



THE UNIVERSITY OF  
**SYDNEY**

**Development of Measurement Scales for Teacher Professional Development in ICT  
Integration: Insights into Program Value, TPACK, and Student Learning Achievement  
in Primary Education**

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A thesis submitted to fulfil the requirements of the degree of Doctor of Philosophy

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## **Statement of Originality**

This is to certify that the content of this thesis is my own work.

This thesis has not been submitted for any other degree or purpose.

I certify that the intellectual content of this thesis is the product of my own work, and that all assistance received in preparing this thesis and all sources have been acknowledged.

Tzu-Ping Lu

January 2026

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"If I have seen further, it is by standing on the shoulders of giants."— Isaac Newton

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## **Abstract**

Researchers have emphasised the importance of considering how teachers value a professional development experience when designing and refining a teacher professional development (TPD) program. Despite evidence that teachers' perceptions shape the successful implementation and impact of TPD, few measurement instruments exist to assess the value that teachers obtain from participation in TPD or the professional growth that they believe it generates. Given the growing global demand for TPD programs to enhance teachers' ability to successfully integrate Information and Communication Technology (ICT) into teaching, it is therefore necessary to ensure that such TPD are valuable from perspective of teachers. However, there is presently a lack of measurement instruments which can measure teachers' perceptions of the value of TPD and the results of their participation. This study addresses this gap by developing two measurement scales - the Value of TPD (VT) scale and the Improvement of TPACK core via TPD Experience (ITTE) scale - using the context of a Taiwanese national ICT integration TPD initiative.

Scale development was grounded in Rasch Measurement Theory, which establishes requirements for constructing instruments that yield meaningful, invariant measurement. Kane's argument based validation framework guided the validation process. Validity evidence was gathered through a literature review, three rounds of focus group discussions, and a large scale questionnaire survey. Focus group feedback contributed to the refinement of initial item pools, and the Rasch analysis was used to evaluate item functioning and provide evidence of the unidimensionality and measurement properties of the VT and ITTE scales. Correlation analyses explored relationships among VT, ITTE, and students' learning achievement; no significant associations were found, suggesting that the implications of VT and ITTE scores may not extend to student outcomes. The relatively small sample size and

the lack of controls in generating the data for this stage of the study, means that these findings warrant cautious interpretation and further investigation.

This study offers three significant contributions. First, it demonstrates the application of Rasch Measurement Theory in developing robust measurement scales. Second, the study's VT and ITTE scales are generalisable to other contexts of TPD beyond the TPD program for ICT integration in Taiwan. The results collected through the VT and ITTE scales can be meaningfully compared across contexts, groups of teachers and means of administration. Finally, the development of VT and ITTE scales provides tools for researchers, policymakers, and system leaders to monitor and refine TPD implementation from teachers' perspectives. Together, the VT and ITTE scales support more evidence informed design, evaluation, and continuous improvement of TPD programs.

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## **Abbreviations**

ICT	Information and Communication Technology
OECD	Organisation for Economic Cooperation and Development
TPD	Teacher Professional Development
EVT	Expectancy-Value Theory
TPACK	Technological Pedagogical and Content Knowledge
TK	Technological Knowledge
PK	Pedagogical Knowledge
CK	Content Knowledge
TPK	Technological Pedagogical Knowledge
TCK	Technological Content Knowledge
PCK	Pedagogical Content Knowledge
TPACK-core	The core domain of Technological Pedagogical and Content Knowledge
VT	Value of TPD
ITTE	Improvement of TPACK via TPD Experience
AI	Artificial Intelligence
RSM	Rating Scale Model
UNESCO	United Nations Educational, Scientific and Cultural Organization
SAAT	Students' Academic Attainment Tests
QCA	Qualitative Content Analysis

## **Glossary of Terms**

**Assess.** To assess refers to the process of judging or determining amount, quality or importance. In this study, the term is used in contexts such as “assessing the implementation of TPD programs for ICT integration into teaching”.

**Assessment.** This term has two meanings in the context of the present study. First, it refers generally to any process related to the collection of information about student performance. Second, it refers more specifically process of reviewing the outcomes of a Teacher Professional Development (TPD) program’s implementation.

**Assessment Instrument.** An assessment instrument refers to a tool used to collect information that can be used to locate the respondent (i.e. teacher) on the scale. Two assessment instruments were developed in this research. The first is the Value of TPD (VT) questionnaire and the second is the Improvement of the core domain of Technological, Pedagogical, and Content Knowledge (TPACK-core) (ITTE) questionnaire.

**Construct.** A construct is a latent theoretical property that researchers aim to measure from objects, persons, institutions, or entities. Constructs are not directly observable and must be inferred through indicators. An example in the present study is the construct of the value of TPD.

**Questionnaire.** A questionnaire is an assessment instrument that includes a set of questions or items used to administer the scales and to gather responses.

**Measurement.** It refers to the process of assigning a number to a performance representative of a point on the developmental continuum which indicates the extent to which a construct is presented (Tognolini, 2018, p. 2).

**Measurement instrument.** A measurement instrument refers to a tool used to quantify and assess a latent construct or an attribute (DeVellis & Thorpe, 2021). In this research, two

measurement instruments were developed. The first is the Value of TPD (VT) scale and the second is the Improvement of TPACK-core (ITTE) scale.

**Scale.** A scale consists of multiple items that are designed to reflect a single underlying construct. A scale is administered through an assessment instrument, such as a questionnaire. In this study, the Value of TPD (VT) scale, and the Improvement of TPACK-core via TPD Experience (ITTE) scale represent two distinct latent constructs.

**Survey.** A survey is a research method involving structured data collection from a sample population.

## **Chapter 1: Introduction**

### **1.1 Background of the Study**

Over the last decade, the improvement of teachers' ability to integrate Information and Communication Technology (ICT) into their classrooms has gained attention worldwide (Al-Emran & Al-Sharafi, 2022; Alkamel & Chouthaiwale, 2018; Hashemi & Kew, 2021). The 2018 Teaching and Learning International Survey (TALIS) report published by the Organisation for Economic Cooperation and Development (OECD) showed that primary school teachers in most countries expressed a strong desire for improving their ICT skills for teaching. The European Commission (2022) proposed that modern society has entered the era of Industry 5.0, the fifth industrial revolution, and emphasised the collective and sustainable usage of advanced ICT by individuals and industries. Teachers worldwide are being encouraged to efficiently incorporate technologies into the classroom to enhance teaching quality and student learning (Akturk & Ozturk, 2019; Al-Emran & Al-Sharafi, 2022; Azmi, 2017; Hsu, 2016; Izquierdo et al., 2017; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021). The OECD (2024) explicitly states that countries should provide a teacher professional development (TPD) program focused on helping teachers overcome challenges in using and teaching ICT.

Many countries, including Taiwan, have introduced TPD programs for ICT integration into teaching to improve teachers' skills in ICT integrations into their classrooms, with Taiwan being one of the leading countries in ICT development (International Trade Administration, 2024). In Taiwan, the Ministry of Education (MOET) introduced a new technological enhancement plan in 2022 across all levels of education. Under the plan, primary school teachers are required to participate in a mandatory TPD program for ICT integration into teaching to enhance their understanding and application of ICT.

Like Taiwan, Australia incorporates ICT within the *Australian Core Skills Framework* (Mclean et al., 2012), which introduces five critical skills for lifetime performance: Learning, Reading, Writing, Oral Communication and Numeracy (p. 190), with engagement across all government and educational sectors (Gekara et al. 2019). Teachers in the Australian state of New South Wales (NSW) are encouraged to share their experience and innovative teaching ideas on ICT within the teacher community through TPD activities (NSW Department of Education, 2019). Germany has also introduced a range of policies and strategies to promote teacher digital literacy and ICT integration into pedagogical approaches across disciplines (OECD, 2020). However, despite a proliferation of TPD programs, the practical application of ICT remains challenging for teachers and there is an over reliance on traditional teaching methods (Hashemi & Kew, 2021). At present, many professional development trainings aimed at improving teachers' skills in integrating ICT are not well-coordinated (Diliberti et al., 2021; Hashemi & Kew, 2021; OECD, 2024).

There has been on-going discussion over the past decades regarding critical features of TPD that may enhance both teachers' competencies in teaching and students' learning (e.g. Bates & Morgan, 2018; Bayar, 2014; Cirocki & Farrell, 2019; Desimone et al., 2002; de Vries et al., 2013; Zeggelaar et al., 2018, 2022; Zhang et al., 2024). In particular, researchers have emphasised the importance of the motivation and the value teachers place on TPD programs (e.g., Lee, 2015; Fishman et al., 2003; Osman, 2017). Teachers tend to place a higher value on TPD programs that incorporate specific desirable features they perceive to be important for their teaching and their students' learning (Shurtleff, 2020). Perceptions of TPD programs are assumed to have a lasting impact on their overall success (Dennis & Hemmings, 2019; Didion et al., 2019; Lee, 2015; Fishman et al., 2003).

Extensive research has discussed the effective features of TPD, only a few studies have shed light on teachers' perceptions of those features (e.g. Zhang et al., 2024; Sokel, 2019). Teachers' perceptions of the value of TPD are a latent trait that cannot be observed directly, nor can it be captured simply through individual description or opinion. A systematic process of measurement can be a means of assigning teacher responses to positions on a continuum represented by measurement instruments, such as scales for indicating the extent to which teachers value the TPD is presented (Tognolini, 2018). Despite its importance for determining the success of TPD programs, a measurement instrument for conducting such a measure does not yet exist. The missing link between features of successful TPD programs and teachers' evaluations of them may raise validity concerns (Kennedy, 2016b; Opfer & Pedder, 2011). Theories and empirical evidence are needed to foster the trustworthiness of the features and their measures (Kennedy, 2016b).

In addition to aligning with teachers' expectations and perceptions, measurements of the success of implementing a TPD program should include metrics for improvements in teachers' relevant knowledge and subsequent gains in student learning (Centre for Education Statistics and Evaluation [CESE], 2023; Fishman et al., 2003; Koh et al., 2017; Kubitsky & Fishman, 2007; Lee, 2015; Wenglinsky, 1998). Consequently, this thesis is focused on developing two measurement instruments in the form of scales to capture teacher perceptions of both the value of TPD programs and personal improvement in relevant knowledge. The scales also seek to demonstrate how improvement of students' learning might be measured following participation in TPD programs. This study explicitly develops its scales on the basis of a TPD program for ICT teaching conducted in Taiwan, where educational reforms for ICT integration into teaching have been actively promoted in recent years. The study's

measurement scales reflect the local educational context in which the examined TPD programs were implemented.

## **1.2 Problem Statement and Purposes of the Study**

This study is inspired by three key research gaps: the potential validity threat related to existing questionnaires used to evaluate the outcomes of TPD programs from teachers' perspectives; validity concerns arising from the use of existing TPACK questionnaires as outcome measures for TPD programs focused on ICT integration into teaching; and lack of evidence indicating the linkage between teachers' participation in TPD programs and student learning achievement.

It is critical for TPD program designers to develop and refine program features based on teachers' perceptions and feedback (Alemdag et al., 2020; Krille, 2020). However, measurement instruments which can assess teacher participants' perceptions of the value of TPD programs in achieving their stated goals are not readily obvious in the current literature. Traditionally, evaluation questionnaires administered following TPD programs have been designed by workshop providers or educators, often without the involvement of the workshop participants. This design feature has the potential to pose a validity threat. For example, workshop content that teacher participants find valuable may not be adequately reflected in evaluation, and the wording used in evaluation questionnaires may be unfamiliar to respondents. These issues may undermine the linkage between questionnaire items and the intended purpose of the measurement.

According to widely used survey platforms such as SurveyMonkey, SurveyCake and Whatfix, the most common post-workshop survey questions are predominantly satisfactory questions, such as "Are you satisfied with the content provided?" or "Are you satisfied with the workshop lecturer?". The scope of such questions is generally not appropriately aligned

with the level of complexity of the goals underpinning TPD programs (Topala & Tomozii, 2014). Surveys of this sort tend to neglect aspects regarding alignment between workshop outcomes and participant expectations, and the extent to which the workshop content was of genuine benefit to teachers' careers.

