020) described creativity as formative processes in innovative design. McElheron (2020) also suggested that creative problem-solving affects the achievement of innovative design in serving the needs of users. This is in line with the results of the present research, indicating that problem-solving is the second indicator of thinking ability. Problem-solving skills enable people to solve problems with innovative methods or improved solutions that require less time and fewer resources. This is consistent with the study of Thompson and Schonthal (2020), which suggested that individuals with design thinking competency are design thinkers that can optimize the creative process of innovation. The third indicator of this component is critical or logical thinking. This indicator is associated with the selective process, where decisions are made using the cause-and-effect principle and integrated approach in order to obtain the most appropriate solution that is free of bias and errors. This is consistent with the concept of Wrigley and Straker (2017), who described design

**Table 7** Results of testing the invariance measurement model across the three disciplines

| Test       | $\chi^2$ | $df$ | $\chi^2/df$ | $p$ | CFI  | $\Delta CFI$ | TLI  | RMSEA | $\Delta RMSEA$ |
|------------|----------|------|-------------|-----|------|--------------|------|-------|----------------|
| configural | 66.65    | 57   | 1.16        | .18 | 0.99 | -            | 0.98 | 0.04  | -              |
| metric     | 85.20    | 71   | 1.20        | .11 | 0.99 | 0.00         | 0.99 | 0.04  | 0.00           |
| scalar     | 77.40    | 65   | 1.19        | .14 | 0.99 | 0.00         | 0.99 | 0.05  | 0.01           |
| residual   | 74.47    | 64   | 1.16        | .17 | 0.99 | 0.00         | 0.99 | 0.04  | 0.00           |

**Table 8** Standardized factor loading of the model of the design thinking competency across the three disciplines

| Factors                     | Standardized factor loading |           |           | $p$ | $R^2$ |
|-----------------------------|-----------------------------|-----------|-----------|-----|-------|
|                             | $\beta_1$                   | $\beta_2$ | $\beta_3$ |     |       |
| First-order factors         |                             |           |           |     |       |
| Knowledge domain            | 0.90                        | 0.90      | 0.90      | .00 | 0.81  |
| Thinking ability domain     | 0.95                        | 0.95      | 0.95      | .00 | 0.90  |
| Skill domain                | 0.98                        | 0.98      | 0.98      | .00 | 0.96  |
| Second-order factors        |                             |           |           |     |       |
| Knowledge domain            |                             |           |           |     |       |
| 1.1 General knowledge       | 0.75                        | 0.75      | 0.75      | .00 | 0.57  |
| 1.2 Professional knowledge  | 0.58                        | 0.60      | 0.60      | .00 | 0.33  |
| 1.3 Technological knowledge | 0.84                        | 0.84      | 0.84      | .00 | 0.71  |
| Thinking ability domain     |                             |           |           |     |       |
| 2.1 Creativity              | 0.76                        | 0.72      | 0.72      | .00 | 0.53  |
| 2.2 Problem solving         | 0.85                        | 0.83      | 0.83      | .00 | 0.69  |
| 2.3 Critical thinking       | 0.84                        | 0.82      | 0.82      | .00 | 0.69  |
| Skill domain                |                             |           |           |     |       |
| 3.1 Soft skill              | 0.58                        | 0.55      | 0.55      | .00 | 0.34  |
| 3.2 Hard skill              | 0.94                        | 0.93      | 0.93      | .00 | 0.87  |

Note: (1) health science (HS); (2) science and technology (ST); and (3) social science and humanity (SH).

thinking as a mindset that should be applied across disciplines, including teaching and learning, and should be assessed from a multidisciplinary perspective.

Skills are composed of two indicators: hard skills and soft skills. In terms of hard skills, educational institutions have set a target to continually develop disciplinary-specific skills of graduates through design thinking workshops and internship programs so that they can apply those skills to work in a rapidly changing environment. Innovative thinking is required for the development of academic and well-structured ideas, which leads to the formation of declarative knowledge (Hokanson & Kenny, 2020). Moreover, academic skills are extremely important for work (Badwan et al., 2018). On the other hand, one of the soft skills is social intelligence, which goes beyond disciplinary specific knowledge. It is considered an interdisciplinary non-professional skill that can be used to deal with challenges when facing unexpected situations.

The three components are vital to performance improvement in learning and workplace settings. Design thinking competency enables individuals to have broader perspectives and higher problem-solving abilities to serve diverse needs and also contributes to improved communication, teamwork, and digital technology skills. Thus, it can be concluded that design thinking competency is one of the most important skills of people in the 21st century (Larson, & Miller, 2011; van Laar et al., 2020).

## Conclusion

Because of the importance of promoting design thinking competency, this skill is integrated into teaching

and learning courses for graduate students. An appropriate measurement for evaluating the students' competency for different disciplines will be useful for assessing all aspects of the knowledge domain, the thinking ability domain, and skills. Moreover, this scale can be used in order to obtain information to promote graduated competency during programs for preparation for one's career. The application of design thinking in learning and workplace settings helps to promote better process management and understanding of different perspectives. The integration among multidisciplinary knowledge, idea management, and skills from classroom learning or social experience leads to the concept of design thinking competency.

## Conflicts of Interest

The authors declare that there is no conflict of interest.

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