Successful implementation of TPD programs should also anticipate an improvement in teachers' knowledge. Improvement in knowledge and skills should be theoretically linked to a subsequent improvement in students' learning (CESE, 2023; Fishman et al., 2003; Lee, 2015; Wenglinsky, 1998; Kubitsky & Fishman, 2007; Koh et al., 2017). In the context of TPD programs for ICT integration into teaching, the level of success and usefulness of such programs should enhance teachers' Technological Pedagogical and Content Knowledge (TPACK) (Fishman et al., 2003; Kubitsky & Fishman, 2007; Koh et al., 2017; Lee, 2015; Wenglinsky, 1998;). Shulman's (1986) framework of Pedagogical Content Knowledge (PCK) was expanded to include technology in teaching by Mishra and Koehler (2006). This augmented framework, called the TPACK framework, integrates technology into teaching (Bajracharya, 2021).

Since the introduction of the TPACK framework, numerous questionnaire-based tools have been developed to assess teachers' TPACK. Previous research has often used self-assessment TPACK questionnaires to evaluate the outcomes of TPD programs for ICT integration into teaching (e.g., Hsu et al., 2013; Koh et al., 2013; Schmidt et al., 2009). These studies often use pre-existing TPACK questionnaires without adequately considering the specific purposes of a given TPD intervention, thus raising concerns about the validity of the resulting measurements (e.g. Kang, 2020; Young et al., 2019). Furthermore, existing questionnaires primarily focus on evaluating training courses within programs that only aim to improve TPACK (e.g. Hsu et al., 2013; Koh et al., 2013; Schmidt et al., 2009), raising the

potential issue that results cannot be generalised to TPD programs with broader program aims.

Finally, while there has been wide acknowledgement in the literature that successful TPD programs should positively influence student learning achievement (CESE, 2023; Desimone, 2002; Myrberg, 2007; Wallace, 2009), most studies investigating student learning achievement as an indicator of TPD program success rely on improvements in students' classroom performance following their teachers' participation in a TPD program. These findings are insightful; however, they are not generalisable beyond the classrooms of the individual teachers conducting the assessments. It has been noted in the literature that more rigorous measures obtained from high-stakes government-administered testing programs (e.g. Koh et al., 2016; Martínez et al., 2022; Merchie et al., 2018) could support claims that TPD leads to students' academic improvement. More comprehensive research examining the relationship between teachers' perceptions of TPD and the improvement of their student learning achievement, using score results from government-led high-stakes tests, is therefore needed (CESE, 2023; Sims et al., 2021).

Given the gaps in the current literature, three research purposes are proposed in this study. The first and second research purposes are addressed through the development of two distinct measurement scales, with each scale corresponding to one research purpose and grounded in a specific construct and theoretical framework. The first purpose of this study is to develop a measurement scale to examine the value of TPD programs from the perspective of teachers. Eccles et al.'s (1983) Expectancy-Value Theory is adopted as a theoretical lens to capture the extent to which teachers value their TPD experiences through a case study of TPD program for ICT integration into teaching conducted in Taiwan. Expectancy-Value Theory has been highly recommended and adopted by recent researchers to evaluate teachers'

perceptions of TPD activities (e.g. Boström & Palm, 2020; Richardson & Watt, 2010; Rutherford et al., 2017; Xu, 2022) as well as their motivations and perceptions regarding their participation in TPD activities (Kennedy, 2016a).

The second purpose is to develop a separate measurement scale to examine the extent to which teachers perceive the TPD program for ICT integration into teaching improved their TPACK. The TPACK framework (Mishra & Koehler, 2006) serves as the theoretical basis for this measure, with a specific focus on the core domain of the TPACK framework (i.e. TPACK-core), within the context of TPD for ICT integration into teaching. The justification of focusing TPACK-core is addressed in Chapter 2, Section 2.4.1.

Previous studies mostly employ deductive methods (Hwang et al., 2018; Osman & Warner, 2020) in which questions or items are generated from pre-existing scales and literature reviews (Hinkin, 1995), or inductive approaches, such as interviews, focus groups, expert panels, and other qualitative methodologies (Martin & González, 2017) to measure the impact of a TPD program for ICT integration into teaching on TPACK-core. No studies have used a measurement scale to measure the impact of TPD.

This study employs Rasch Measurement Theory (RMT), introduced by George Rasch in 1960, to develop measurement scales. Rasch analysis is considered most appropriate for providing scale validation evidence in addition to Classical Test Theory, as it is the only method capable of transforming ordinal data into log odds ratios over an interval scale (Cox et al., 2015). It is a measurement theory that allows for determining whether items are pertinent to the constructs proposed in this study and is employed to identify whether the items are appropriate and consistent across participants with diverse backgrounds—a determination which Classical Test Theory alone cannot achieve (Fox & Jones, 1998).

The third research purpose of this study is to implement the two developed measurement scales within the Taiwanese education context to explore their empirical relationships among primary school teachers' perceptions of the value of a TPD program for ICT integration conducted in Taiwan, their perceived improvements in TPACK-core from participation in the program, and students' learning achievement. Overall, the findings of this study provide insights into the successful design and implementation of TPD programs, particularly those focused on ICT integration into teaching, with implications for program designers, educational leaders and policy makers.

### **1.3 Taiwanese Context**

Since 2022, the Ministry of Education Taiwan has implemented a series of digital learning enhancement plans with an investment of twenty billion New Taiwan dollars (NTD) (~ one billion Australian dollars [AUD]) to facilitate the enhancement of digital learning environments in schools and strengthen students' ICT capabilities. The Taiwanese government has also promoted a series of TPD programs to increase teachers' ability to adapt and adopt ICT into their teaching. While the present study specifically focuses on Taiwan, the process used for building and refining measures is applicable to all countries seeking to implement technological advances in teaching for their schools.

The Taiwanese government's initiative established a compulsory TPD program for ICT integration into teaching for primary school teachers, including those teaching English as a Foreign Language (EFL) and mathematics. Within this context, the present study collected data from primary school EFL and mathematics teachers to investigate their perceptions of the value of the TPD program and to examine the relationships among the value of the program, teachers' perceived improvement in TPACK-core through TPD experience, and students' learning achievement.

Taiwanese primary school students in Year 5 and Year 6 are required to undertake the Student Academic Attainment Test (SAAT) in mathematics and English at the end of the school year. In the mathematics test, the students are requested to answer 25 questions based on the dimensions of Number and Calculation, Units and the Direct Measurement, Geometry, and Algebra. There are 25 questions in the English test which assess nine dimensions: Phonemic Discrimination in Listening, Lexical Recognition in Auditory Processing, Comprehension of Classroom Discourse, Appropriate Responses to Classroom Discourse, Listening Comprehension of Cultural and Festival-related Discourse, Orthographic and Lexical Recognition, Syntactic and Semantic Sentence Comprehension, Interpretation of Short Texts, and Visual Representations and Reading Comprehension of Cultural and Festival-related Texts. The present study collected the Year 5 and 6 results of students whose teachers participated in the government's mandatory TPD program for 1 year and uses the mean SAAT score difference of classes across both years as a measure of students' learning achievement.

In addition to its digital learning enhancement plan and the SAAT, the Taiwanese government has also introduced and implemented a policy to elevate the proficiency of English among both teachers and students in Taiwan (Financial Supervisory Commission, Republic of China (Taiwan), 2019). The policy has contributed to an increase in English teaching at all stages and phases of education. English as Foreign Language (EFL) teachers across various school sectors are expected to support colleagues and students to effectively integrate English and ICT in classrooms. However, the willingness of EFL teachers in Taiwan to participate in TPD programs for ICT integration into teaching is low (Hung & Yeh, 2013). The participation rates of mathematics teachers in TPD programs for ICT integration into teaching is relatively higher, as mathematics-focused TPD programs have

been ongoing for years in response to the international reports published by the National Council of Teachers of Mathematics (NCTM, 1989, 2000, 2014). Nonetheless, there are still challenges for TPD program designers seeking to maximise the likelihood that teachers can successfully apply what they learn from the program in their classes towards improving student's mathematics achievements (Kholid et al., 2023; Polly, 2011).

#### **1.4 Significance of the Study**

An investigation of teachers' perceptions of TPD (Hwang et al., 2018; Martin & González, 2017; Osman & Warner, 2020) articulates a need for developing an instrument, supported by validity evidence, that can evaluate the value of TPD experiences from teachers' perspectives. Although this study is focused on TPD programs for ICT integration in teaching for mathematics and EFL teachers in primary schools in Taiwan, its theoretical and empirical bases for scale development are drawn from the broader literature on general TPD. Casting a wide net ensures that the scale captures the fundamental features of the value of TPD, regardless of subject area or specific focus. This study's process for collecting evidence to support arguments for the validity of its scales is theoretically generalisable and can be adapted for evaluating other TPD programs across different subject areas and contexts.

Technology in education has been most prevalent in studies regarding science subjects, especially with the use of the TPACK framework (Tseng et al., 2020). The framework of TPACK consists of three domains of based knowledge: pedagogy, content, and technology. While the TPACK framework has been commonly applied in much of science education research, there seems to be little research examining its impact on language teachers. The present study has extended the TPACK framework into language education. This extension justifies the generalisability of technology's application in education beyond science subjects. By considering the context of a given TPD program within the TPACK

framework, this study contributes to expanding theoretical understandings of the TPACK framework.

There is also a lack of studies explicitly examining teachers' improvement in TPACK-core resulting from TPD programs, with consideration to the context and purposes of a given TPD. This study addresses this gap by developing a measurement scale that captures teachers perceived improvement in TPACK-core from participation in a TPD for ICT integration into teaching.

Although the empirical validation of this study's scales is conducted within the Taiwanese educational context, this study is a response to broader policies aimed at strengthening ICT integration through TPD across countries. National policies in Taiwan have actively promoted ICT integration across all levels within the education sector, leading to the widespread implementation of national-led TPD programs for ICT integration into teaching. Similar initiatives are evident internationally, including in the United States and Australia, where governments have introduced TPD programs to enhance teachers' ability to use ICT in teaching (Havard et al., 2018), particularly in response to the increasing adoption of hybrid and online teaching modes (Niess & Gillow-Wiles, 2021; New South Wales government, 2022). In light of this broader policy context, the findings of this thesis and the measurement scales developed here provide empirical insights to support the design, evaluation and refinement of TPD programs across diverse educational contexts.

## 1.5 Research Questions

The first purpose of this study is to develop a measurement scale that enables primary school teachers to indicate their perceptions of the value of TPD. Achieving this requires identifying features that teachers believe indicate a successful TPD program. These features are then theoretically structured using Expectancy-Value Theory (EVT) (Eccles et al., 1983) to conceptualise the value of the TPD construct. The second purpose is to develop a separate measurement scale for investigating the extent to which Taiwanese primary mathematics and EFL teachers perceive that the given TPD program has improved their TPACK-core. Finally, the third purpose of this study is to implement the two scales to examine the relationships between the value of TPD from teachers perspective, their perceived improvement in TPACK-core, and the extent of students' learning achievement. Based on the three research gaps identified in Section 1.2 and the corresponding research purposes, four primary research questions have been developed:

- (1) To what extent do mathematics and EFL primary school teachers in Taiwan value a given TPD program for ICT integration into teaching?
  - a. What are the features of TPD that teachers value?
  - b. How do these features align with the four domains of value derived from Eccles et al.'s (1983) Expectancy-Value Theory?
  - c. To what extent does the measurement scale proposed in this study reflect the intended construct of the value of the TPD?
- (2) To what extent do primary school mathematics and EFL teachers in Taiwan perceive that the given TPD program for ICT integration into teaching has improved their TPACK-core?

- a. How do items developed from existing TPACK questionnaires align with the context of TPD for ICT integration into teaching in Taiwan?
  - b. To what extent does the measurement scale proposed in this study capture teachers' perceived improvement in TPACK-core resulting from participation in the given TPD program for ICT integration into teaching?
- (3) To what extent do Taiwanese primary school mathematics and EFL teachers' ratings of the value of the given TPD program for ICT integration into teaching and their perceived improvement of TPACK-core through participation in the program correlate with their students' learning achievement?

## **1.6 Overview of the Thesis**

The thesis consists of seven chapters. The present chapter has provided an overview of the study background and purposes of the study. Problems and research gaps in the current literature regarding measures of the value of TPD programs and related teacher knowledge, TPACK-core, as well as links between TPD, the TPACK framework and students' learning achievement were identified through the lens of TPD programs for ICT integration into teaching in Taiwan. The Taiwanese context of the research has been introduced and justified, and the importance of the present study in addressing identified gaps as well as its generalisability to other contexts has been emphasised.

Chapter 2 outlines the theoretical bases for the scales developed in this study. It discusses a development framework as the basis for scale development. It also discusses Expectancy-Value Theory (Eccles et al., 1983) and TPACK framework (Mishra & Koehler, 2006) and elaborates how these theories are applied to build the operational constructs underlying the two measurement scales. Rasch Measurement Theory (Rasch, 1960/1980) and

Kane's (2006) argument-based validation framework are introduced to provide a theoretical basis for the collection of evidence in support of the validity of the scales.

Chapter 3 presents a review of literature related to the theories discussed in Chapter 2. It first introduces the role of ICT in education and the importance of TPD for ICT integration into teaching. It then discusses critical features of successful TPD and explains how these features can be systematically aligned to the four value domains derived from Eccles et al.'s (1983) Expectancy-Value Theory to form the construct underlying the scale developed to assess the value of TPD programs. The chapter then reviews how previous TPD studies have adopted the TPACK framework to rationalise the development of a scale for assessing teachers' variation in TPACK-core through participation in TPD for ICT integration into teaching. It also discusses the definition of students' learning achievement and how it can be regarded as evidence of the success of a TPD program with a particular focus on national standardised achievement tests in Taiwan. Three major educational policies in Taiwan are outlined to elaborate the contextual basis for the study. Finally, the Rasch model is introduced as a measurement model used to govern the construction of the measurement scales and its usage with polytomous type items (of the Likert type).

Chapter 4 explains the study's methodology and approach to addressing the research questions. It begins by presenting the conceptual framework and research design, introduces the validation strategies used to support the measurement scales. The data collection and analysis methods applied in focus group discussions and towards developing questionnaire surveys are also presented.

Chapters 5 and 6 present results and analyses derived from the three stages of focus group discussions conducted between October 2023 to January 2024, as well as results and

analyses obtained from questionnaire surveys collected in Taiwan between July 2024 and October 2024.

Chapter 7 provides a conclusion and discusses the findings of the focus group discussions and questionnaire surveys in relation to the research questions. The implications and limitations of the thesis, as well as directions for future research in similar fields are proposed.

## **Chapter 2: Theoretical Framework**

### **2.1 Introduction**

There are few measurement scales available which can evaluate the implementation of teacher professional development programs (TPD). This is especially true for programs focused on integrating Information and Communication Technology (ICT) into teaching. In addition, there is limited empirical evidence demonstrating the extent to which the value that teachers assign to a professional development program, together with their perceived improvement of the core domain of Technological Pedagogical and Content Knowledge (TPACK-core) through the program, are related to their students' learning achievement. Accordingly, this study designs and collects validity evidence for a scale that enables the measurement of the perception of primary school teachers' perceptions of the value of TPD through the lens of a TPD program for ICT integration into teaching conducted in Taiwan. It develops a scale that enables the measurement of perceived improvement in TPACK-core arising from participation in a TPD program for ICT integration into teaching. Finally, it implements both scales in practice by examining relationships among teachers' evaluations of the TPD program, their perceived improvement in TPACK-core, and their students' learning achievement.

This chapter discusses the theoretical frameworks that guide the development and the validation of this study's measurement scales. First, development frameworks for measurement scales are introduced. Expectancy-Value Theory (Eccles, 1983) is then introduced as a theoretical lens for building the scale measuring the value of TPD programs from primary teachers' perspectives. This scale is referred to as the Value of TPD Scale (VT Scale).

Next, the TPACK framework and previous measures of TPACK-core are discussed to specify the research scope for developing a separate measurement scale that captures teachers' perceived improvement in TPACK-core resulting from their participation in the TPD program (i.e. the Improvement of TPACK-core via TPD Experience scale [ITTE] scale). Rasch Measurement Theory (Rasch, 1960/1980) and Kane's (2006) argument-based validation frameworks are introduced to provide the theoretical insights into how the study's measurement scales are developed and to provide evidence linking theoretical constructs with the two measurement scales developed in this study. Finally, a summary of scale development and validation is presented.

## **2.2 The Development Framework of Measurement Scales**

Tognolini provides a specific definition of measurement as “the process of assigning a number to a performance to represent a location with respect to the developmental continuum underlying the performance that indicates how much of the construct being assessed is present” (2018, p. 2). In this study, measuring the value of TPD programs refers to assigning a numerical score that captures the degree of value teachers attribute to their participation in a given TPD program. Measuring the improvement of TPACK-core refers to assigning a numerical score that reflects the extent of perceived growth in TPACK-core that teachers attribute to the participation of a given TPD program.

In the field of social sciences research, researchers are usually interested in measuring the latent traits of entities; the construct, instead of the entity itself (Andrich & Marais, 2019). In order to make a construct measurable, it is necessary to operationally define it, delineate growth in relation to the construct and then develop appropriate measurement instruments capable of quantifying the construct (DeVellis & Thorpe, 2021). Data for measurement are

obtained through assessment instruments, such as tests and questionnaires, which serve as tools for collecting information. This information is then used in the process of measurement to locate teachers on a latent continuum presented by measurement instruments. Common assessment instruments include tests and questionnaire surveys, many of which have associated measurement instruments such as scales and rubrics.

This study seeks to develop two measurement scales: one to measure teacher perceptions of the value of TPD and one to measure their perceived improvement in TPACK-core attributes as a consequence of participation in TPD programs for ICT integration into teaching. A questionnaire was seen as the most appropriate type of assessment instrument, given the value-laden construct being measured. The development of a measurement scale can be facilitated by deductive approaches in which the items are generated from pre-existing questionnaires and literature reviews (Hinkin, 1995). Inductive approaches, such as interviews, focus groups, expert panels, and other qualitative methodologies (Martin & González, 2017), and a combination of approaches were also used to develop the study's questionnaires and assessment devices.

A combination of deductive and inductive approaches is recommended by development researchers to minimise inadequate construct definition or the use of low-quality items (e.g. MacKenzie et al. 2011; Morgado et al., 2017). Using combined approaches, Gehlbach and Brinkworth (2011) provide a step-by-step framework for scale development which suggests the following: (1) undertake a comprehensive literature review for construct development, (2) conduct interviews or focus groups with stakeholders to provide evidence of the linkage between a construct and an assessment instrument, (3) synthesise data from the literature review and the interviews to provide a fully operational

definition of the construct, (4) develop preliminary items based on this definition, (5) have experts review the developed items, (6) conduct cognitive pretesting to observe how respondents may interpret items. After going through the above steps, Gehlbach and Brinkworth (2011) suggest conducting a pilot test on a larger population of participants to identify problematic items by testing the function of the items and their suitability for producing measurement scales before administering the large-scale survey. Others, such as DeVellis and Thorpe (2021), propose more steps (nine steps) to develop a scale based on a validation process from Classical Test Theory. While there is disagreement in the number of steps needed for constructing the assessment and developing a measurement scale, the processes are very similar.

This study adopts Gehlbach and Brinkworth's methods to guide the development of the questionnaires and the measurement scales by employing both deductive and inductive approaches. DeVellis and Thorpe (2021)'s nine steps of scale development were proposed more recently, but Gehlbach and Brinkworth's (2011) scale development guidelines provide more detailed guidance on data collection.

### **2.3 Expectancy-Value Theory (EVT) and Teacher Perceptions of TPD**

Atkinson (1958, 1964)'s Expectancy-Value Theory (EVT) suggests that an individual's motivation to participate in an activity depends on the expected consequences of their participation and the subjective value they assign to this participation. Eccles et al. (1983) expanded EVT to the field of education, initially focusing on students' motivation to participate in learning activities. According to Eccles et al.'s study, students' expectations of success and perceptions of the value of activities may affect their performance and engagement in classes (Eccles et al., 1983; Eccles & Wigfield, 2002).

EVT can also be used to explain teachers' motivations for engaging in a particular subject or activity (e.g. Boström & Palm, 2020; Richardson & Watt, 2010; Rutherford et al., 2017; Xu, 2022). Although teachers' willingness to participate in TPD programs has been found to be influenced by their assessment of the program's value (Karabenick & Conley, 2011; Osman & Warner, 2020), more comprehensive studies are still needed to gain a deeper understanding of teachers' perceptions of TPD (Osman & Warner, 2020).

According to EVT (Eccles et al., 1995; Richardson & Watt, 2010; Osman & Warner, 2020), there are two main factors that determine teachers' willingness to participate in TPD: their expectation to successfully complete the program, and their perception that participating in the program will be of some benefit (i.e., the value of the TPD). Sims et al. (2021) reviewed 104 publications on TPD research and found that the success of a TPD intervention is determined by how valuable the TPD is when viewed from the teachers' perspective. TPD programs have been found to be more impactful when teachers "buy into" the training and link it with their teaching and students' learning (Cordingley et al., 2015; Sims et al., 2021).

This study focuses on developing a measurement scale that provides evidence of the value that teachers attribute to TPD programs. That is, the extent to which the teachers "buy into" the program after their participation. Eccles et al. (1983) indicate that the construct of value in EVT theory comprises four domains: attainment value, intrinsic value, utility value, and cost. Since this theory is central to the present work, the definition of each domain of value based on Eccles et al.'s (1983) research and further study (e.g. Eccles, 2009; Eccles & Wigfield, 2020) is presented below.

### **Attainment value**

Attainment value is defined as teachers' perceived importance of an activity. Attainment value is higher when the features of the activity are congruent with the teacher's demands and identity. For example, a TPD program might be regarded as having high attainment value if it aligns closely with participating teachers' identities and instructional philosophies (Osman & Warner, 2020). Eccles (2009)'s definition of identity includes teachers' personal values, gender, religions, and social backgrounds.

### **Intrinsic value**

Intrinsic value refers to the immediate, inherent enjoyment that individuals obtain from engaging in an activity or their own interests in the activity (Eccles & Wigfield, 2020). When individuals regard an activity as having high intrinsic value, they usually become more engaged and sustain involvement over a longer period (Eccles, 2005). Emo (2015) found that teachers looked for TPD experiences for novelty and to avoid monotony. It has been suggested that some teachers might be more willing to engage in TPD programs that consist of meaningful, active intellectual engagement (Kennedy, 2016a).

### **Utility value**

Utility value refers to the perceived usefulness of a task in achieving teachers' short- and long-term goals. When a TPD program is perceived as having high utility value, teachers anticipate that it will benefit their classroom management and improve student learning (Gaines et al., 2019; Osman & Warner, 2020). For example, Herranen et al. (2021) investigated teachers' expectations and perceptions of a TPD

focused on ICT integration into teaching course and found that teachers who chose to participate had high expectations for the program's positive effects on their future teaching. When teachers identify direct benefit to their teaching, their willingness to participate in a TPD program will increase (Eccles et al., 1983). That is, teachers' engagement is determined by the how useful they perceive a TPD program to be (Herranen et al., 2021).

Since teachers' personal or professional goals may be deeply linked with personal identity, utility value may overlap with attainment value (Eccles & Wigfield, 2020). For example, if a TPD program is perceived to be high in utility value, it likely corresponds to teachers' career goals and is likely to take on personal significance beyond its usefulness. Distinctions between attainment value, intrinsic value and utility value can be subtle and highly related, depending on how central a goal is to an individual.

### **Cost**

Eccles et al. (1983) defined cost as a negative value. Unlike the concept of cost in a business context, where a higher cost of a product might imply higher quality or value, in EVT, cost refers to what a person must give up or endure to participate in an activity. As the cost of an activity increases, the activity's overall perceived value may decrease. Eccles et al., (1983) proposed three types of cost. The first type is the cost of effort, which is the physical or mental exertion required to accomplish an activity, such as financial investments or time investments. The second type is the opportunity cost relative to involvement in other valued tasks. For example, teachers might have spent time marking students' homework or being with their families

instead of participating in a TPD program. The third type of cost is the emotional cost associated with fear of failure, stress, or frustration when engaging in an activity.

When evaluating a TPD program, teachers frequently mention cost-related concerns, such as financial investment, time commitment, and negative emotions like stress, anxiety, and frustration (Osman & Warner, 2020).

There has been debate regarding whether cost should be separated from the remaining value domains within EVT (Barron & Hulleman, 2015; Osman & Warner, 2020). Some researchers argue that, due to its negative nature, cost remains a unique factor influencing a teacher's motivation to participate in a task (e.g., Barron & Hulleman, 2015; Jiang et al., 2018; Osman & Warner, 2020). Researchers supporting the separation of the cost domain from the original construct have proposed an alternate model, the Expectancy-value-cost model (Barron & Hulleman, 2015; Jiang et al., 2018), to emphasise the importance of cost and differentiate it from the traditional Expectancy-Value model.

Eccles and Wigfield (2020) point out that research regarding the separation of the cost domain often considers this domain from a negative perspective, overlooking its potential positive influence on motivation. They propose that all four original domains (attainment, intrinsic, utility, and cost, as proposed by Eccles et al., 1983) contribute to willingness to participate in a task and that cost should not be treated separately. Findings from Part et al.'s (2020) research support Eccles and Wigfield's (2020) argument and the present study adopts the original four-domain structure advocated by Eccles and Wigfield (2020).

Moving beyond individual value domains, this study seeks to capture a comprehensive profile of the value of TPD. Accordingly, critical features of TPD identified in the literature are drawn upon as indicators of the four value domains within the value construct. These features are reviewed and categorised into the four value domains through a series of validation processes. The questionnaire was used to produce a measurement scale, the Value of TPD (VT) scale, which was then defined to represent the latent construct of teachers' perception of the value of a given TPD program. The theoretical basis for the validation process of the VT scale is outlined in Sections 2.5 and 2.6. The features and their alignment with the value domains are further discussed in Chapter 3 of this thesis.

The next section discusses the use of the TPACK framework as the theoretical basis for a scale that examines teachers' perceived improvement in their knowledge after participating in a TPD for ICT integration into teaching.

## **2.4 TPACK Framework**

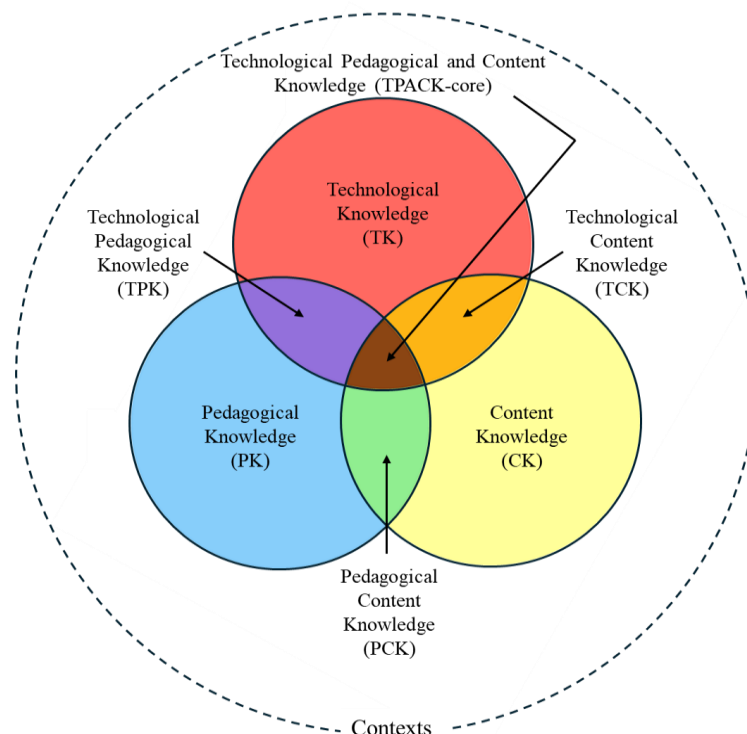
In the late twentieth century, as teacher preparation and certification programs shifted their focus from content knowledge to more pedagogical knowledge, Shulman (1986) argued that the intersection of content and pedagogical knowledge should be given greater importance, introducing the concept of Pedagogical Content Knowledge (PCK). Improving teachers' PCK has become a popular goal within teacher education and school sectors (Hofer & Grandgenett, 2012). Given the impact of ICT on teaching and learning, researchers have argued that teachers must not only understand how to teach and what content to deliver but must also know how to effectively integrate ICT into their teaching practices (Mishra & Koehler, 2003). Mishra and Koehler (2006) expanded Shulman's (1986) framework of PCK and introduced a new framework that incorporates more directly the role of ICT in teaching.

This augmented framework is called the Technological Pedagogical and Content Knowledge (TPACK) framework.

TPACK explains how teachers must adapt their PCK with Technology Knowledge and integrate technology into their teaching (Bajracharya, 2021). The framework comprises three sources of knowledge, namely, Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK), as well as four domains, including Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), The Technological Pedagogical and Content Knowledge (TPACK-core) and context.

**Figure 2.1**

*The TPACK framework (Koehler, 2017)*



### **Technological Knowledge (TK, red circle)**

This domain of knowledge refers to knowledge about various technologies and their applications. Technologies can be low-tech, such as a pencil-and-paper, or high-tech, such as the Internet, the newest digital tools, or software programs (Bajracharya, 2021; Schmidt et al., 2009). Technology is constantly developing and changing. Therefore, its mastery is a life-long process (Kang, 2020; Koehler & Mishra, 2009). The concept of technological knowledge is built on the Fluency of Information of Technology (FITness) proposed by the Committee of Information Technology Literacy of the National Research Council in the United States (Koehler & Mishra, 2009). FITness and TK require a more in-depth understanding of information technology and its mastery of usage in communicating, problem-solving, and operating than does traditional computer literacy (Koehler & Mishra, 2009). Teachers with a better understanding of TK are better able to distinguish the pros and cons of using different information technologies, choosing the proper one to assist their instruction, and developing different strategies to accomplish tasks (Bajracharya, 2021; Kang, 2020; Koehler & Mishra, 2009).

### **Pedagogical Knowledge (PK, blue circle)**

This domain of knowledge refers to teachers' understandings of the action of teaching and learning, including objectives, processes and strategies (Koehler & Mishra, 2009; Mullock, 2006). General pedagogical knowledge comprises a general understanding of students, learning theories, instruction principles, classroom management strategies, educational philosophies (Grossman & Richert, 1988), the knowledge of assessment, lesson planning, and education purposes and backgrounds (König et al., 2011). A teacher with better PK is equipped with a better understanding

of how students form their knowledge, skills and outlook on learning, and also knows how to apply pedagogical theories in the classroom (Koehler & Mishra, 2009).

### **Content Knowledge (CK, yellow circle)**

Content Knowledge is knowledge about the subject matter of what is learned or taught, such as, language arts, foreign language, science, or mathematics. A teacher should master in-depth knowledge fundamentals of the subjects they teach (Hattie, 2012; Kang, 2020; Koehler & Mishra, 2009). A teacher's content knowledge is critically important since knowledge and modes of inquiry differ substantially across disciplines. The consequence of not having an adequate and comprehensive base of content knowledge may be harmful to students' learning (Kang, 2020; Koehler & Mishra, 2009; Pfundt & Duit, 2000).

### **Pedagogical Content Knowledge (PCK, green area)**

PCK is the amalgamation of pedagogical and content knowledge. It emphasises linkages and interactions among CK and PK, such as ideas of teaching content, assessment, curriculum, students' prerequisite knowledge, learning behaviour and reasons why students must learn (Kang, 2020). Shulman (1986) described PCK as including the understanding of student conceptions, misunderstandings and obstacles, as well as strategies and portrayals of instruction. Transformation of subject matter is the core conceptualisation of PCK (Koehler & Mishra, 2009). "This transformation occurs when teachers represent subject content in diverse forms, find alternative ways of looking at the same concept or problem, explore multiple teaching strategies in a particular discipline, and tailor instructional materials to cater to students' prior knowledge, which are essential to effective teaching." (Koehler & Mishra, 2009, p. 64).

In addition to CK and PK, recent research has also included understanding of students, teaching context and curriculum, as well as teaching purposes within the concept of PCK (Evens et al., 2016; Liu, 2013; Meijer et al., 1999; 2002; Wilbur, 2007).

### **Technological Pedagogical Knowledge (TPK, purple area)**

TPK knowledge is the integration of PK and TK. TPK refers to understanding changes in teaching and learning when technologies are applied (Koehler & Mishra, 2009). TPK includes mastering the affordances and constraints of the technological tools adopted in teaching and learning, which are in turn influenced by differences in educational design and methods across subjects (Kang, 2020; Koehler & Mishra, 2009). Cox (2008) investigated perceptions of the definition of TPK using a sample of seven TPACK experts, defining TPK as “a knowledge of the technologies that may be used in a generic pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies and student learning.” (p. 63). Teachers with advanced TPK should know how to appropriately use technologies in their pedagogy to facilitate student learning.

### **Technological Content Knowledge (TCK, orange area)**

TCK refers to the understanding of the appropriateness of technological tools in specific disciplines and the influence and constraints that occur between technologies and content (Koehler & Mishra, 2009; Koehler et al., 2017). Extant research has considered the current condition and measurement of teachers' TCK in different disciplines (e.g. Hidayah et al., 2019; Pradana, 2019) within a country. Few studies examine and compare TCK across countries.

### **Technological Pedagogical and Content Knowledge (TPACK-core, brown area)**

The core domain of the TPACK framework is developed on the basis of three key educational knowledge domains (i.e., technology, pedagogy, and content), and the interactions between these three knowledge domains (Koehler et al., 2017). In order to clearly distinguish between the TPACK framework and the core domain of the framework, the core domain is referred to as TPACK-core in this study and is the intersection of all areas in Figure 1.

TPACK-core refers to an understanding of how appropriate technologies and pedagogical techniques which are effectively adopted in particular teaching content areas (Tondeur et al., 2017). It also includes teacher knowledge of how technology helps students learn and solve problems, as well as the building of new teaching techniques and strengthening of old ones (Cox, 2008; Koehler et al., 2017).

### **Context**

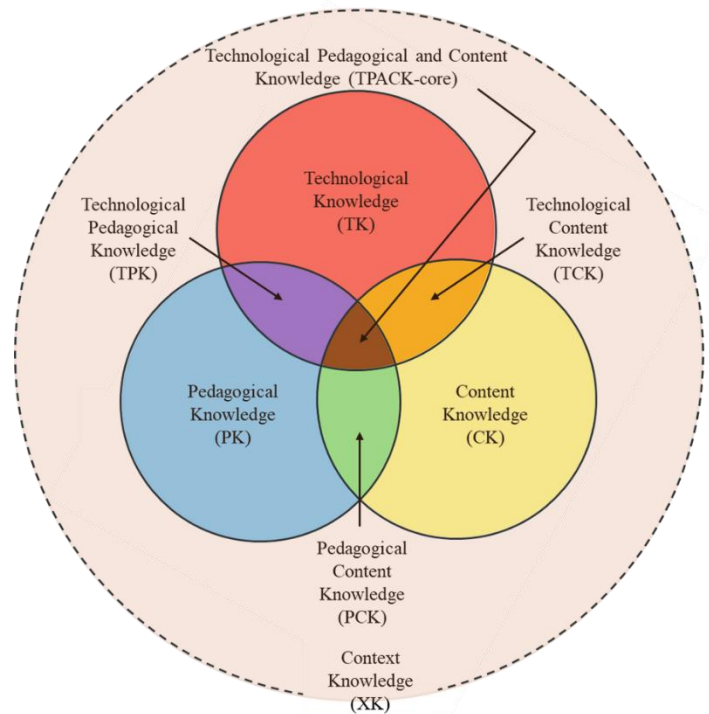
Another vital domain within the TPACK framework is the context in which it is implemented (the dotted circle in Figure 1). The role of context within the framework highlights how the seven domains of knowledge exist within a range of learning and instructing applications (Koehler et al., 2017). Context includes factors influencing TPACK, including learning environments, support from schools and national policies (Brianza et al., 2022; Rosenberg & Koehler, 2015). Context has always interested TPACK researchers. Brianza et al. (2022) summarised four types of understandings of the role of context within the TPACK framework found in the literature: as intrinsically embedded in teaching activities, as a separate domain alongside TK, PK and CK activities, as an integral part of PCK and TPACK-core activities and as an outer construct embedding TPACK activities. Expanding the

fourth type of context, Porras-Hernández and Salinas-Amescua (2013) proposed a further three levels of context: the microlevel, such as the classroom or learning environment; the mesolevel, such as the school environment; and the macrolevel, such as national policies or the technological conditions of a society. Mishra (2019) includes context as Context Knowledge (XK, see Figure 2.2) with the goal of resolving this variable's ambiguous position within the framework. However, perspectives on context as a new knowledge domain remain inconsistent (Brianza et al., 2022; Petko et al., 2025).

While many studies focus on the separate domains of the TPACK framework or even on extending the framework (e.g., Koh et al., 2017; Widowati et al., 2020; Yurdakul et al., 2012) rather than empirically validating the original TPACK-core (Saubern et al., 2020; Schmid et al., 2020), this study explicitly focuses on the TPACK-core domain, rather than the overall TPACK framework).

**Figure 2.2**

*Revised TPACK framework (Mishra, 2019)*



### **2.4.1 Measuring TPACK**

The TPACK framework (Mishra & Koehler, 2006, see Figure 2.1) is one of the most widely applied frameworks in relevant fields (Schmid et al., 2024). A plethora of assessment instruments for assessing teachers' TPACK have been developed. Among these, questionnaire-based instruments are predominant among researchers. Between 2006 and 2023, over 353 published research articles used questionnaires to assess pre-service and in-service teachers' TPACK (Lu, 2024). While some studies implemented self-developed TPACK questionnaires, the majority adapted existing instruments (Scott, 2021).

The 47-item TPACK questionnaire designed by Schmidt et al. (2009) is the most frequently adapted and is regarded as the “grandmother” of TPACK survey instruments (Scott, 2018, p. 36). This questionnaire was originally developed for pre-service teachers in the U.S. but has been widely adopted in research involving in-service and pre-service

teachers across all sectors of education. Despite its extensive adaptation, most studies that have used this questionnaire do not produce evidence from all seven intended domains of the TPACK framework (Scott, 2021). The challenge of distinguishing between the seven domains when developing questionnaires might be due to the compounded nature of the TPACK framework (Koehler et al., 2017), the imprecise definition of each domain (Graham, 2011) and inadequate validation processes in developing the questionnaire. Issues relating to the complexity of the TPACK framework raise concerns regarding evidence of validity.

The compounded nature and the inconsistency of the interpretation of the definition have led to different interpretations of the TPACK framework. Differing interpretations of the domains in the TPACK framework sometimes generate conflict between two integrative and transformative perspectives (Angeli et al., 2016; Schmid et al., 2020). An integrative interpretation regards the core domain of TPACK as a domain derived from and related to the other six domains. Within this interpretation, the improvement of the other six domains will result in a higher level of the core TPACK domain. If a questionnaire is developed from an integrative perspective, it is necessary to distinguish all the seven domains during its development, to precisely determine the extent of teachers' TPACK-core.

On the other hand, the transformative perspective asserts TPACK-core as a unique type of knowledge beyond the other six based domains which cannot be determined by summing the other six domains. The transformative interpretation challenges the statement that TPACK-core can be measured by assessing its domains and instead positions TPACK-core as a practically oriented form of knowledge, embedded within context. Saubern, et al. (2020) reviewed twenty publications on the TPACK framework and argued that research should focus more on the central idea of TPACK framework and its impact on teaching and

learning. They state that questionnaires used to assess TPACK should be evaluated by the extent to which they provide evidence of how effectively and precisely technologies for teaching and learning have been adopted (i.e., the TPACK-core domain).

It is worth noting that although the integrative interpretation appears to be better aligned with the Venn diagram that Mishra and Koehler (2006) used for presenting the TPACK framework, the transformative interpretation aligns better with their description of the TPACK framework (Graham, 2011).

Contextual factors must be carefully considered when developing a TPACK measurement scale. As stated by Mishra and Koehler (2006), the TPACK framework reflects a “context bound” (p. 1032) view of knowledge. Neglecting the context of a TPACK framework risks failing to capture the real-world complexities of ICT integration in education and reduces the validity of measurement (Koehler et al., 2017). Although improving teachers’ TPACK has been widely recognised as a primary goal in the implementation of TPD program for ICT integration into teaching (e.g., Koh et al., 2027; Mahmoudi et al., 2021), TPACK questionnaires used as the evidence of teachers’ overall TPACK after participating in TPD often adopt existing questionnaires from previous research. Such instruments neglect the context of TPD intervention in their questions.

For instance, Kang’s (2020) study aims to investigate Chinese teachers’ TPACK after participating in a TPD program that involved the incorporation of Chinese language teaching and ICT. The following question, which was one of the TPACK-core questions did not take into account the Chinese context of the program: I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g., blogs, WebQuests).

Misalignment between questionnaire and context undermines the validity of resulting evidence (Messick, 1989). In line with this concern, the TPACK-core measurement scale developed in this study explicitly incorporates the context of teachers' participation in the TPD program for ICT integration into teaching, referred to as the Improvement of TPACK-core via TPD Experience (ITTE) scale.

Furthermore, most of the questionnaires that have been used to assess teachers' TPACK-core have been analysed using Classical Test Theory, with their results have been interpreted according to this theory. However, Classical Test Theory is a theoretical framework in educational measurement and psychometrics used to understand and evaluate the reliability and validity of test scores (Bond et al., 2020; Finch & French, 2018). Due to its limitations, Classical Test Theory fails to satisfy the requirements of measurement: linearity, additivity and invariance (Bond et al., 2020, p.273). Hence, it is not regarded as a measurement theory (Bond et al., 2020). A theoretical measurement framework, Rasch Measurement Theory, is selected as the theoretical basis for scale development in the present study.

## **2.5 Rasch Measurement Theory**

Originally formulated by George Rasch in 1960, Rasch theory specifically focuses on developing measures of latent traits from observations typically manifested as test items or questions. Rasch Measurement Theory has been adopted in this thesis because it is a measurement theory that can be used to govern the construction of assessment instruments with the same properties as measurement devices in the physical sciences.

The Rasch model, which evolves from and is an operationalisation of Rasch Theory, maps constructs (like the two identified in the research questions of this study: "teachers'

perception of the value of TPD” and “teachers’ perceived improvement in TPACK-core through participation in the TPD”) onto linear continua, which denote increasing amounts of a given construct and are calibrated with equal units. These linear continua are referred to as measurement scales in this thesis.

In his work in the 1920’s, Thurstone (1929) was meticulous in describing the theoretical conditions (requirements) for valid measurement. Validity evidence obtained from an assessment instrument used to produce a measurement scale requires that the data have evidence of independence, unidimensionality, equality of item discrimination, invariance of parameter estimation, and no guessing effect (Andrich & Marais, 2019; Rasch, 1960; Tognolini, 1989; Wind & Hua, 2021). These requirements are described in detail in the following subsections.

### **2.5.1 Local Independence**

The responses to an item (question, statement or stimulus) should not impact or inform/influence responses to other items. Violation of this requirement results in dependencies between items, which will decrease the validity of the stochastic outcomes of the Rasch model.

For example, if a mathematics test sheet is designed to test on algebra, a student’s response to one question should not be informed by the response to the other questions. However, if the questions are designed to be interrelated, such as in a question set, further examinations are required to examine whether the questions demonstrate local dependence and to determine how this dependency affects the meaning of the test results.

### **2.5.2 Unidimensionality**

Unidimensionality requires that all items assess the same single latent variable or construct. Application of the Rasch model provides an indication of the unidimensionality of the collection of items used to assess a construct. For example, in a Year 7 algebra test, all questions should assess the understanding of algebra in that particular year of students. If some questions require a comprehensive reading skill to interpret the meaning of the questions, then the test may assess more than one underlying construct, such as reading skills and algebraic understandings, which would violate the requirement of unidimensionality.

### **2.5.3 Equality of Item Discrimination**

The parameter of equality requires each item either contributes equally to the overall measurement of a latent trait or construct, or else has the same capacity to discriminate between individuals who possess more or less of the construct. For example, if a set of questions designed to assess students' algebraic understanding, all questions should be equally effective at recognising between students with higher or lower algebra understanding to meet this requirement.

### **2.5.4 Invariance of Parameter Estimation**

A person's (student or teacher's) measure of a construct, which represents their location on the measurement scale, should remain the same even if they were given a different set of items that had been calibrated to fit the Rasch model. Likewise, an item's location on the measurement scale (which reflects the inherent challenge posed by an item) should remain constant across populations being tested. For example, if two sets of questions are derived from the same measurement instrument measuring Year 7 students' algebraic

understanding, students' results from both sets should be comparable and reflect the same underlying construct (i.e. Year 7 students' algebraic understanding).

### **2.5.5 No Guessing Parameter**

A person's (student or teacher's) location on the measurement scale (the measurement capturing how much of the construct a person has displayed) and an item's location on the same measurement scale (the item's difficulty) are the only two parameters that determine the outcome of the interaction between person and item. The occurrence of random guessing, which contains no information about the person's location on the measurement scale, is not an acceptable property of a measurement system (Andrich & Marais, 2019). For example, if a measurement instrument is designed to measure students' algebraic understanding, the students' probability of answering the questions correctly should only depend on the students' understanding of algebra and the difficulty of the questions in the instrument.

The initial Rasch model focused on simple dichotomous responses to test items (often referred to as the Simple Logistic Model of Rasch) to build a measurement scale to represent a construct (Rasch, 1960, 1980). With increasing scholarly engagement, the model has been extended to include assessment instruments comprised of items that are polytomously scored (e.g., Andrich, 1978; Wright & Masters, 1982). Specifically, Andrich (1978) proposes a type of Rasch model especially suitable for the Likert rating items, the Rating Scale Model (RSM).

Likert rating scales are frequently used in educational research to support numerous empirical claims (Jebb et al., 2021; Joshi et al., 2015; Yamashita, 2022). Scoring Likert rating items is typically numerically ordered via categories (e.g., strongly disagree scored 1; neutral scored 3; strongly agree scored 5). A respondent's score on each item is aggregated into a total score, which is then used to produce a measurement location within the construct.

Classical Test Theory (CTT) operates under the assumption that the distance between scoring categories is the same. However, in practice, this assumption does not necessarily hold true, as the persons responding to the questionnaire items might have different interpretations of the meaning of each category and item description. In addition, the assumed number of categories and the actual number of categories might be different if none of the respondents choose a particular category (Bishop & Herron, 2015). This disparity can create validity concerns when analysing output from the data analysis.

The RSM effectively addresses these challenges (Andrich, 2010; Yamashita, 2022) since the distance between each category can be measured and visualised in the RSM by estimating thresholds based on the probability that respondents will select a particular response category in preference to the adjacent categories (Choi, 2019; Yamashita, 2022). When the distances between response categories are equal, scores can be regarded as interval data. Conversely, when distances between categories are unequal, scores should be regarded as ordinal data. The RSM can distinguish the appropriateness of items for respondents, since the items and teacher locations are presented together on the same scale in the RSM.

In conclusion, employing Rasch Theory, and particularly RSM, can significantly enhance the information needed for validating and interpreting a measurement scale. Employing these theories helps justify score interpretations and also helps in examining item and test appropriateness across diverse respondents within specific contexts, while also enabling educational researchers to perform similar statistical analyses in future research. For this reason, this study applies RSM to produce data that can be used to strengthen the claim regarding the validity and reliability of measurement scales that reflect data obtained from Likert style questionnaires.

## **2.6 Argument-based Validity Evidence for Questionnaire Scales**

To provide a coherent theoretical basis for the validation of its scales, the present study adopts Kane's (1992, 2006, 2021) argument-based validation framework. Kane (2021) defined validity as "the extent to which the proposed interpretations and uses of test scores are justified" (p. 198), emphasising that validity is established through accumulating evidence to support inferential phases. From this perspective, when developing a measurement scale, the scale developer needs to explicitly articulate and conceptually analyse the intended interpretations/arguments and uses of the results from an analysis of the evidence used to develop the measurement scale. These collected data are then used to test the extent to which the claims from the uses align with the explanations and interpretations and are supported by the data.

Within Kane's framework, validity for the use of the measurement framework and the resulting scale is developed across four inferential phases: scoring, generalisation, extrapolation and implication (Cook et al., 2015; Kane, 2006). These four phases link observed responses to the intended use and consequences of measurement outcomes. It is critical to have sufficient and favourable evidence to support key assumptions within these inferences. If validity evidence is not strong or not favourable, the measurement tool used to construct the measurement scale might have to be revised (Cook et al., 2015; Kane, 2006). In the present study, this inferential structure is applied to frame the validation logic for the VT and ITTE scales, consistent with the fundamental measurement requirement articulated by Thurstone (1920) and later formalised in Rasch Measurement Theory (Andrich & Marais, 2019; Rasch, 1960; Tognolini, 1989; Wind & Hua, 2021). The specific sources of validity evidence corresponding with Kane's (2006) four phases of his framework are detailed in Chapter 4, following a review of the literature in Chapter 3.

## 2.7 Chapter Summary

This chapter has established the theoretical foundations guiding the development of two assessment instruments that used to construct two measurement scales: the VT scale and ITTE scale. Five theoretical perspectives were introduced. First, a measurement-scale development framework was introduced. Second, EVT was presented. The value domains that shape teachers' motivations and experiences when engaging in TPD programs were delineated to provide a theoretical basis for the VT scale. Third, the TPACK framework was described, and explicit definitions given for each domain. The rationale for focusing on the core domain (i.e., TPACK-core) was also articulated and the need for developing a TPACK measurement for context of TPD (i.e., ITTE scale) demonstrated.

The chapter also discussed Rasch measurement theory (Rasch, 1960/1980) and Kane's (2006) argument-based validation framework, which together inform the evidence collection methods and validation process for the study's proposed scales. The next chapter provides a review of the literature, examining the role of TPD for ICT integration in education, the relationships between the theoretical frameworks outlined above and the success of an TPD program for ICT integration into teaching. The conceptualisation of students' learning achievement and relevant educational policies are also presented.

## **Chapter 3: Literature Review**

### **3.1 Introduction**

This chapter presents a review of the literature, serving as a conceptual basis for the study. It begins by discussing the role of Information and Communication Technology (ICT) in education and the growing need to implement TPD. The definition of Teacher Professional Development (TPD), as situated within the context of this study, is then clarified. This is followed by an identification of critical features of successful TPD, with a special focus on successful TPD programs which have integrated ICT into teaching.

Building on the discussion of Technological Pedagogical and Content Knowledge (TPACK) given in Chapter 2, this chapter then reviews how previous studies have positioned the TPACK framework within TPD research to support and rationalise the need for building a new measurement scale (i.e. the Improvement of TPACK-core via TPD Experience scale, ITTE scale).

Following that, this chapter examines students' learning achievement as additional evidence of the success of a TPD program, with a particular focus on the use of results from Taiwan's national standardised achievement test as evidence of students' learning achievement. It then outlines three major educational policies currently implemented in Taiwan, each of which has a significant influence on the study aims, as well as the selection of the constructs developed, and the evidence collected. The chapter concludes with discussion of the Rasch model and its application in Likert-style studies and thus acts as a bridge with the subsequent methodology chapter.

### 3.2 The Role of ICT in Education

ICT, or Information and Communication Technology, is widely used in teaching and learning in all educational sectors globally (Sabiri, 2020; Selinger, 2001). According to the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2009), the definition of ICT is “A diverse set of technological tools and resources used to transmit, store, create, share or exchange information” (p. 120). ICT comprises all the virtual and physical technological devices at schools that support teaching and learning, such as software, hardware, tablets, interactive white boards and media (Al-Rahmi et al., 2020). In an educational context, Ratheeswari (2018) defined ICT as “the computer and internet connections used to handle and communicate information for learning purpose” (p. 45).

There are other terms that are like ICT and sometimes might be used synonymously: terms such as Digital Technology (DT) and Information Technology (IT). These two types of technologies are a subset of ICT (International College of Management ICMS, 2024; James, 2011). IT focuses on the computer, as well as systems and technologies related to the computer (ICMS, 2024), whereas the concept of DT refers to technology that applies electrical signals to encode data and share information (Johnstone et al., 2022).

According to the 2017 *Qingdao Statement* released by UNESCO, big data and artificial intelligence (AI) are recognised as two recent ICT breakthroughs with the potential to transform traditional educational systems (UNESCO, 2017). Therefore, in this study, the term ICT refers to all the virtual and physical technological tools that teachers use in their classrooms to support teaching. This includes IT, such as computers and projectors, DT, such as tablets and digital whiteboards, as well as other educational software that employs big data and AI technology.

ICT is constantly evolving with the development of new and enhanced technologies. For example, ChatGPT, a type of generic AI, has raised the international profile of ICT worldwide since its launch in early 2022. Following this trend, the focus of ICT enhancement in education across most countries has shifted from traditional technology to the integration of AI into classrooms and related issues. Taiwan launched the *AI Taiwan Action Plan 2.0* in 2023, which includes a project aimed at promoting AI integration into teaching. This action plan seeks to develop teachers' competencies in using AI to enhance instruction while improving students' understanding of generative AI so that they become informed developers and users of such technologies moving forward. In another example, the New South Wales government in Australia developed a new generative AI tool, NSWeduChat in 2024 to assist the teachers and guide students' learning (NSW government, 2025).

There is a general belief that the successful integration of ICT in schools can effectively improve teaching quality and students' learning achievement (Dinh, 2015; Sabiri, 2021). It is especially important for teachers to learn how to use ICT themselves in order to assist teaching and teach students how to incorporate ICT into their learning across different disciplines. However, there is a body of research that reveals that teachers' lack of relevant knowledge and skills with ICT has inhibited, to some extent, the integration of ICT into the classroom (Khan, 2014; Lehiste, 2015). In response to this issue, various TPD for ICT integration into teaching have been developed and conducted. For example, TPD developed by Bustamante (2020), Chaipidech, et al. (2021), and Koh et al. (2016) aim to strengthen teachers' overall Technological Pedagogical and Content Knowledge (TPACK) through targeted TPD workshops for ICT integration into teaching. As outlined in Chapter 1, Section 1.3, the Taiwanese government launched a nationwide TPD program in recent years aimed at

improving primary and secondary school teachers' knowledge and skills in integrating ICT into their classrooms.

The next section discusses the definition of TPD and the features that have been found to be critical to the successful implementation of TPD.

### **3.3 TPD for ICT Integration into Education**

This section begins by defining TPD in the context of this study. Then, drawing from both empirical and theoretical perspectives, it identifies critical features of successful TPD, with a particular focus on TPD programs aimed at integrating ICT into teaching. Finally, it attempts to capture teachers' perceptions and motivations toward participating in TPD programs by conceptually mapping critical features identified in the previous section onto the four value domains of the EVT: attainment, intrinsic, utility, and cost. These relationships form the basis for the present study's VT construct.

#### **3.3.1 The Definition of TPD**

According to the Oxford Dictionary, the term "Professional Development" was first found in Tuckerman's (1857) book, where it was applied to describe the development of the drama industry in England (p. 224). Currently, the term refers to the acquisition of new skills to enhance one's career through ongoing education and training (Parsons, 2022).

There is no single definition of TPD. The OECD (2009) describes it as "activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher" (p. 34). Borg (2015) regards TPD as the process of an individual's growth, improvement and extended actions in knowledge, techniques, and emotion in the workplace. This latter perspective emphasises the personal role of teachers related to the use of TPD and includes their personal characteristics, demands, participation, competencies, and prior knowledge (Borg, 2015; Canaran & Mirici, 2019).

Some researchers have argued that TPD should also focus on student learning and school output. They define TPD as the processes or activities arranged to improve teachers' professional knowledge, skills, beliefs, classroom practices, students' learning achievement, and school outputs (Coldwell, 2017; Darling-Hammond et al., 2017; Desimone, 2009; Sancar et al., 2021; van Veen et al., 2011). The definition of TPD stated on the website of Cambridge International Education aligns with this perspective since it links enhanced teacher knowledge and skills to student learning improvement.

Teacher Professional Development involves a continuous process of reflection, learning and action to further a teacher's knowledge and skills, leading to enhanced teaching practices that positively impact on students' learning (Angus-Cole, 2021, p. 1).

The Ministry of Education in Taiwan (MOET) (2012) provides a specific definition of TPD.

Through independent, cooperative, formal, or informal learning, or training activities and through the process of self-reflection, teachers enhance their professional knowledge, skills, and image. Teacher professional development aims to improve the quality of school education and reach the target of school education effectively. (p. 127).

The definition of TPD by MOET (2012) aligns more closely with the definitions provided by Coldwell (2017), Darling-Hammond et al. (2017), Desimone (2009), Sancar et al. (2021), van Veen et al. (2011), and Angus-Cole (2021), all of which recognise the professional growth of the individual and acknowledge the influence of TPD on the improvement of school outcomes and student learning. Given that this study's focus is

Taiwanese TPD, TPD and its outcomes are here conceptualised through the lens of MOET (2012) and other studies with similar perspectives.

Richter et al. (2011) classified TPD into two forms: formal and informal. Formal TPD refers to structured and curriculum-based learning environments that typically occur within institutional settings, such as mandated workshops or staff development sessions. The focus of this form of TPD is typically aligned with a traditional perspective (Garent et al., 2001) which emphasises enhancing teachers' knowledge and skills to meet the needs of schools and governments. This form of TPD tends to provide clear instructions regarding program content and the purposes of program activities (Richter et al., 2011).

Formal TPD is commonly used in national-level and state-level TPD programs (Richter et al., 2011). For example, the Taiwanese government mandates participation in structured workshops on ICT integration in alignment with its 12-Year Basic Education Curriculum Guidelines. Every primary school teacher was required to complete at least six hours of workshops within a TPD program that focuses on ICT integration into classrooms before 2024 (Kuo et al., 2023). Similarly, in the state of New South Wales (NSW), Australia, all teachers are required to complete 100 hours of TPD accredited by the NSW government every five years (NSW Government, 2023). In contrast, informal TPD does not follow a specified curriculum or occur in a certain formal setting. Common examples of informal TPD activities include mentoring, informal communication with colleagues and parents, and teacher study groups (Desimone, 2009). Regardless of the different forms of TPD, it is the features of TPD that determine the success of the programs (Desimone, 2002; Nawab & Bissaker, 2021).

With respect to TPD for ICT integration into teaching, the U.S. Department of Education defines it as the various learning activities for teachers and other staff in schools to

be equipped with the knowledge and skills to effectively use the ICT provided and integrate the ICT into teaching, learning and administrative works (U.S. Department of Education, National Centre for Education Statistic, 2002). In general, most of the TPD for ICT integration into teaching activities designed across states in the U.S. are formal in nature, as the integration of ICT into education requires sufficient technological infrastructures, and structured curriculum-based training led by experts or technology specialists (Lawless & Pellegrino, 2007). The national-level TPD for ICT integration into teaching examined in the present study would also be classified as formal TPD, because it is mandatory, follows a specific curriculum and involves delivery of content by relevant experts.

The primary goal of TPD is to support teachers' individual growth in terms of skills, knowledge and expertise, or enhancing students' learning and school outputs (Angus-Cole, 2021; OECD, 2009; MOET, 2012). The next section explores specific features of successful TPD.

### **3.3.2 Critical Features of Successful TPD**

TPD is often regarded as complex and diverse due to high variability of contexts and content (Kennedy, 2016b). Over the past two decades, researchers have investigated critical features of successful TPD to capture this complexity and examine what works in TPD (e.g. Bates & Morgan, 2018; Bayar, 2014; Darling-Hammond et al., 2017; Desimone et al., 2002; Richter et al., 2025; de Vries et al., 2013; Zeggelaar et al., 2017, 2022). A summary of features identified in these studies with supporting references is presented in Appendix A.

A substantial proportion of the studies cited here have sought to identify the features of successful TPD using literature reviews of empirical studies on TPD implementation (Asterhan & Lefstein, 2024). These reviews synthesise evidence demonstrating the effectiveness of TPD as it pertains to teachers' knowledge and pedagogy in terms of

improvement in student learning outcomes. Among the critical features consistently highlighted as indicative of successful TPD are: (1) focus on specific content, knowledge and skills; (2) recognition of the experiences and prior knowledge of teachers, (3) provision of feedback, assessment and reflection, (4) active learning, (5) provision of proper instructors, (6) collaborative learning, (7) follow-up supports, and (8) sustained duration (Bates & Morgan, 2018; Darling-Hammond et al., 2017; Desimone et al., 2002; Dunst et al., 2015; Zeggelaar et al., 2017, 2022; Zhang et al., 2024). These features can be regarded as implementation-oriented features because they are based on empirical evidence that links with measurable improvements in the knowledge and pedagogy of teachers with the ultimate goal of improving student learning. Although implementation-oriented features demonstrate an effective TPD in general, they do not guarantee that teachers will choose to engage with or gain from participation in such programs.

A parallel body of research focuses on identifying features of TPD that motivate teachers to participate in and remain engaged with TPD activities (e.g., Bayar, 2014; Chang et al., 2022; Karabenick & Conley, 2011; Kao et al., 2011; Richter et al., 2019; Richter et al., 2025; Sokel, 2019). These studies have found that teachers are more likely to engage in TPD when they believe that it:

- is capable of advancing their careers;
- offers them novel content;
- provides interaction opportunities with other teachers;
- fits with school and personal goals and demands; and,
- is perceived as time efficient.

In contrast to implementation-oriented features, which emphasise measurable improvements in teachers' knowledge and skills in teaching, as well as student learning

outcomes, these features specifically address the psychological and contextual factors affecting teachers' willingness to engage in and sustain participation in TPD activities and are therefore referred to as motivation-oriented features.

It is vital to consider both the implementation-oriented and motivation-oriented features, when planning and evaluating the success of a TPD program. TPD designed with only implementation-oriented features may neglect the factors that influence teacher engagement and attendance, which could lower expected positive outcomes (Dennis & Hemmings, 2019; Didion et al., 2019; Fishman et al., 2003; Lee, 2015). For example, Thomson and Kaufmann's (2013) study revealed motivation-oriented features caused teachers to drop out of a TPD program when teachers perceived limited applicability of TPD content to teaching practice.

As the present study is conducted through the lens of a TPD program for ICT integration into teaching implemented in Taiwan, studies that have implicitly addressed features perceived important to TPD for ICT integration into teaching (e.g. Alemdag et al., 2020; Diamah et al., 2022; Getenet, 2020; Herranen et al., 2021; Hu et al., 2021; Kimav & Kürüm-Yapicioglu, 2021; Lin, 2022) were reviewed along with studies addressing implementation-oriented and motivation-oriented features for TPD. Drawing from a review of studies published between 2009 and 2024 that investigated successful TPD in both general TPD program and TPD programs specific for ICT integration into teaching contexts, along with studies addressing implementation-oriented and motivation-oriented features for TPD.

Studies were sourced from two English-language dominated databases: ProQuest and Scopus, as well as from educational research journals in Taiwan, including Journal of Taiwan Education Studies, Taiwan Educational Review Monthly and Journal of Research in

Education Sciences. The inclusion of Taiwanese journals is necessary given the context of the study in Taiwan, where most educational studies are written in Chinese and cannot be accessed through English-language dominated research databases such as ProQuest and Scopus (Bahji et al., 2023). Features identified in two or more empirical studies that addressed the relationship between the success of TPD and the two key perspectives of TPD design—implementation-oriented and motivation-oriented, were identified and noted.

At the end of this process, seventeen features, considered critical to the increasing the value of TPD, were identified through analysis of previous literature. The seventeen critical features of successful TPD are that they:

- (1) focus on specific content, knowledge and skills;
- (2) recognise the experience and prior knowledge of teachers;
- (3) provide feedback, assessment and reflection;
- (4) provide career advancement;
- (5) target active learning;
- (6) provide well-qualified instructors;
- (7) encourage collaborative learning;
- (8) target novelty;
- (9) provide opportunities for hands-on learning;
- (10) help with students' development;
- (11) align with current demands and visions;
- (12) provide convincing exemplary material;
- (13) provide follow-up support;
- (14) provide content, ideas that are relatively easy to implement in class;
- (15) make teaching materials introduced in the sessions easy to access;

(16) provide teaching materials; and,

(17) are conducted over a sustained period.

Each of these features relating to successful TPD are now addressed individually.

### **(1) Focuses on specific content, knowledge and skills**

A focus on content and knowledge attracts teachers to participate in TPD (Karabenick & Conley, 2011). This feature is, consequently, considered one of the most influential in determining the success of TPD (Darling-Hammond et al., 2017; Desimone, 2009). Addressing what is taught in TPD enables teachers to connect theoretical concepts with real-life classroom practice (Bates & Morgan, 2018) and is positively associated with improvements in relevant teacher knowledge and instructional practices (Desimone, 2009). The combination of focusing subject content, pedagogical knowledge and specific skills for implementing subject matter can further enhance TPD impact on both teaching quality and student learning outcomes (Bates & Morgan, 2018). This feature is foundational and essential for strengthening the engagements and overall success of TPD, as it maximises the likelihood that the focus of TPD is applicable and responsive to classroom realities.

### **(2) Recognises the experience and prior knowledge of teachers**

Recognising participating teachers' knowledge and teaching experience is important before planning and implementing a TPD program since adult learners' prior experience and knowledge influences ways of learning and the development of a professional identity (NSW Education Standards Authority, 2021). Similarly, Desimone (2009) emphasises that effective TPD should align with teachers' knowledge and beliefs. Likewise, Lindvall (2017) found that TPD programs were

more effective in enhancing students' learning achievement when participating teachers were already familiar with the program content.

Similar findings were identified in Covay Minor et al.'s (2016) study, which revealed that mathematics teachers' learning outcomes from TPD were significantly influenced by their prior knowledge and teaching experience. In their study, a TPD workshop focusing on the use of ICT in teaching geometry was conducted. It was found that teachers with stronger knowledge and more extensive teaching experience in geometry were more successful in applying what they learned than those with less prior knowledge and experience.

### **(3) Provides feedback, assessment and reflection**

Another feature of successful TPD is the provision of feedback, assessment and opportunities for reflection (Bates & Morgan, 2018; Bayar, 2014; Darling-Hammond et al., 2017; de Vries et al., 2013; Krille, 2020). Constructive feedback, combined with opportunities for teachers to assess their progress and reflect on their practice, is crucial in fostering teachers' professional knowledge (Pitsoe & Maila, 2013; Schön, 1987).

Feedback is also a means of supporting teachers in progressing deliberately toward visions of practice informed by experts throughout the course of a given TPD (de Vries et al., 2013). Notably, these activities are often facilitated through coaching sessions or expert-led activities (Bates & Morgan, 2018; de Vries et al., 2013), which correspond the expert-led structure of the national-level TPD program for ICT integration into teaching examined in the present study.

#### **(4) Provides career advancement**

Teaching is often considered a long-term career. Many teachers prefer participating in TPD programs that have the potential to advance their careers in order to maintain their current roles or pursue higher positions (Chang et al., 2022; Kao et al., 2011; Karabenick & Conley, 2011). This feature seems to be particularly valued by teachers in Taiwan. For instance, Chang et al. (2022) found that work-related incentives were the most significant motivator for special education teachers in Taiwan to engage in TPD programs. Similarly, Kao et al. (2011) revealed that the potential for occupational promotion following participation in a voluntary TPD program targeted ICT integration into teaching was one of the main reasons why many Taiwanese primary school teachers decided to join. These insights highlight the importance of linking career advancement opportunities to TPD, as doing so serves as a strong motivator for teacher engagement and sustained participation in a TPD program.

#### **(5) Targets active learning**

In contrast to traditional lecture-based approaches, TPD activities which provide active learning opportunities allow participating teachers to analyse, implement and reflect on what they have learnt (Darling-Hammon et al., 2017). In the context of TPD for ICT integration into teaching, Alemdag et al. (2020) found that ensuring active involvement during workshop activities is critical to improving teachers' TPACK-core. The more engaged teachers are in TPD activities, the more likely they are to internalise and transfer new knowledge into their classroom practices (see Bates & Morgan, 2018; Bayar, 2014; Darling-Hammond et al., 2017; Desimone, 2009). It is also worth noting that active learning is often considered an

“umbrella” feature that encompasses several other critical features of TPD, such as collaboration, feedback, reflection, and instructional strategies (Darling-Hammond et al., 2017).

Active learning also provides a foundational structure through which multiple features of TPD interact, thereby enhancing the successful implementation of the TPD in classroom practice.

#### **(6) Provides well-qualified instructors**

The quality of instructors in workshops is foundational to the success of a TPD program (Bates & Morgan, 2018; Bayar, 2014). Instructors play a central role in guiding the flow of activities and facilitating intended learning experiences. Poorly prepared or ineffective instructors may fail to effectively deliver on the essential TPD features outlined above, such as targeting active learning, focusing on specific content, knowledge and skill, or providing feedback, assessment and reflection (Bates & Morgan, 2018). Teachers who encounter ill-suited or unqualified TPD instructors may feel frustrated and become disengaged, potentially diminishing their interest in participating in future TPD programs (Bayar, 2014).

Providing well-qualified instructors is critical to the success of TPD as it not only influences the delivery of other critical features of TPD but directly impacts teachers’ motivation and attendance in future relevant TPD programs.

#### **(7) Encourages collaborative learning**

Collaborative learning has been consistently identified as a critical feature of successful TPD (Bates & Morgan, 2018; Bustamante, 2020; Darling-Hammond et al., 2017; de Vries et al., 2013; Lu, 2021; Naylor & Gibbs, 2018; Njiku et al., 2021). Collaboration opportunities in TPD can take place in various formats, such as one-on-

one interactions, small-group discussions and schoolwide activities (Darling-Hammond et al., 2017; Vygotsky, 1978). All of these formats can help individual teachers reduce stress levels, improve confidence and build collective knowledge; extending the impact of TPD beyond individual classrooms (Bates & Morgan, 2018; Darling-Hammond et al., 2017; Vygotsky, 1978). Bates & Morgan (2018) further stress that collaboration during TPD should be steeped in trusting relationships to maximise its positive impact on teachers.

Conversely, insufficient time and shallow engagement in TPD might decrease positive impacts of collaborative learning on teachers (Hargreaves & Fullan, 2012). This suggests that teachers require adequate time and a collegial environment to build trusting relationships, understand each other's teaching background and engage in joint inquiry to promote real professional learning (Bates & Morgan, 2018; Hargreaves & Fullan, 2012).

#### **(8) Targets novelty**

Teachers often look forward to receiving new knowledge and teaching approaches when attending a TPD (Cordingley et al., 2015; Richter et al., 2025). Novel information and experiences allow teachers to critically reflect on their existing perceptions and teaching approaches (Cordingley et al., 2015). The meta-review research conducted by Cordingley et al. (2015) found that TPD is most effective when it introduces new theories or unfamiliar teaching approaches. Similarly, Naylor and Gibbs (2018) introduced new ICT, such as iPads and eBooks, during a TPD activity designed for pre-service teachers in Norway and the United Kingdom. They discovered that this novel addition to their TPD significantly changed teachers' perceptions of teaching and learning. It is worth noting that both Cordingley et al.'s

(2015) study and Naylor and Gibbs (2018)'s study have stressed that these transformations did not solely result from the novelty feature itself, but it's in conjunction with other features of TPD, such as collaborative learning, hands-on learning and convincing teaching exemplars.

These findings highlight how targeting novelty when designing TPD can serve as a powerful driver for teacher reflection and pedagogical change. The transformative potential of novelty is most fully optimised when integrated with other TPD critical features, a fact which further emphasises the need for holistic and well-structured TPD design.

#### **(9) Provides opportunities for hands-on learning**

Integrating hands-on learning within TPD for ICT integration into teaching not only increases teacher engagement but also supports the effective application of new knowledge in classroom contexts (Chen, 2020; Kimav & Kürüm-Yapıcıoğlu, 2021). Teachers often value the chance to conduct hands-on activities during a TPD program (Chen, 2020; Huang, 2021; Kimav & Kürüm-Yapıcıoğlu., 2021; Sáez-López et al., 2020). Kimav and Kürüm-Yapıcıoğlu (2021) conducted a ten-week blended TPD workshop for ICT integration into teaching for English teachers in Turkey. Participating teachers regarded the workshop's hands-on learning activities as the most important parts of the TPD program. Similar conclusions were reached in Huang's (2021) research in Taiwan, where the teachers she interviewed expressed a strong demand for hands-on activities for the upcoming nationwide TPD program.

It is worth noting that multiple researchers suggest that the impact of hands-on learning activities is more significant when it is combined with a collaborative and

active learning environment (e.g. Chen, 2020, Kimav & Kürüm-Yapıcıoğlu, 2021). On the other hand, workshops provided by a program with content which is too theoretical risk lower teacher engagement and failure in developing participating teacher knowledge (Villegas-Reimers & Reimers, 2000).

The positive impact of hands-on learning can be further reinforced when situated within other features of TPD.

#### **(10) Helps with students' development**

It is widely recognised that the ultimate goals of TPD is to advance students' knowledge on specific learning content or to cultivate a more holistic and adaptive mindset (Desimone, 2009; Gozukucuk & Gunbas, 2022; Mumcu et al., 2022; Naylor & Gibbs, 2018). Teachers' primary intention for participating in TPD lies in the prospect of improving their students' learning achievement. Evidence from a study of 644 Turkish STEM teachers conducted by Mumcu et al. (2022) demonstrates that teachers considered the investment of time in TPD worthwhile when they observed growth in their students' acquisition of 21st century skills. Accordingly, it is important for a TPD to explicitly demonstrate how new skills acquired by teachers translate into improvements in students' learning (Sáez-López et al., 2020).

Despite this critical linkage, prior studies often neglect to include students' development as a defining feature of TPD (see Bates & Morgan, 2018; Bayar, 2014; Darling-Hammond et al., 2017; Desimone, 2009; Dunst et al., 2015; Zeggelaar et al., 2017, 2022; Zhang et al., 2024). This oversight may partly explain the limited success of subsequent TPD activities in improving students' learning achievement (Asterhan

& Lefstein, 2024). These findings highlight the need for TPD programs to make explicit the connection between teacher learning and student development.

#### **(11) Aligns with current demands and visions**

TPD programs that align with teachers' needs reinforce the engagements of teachers. In addition to address teachers' personal needs, meaningful TPD programs for ICT integration into teaching must be carefully designed to meet the demands and visions at school or national levels, ensuring that these programs remain contextually relevant and sustainable. Successful TPD should address specific instructional challenges that teachers have encountered in their schools and classrooms (Alemdag et al., 2020; Bayer, 2014; Cirocki & Farrell, 2019). This alignment seems to be strongly emphasised by teachers. In Bayer's (2014) qualitative study, primary school teachers in Turkey consistently complained about the failure of TPD activities in reflecting their day-to-day instructional needs. The participating teachers in Bayer's (2014) study expressed that TPD is most effective when it fits with existing needs of a given school. TPD is more meaningful when it responds to school-specific issues, such as the implementation of new school policies and low student engagement (Bayer, 2014). Cirocki and Farrell (2019) similarly observed that many Indonesian EFL teachers were less engaged in a TPD when it was designed top-down and disconnected from their actual classroom challenges.

Alemdag et al. (2020) also highlight the significance of designing TPD programs that relate to both teachers' current needs and schools' curriculum framework and educational goals. Their study found that towards the goal of ICT integration into education, TPD must be structured based on the curriculum goals of

21st century learning to support teachers in applying new classroom teaching strategies such as digital learning (Alemdag et al., 2020).

**(12) Provides convincing exemplary material**

The inclusion of authentic, high-quality, context-relevant exemplars and models in TPD can help teachers visualise and emulate what they have learnt from TPD (Buchner & Hofmann, 2022; Getenet, 2020; Lin, 2022). The inclusion of exemplary material is especially important under the context of TPD for ICT integration into teaching. Getenet (2020) stresses that well-designed exemplary materials, such as sample lessons or contextual ICT integration scenarios, can help teachers recognise the feasibility of integrating ICT into actual mathematics teaching. In another example, Buchner and Hofmann (2022) introduced a Tell-Show-Enact-Do model in a TPD program to incorporate virtual reality into teaching. The “Show” and “Do” phases involve providing authentic examples, such as pre-designed scenarios using virtual reality in a classroom setting. They found that the incorporation of such scenarios significantly enhanced teachers’ confidence in applying ICT learned during the TPD program. Providing high-quality, effective and convincing exemplary material stands to not only improve teachers’ attitude toward integrating ICT into teaching but also may help them to explore its actual application (Lin, 2022).

**(13) Provides follow-up support**

Systematic and ongoing assistance that supports teachers in applying knowledge and skills acquired through TPD in real-world classrooms is essential. Support determines the sustainability of educational improvement, particularly in the context of ICT applications (Lu, 2021; Ranna et al., 2022). Rana et al (2022) conducted a TPD program for ICT integration in rural Nepalese schools. They found that teachers often lacked confidence in using what they had learnt after the program, and that ongoing and timely support following the initial program was essential for ensuring continued use of ICT. Another example is Lu's (2021) longitudinal study, which conducted a TPD program in a rural Taiwanese primary school undergoing curriculum reform. The study highlights how systematic follow-up supports, including on-site coaching, sustained mentorship, and timely situational guidance, helped rural primary teachers overcome the uncertainty and anxiety of implementing a new curriculum framework.

These research findings highlight follow-up support as a foundational element of successful TPD for ICT integration into teaching. Adequate support ensures that teachers can translate new knowledge into sustainable classroom practice and builds teachers' confidence in adapting ICT into their classrooms.

**(14) Provides content, ideas and materials that are relatively easy to implement in class**

One of the major barriers to the success of TPD is teachers' confusion about applying newly acquired knowledge and skills in lessons (Kjaergaard & Foug, 2016). In particular, teachers often feel a lack of confidence in applying new ICT in their

classrooms (Buchner & Hofmann, 2022). A successful TPD program must convince teachers that what they are learning is straightforward and easy to translate into classroom use (Kimav & Kürüm-Yapıcıoğlu, 2021; Naylor & Gibbs, 2018). In Naylor and Gibbs's (2018) research, teachers expressed positive perceptions about iPad activities they learned during TPD once they saw how effortlessly students could use the devices, and how excited their students were when using the iPads. These insights suggest that when TPD activities for ICT integration into teaching provide content, ideas and materials that are relatively applicable, they not only increase teachers' confidence but also support the sustained use of ICT in classrooms and fosters greater student engagement.

**(15) Makes teaching materials introduced in the sessions easy to access**

Providing accessible teaching materials is essential for a TPD targeted to ICT integration (Hu et al., 2021; Mumcu et al., 2022). A review of TPD specific for ICT integration into teaching conducted by Hu et al. (2021) points out that an online ICT platform with equal access can not only improve the effectiveness of the TPD but also mitigate resource disparities and imbalanced teacher quality between urban and rural schools. Teachers usually expect ICT taught in TPD workshops to be accessible for their use after completing the workshops. According to the research by Mumcu et al. (2022), mathematics and sciences teachers sought to learn the ICT tools that they could easily access and apply to interdisciplinary lessons to deliver active lessons for students. Ensuring that teaching materials are accessible after TPD for ICT integration into teaching is especially critical in not only reducing inequities across divers

educational contexts (see Hu et al., 2021) but in encouraging teachers to apply what they have learned in their classrooms (see Mumcu et al., 2022).

**(16) Provides teaching materials**

This feature specifically refers to the provision of teaching materials by schools or the TPD program organisers during training sessions. Studies have shown that providing teaching materials that teachers can use or adapt in their classrooms enhances and active learning environment and teachers' engagement with a TPD course (e.g. Herranen et al., 2021; Hu et al., 2021; Naylor & Gibbs, 2018; Rana et al., 2022; Sáez-López et al., 2020). One example is the TPD program for ICT integration into teaching conducted by Herranen et al. (2021), which provided teaching materials relevant to the course, such as lesson plans, experiments and activity templates. The participating teachers expressed a strong interest in applying these teaching materials to what they taught in their classes. These findings support the suggestion that the provision of teaching materials is critical in transferring TPD content to actual classroom implementation (Herranen et al., 2021; Hu et al., 2021).

**(17) Conducted over a sustained period**

Meaningful professional learning requires time to translate into actual practice (Darling-Hammond et al., 2017; Guskey, 1994). Previous studies have stated that one-shot, short-term TPD activities are less efficient than sustained TPD activities carried out over time (Bates & Morgan, 2018; Bayar, 2014; Hodkinson & Hodkinson, 2005). Cordingley et al. (2015) conducted a systematic review of the literature and concluded that at least two school terms are needed for a TPD program to affect a significant change among schools and teachers. However, most teachers still prefer to participate

in short-term TPD activities (Chang et al., 2022; Karabenick & Conley, 2011). Teachers' fears of increased workloads and difficulty finding substitute teachers for their classes can prevent them from participating in sustainable and long-term TPD programs (Krille, 2020). These findings highlight that although duration is critical to the success of the TPD, its implementation must carefully accommodate practical constraints such as teachers' time availability, workload and access to resources.

This section has summarised seventeen critical features of successful TPD based on the previous literature. The success of a TPD program relies on a combination of these features. Some features are naturally related to others. For example, the feature "active learning" incorporates aspects of collaborative learning, hands-on learning, feedback and reflection (Darling-Hammond et al., 2017). Kimav and Kurum-Yapicioglu (2021) and Huang (2021) stress that the success of hands-on learning activities depends on the provision of active learning environments, where teachers can jointly collaborate, reflect and refine ideas. Thus, the absence of any one of these three features would risk weakening the other two. In addition, the provision of proper instructors is key to realizing essential features during a given course. Bates and Morgan (2018) warn that poorly prepared or ineffective instructors may not be able to create an active learning environment, as many do not focus on specific content and may not provide constructive feedback to participating teachers. Accordingly, it can be assumed that the seventeen critical features identified here do not operate independently. Instead, they can be treated as attributes of a single construct.

Being trained to be a teacher should maximise the likelihood that teachers have a conception of what features of successful TPD would look like and how these could then be beneficial to teaching and student learning (Asterhan & Lefsten, 2024). While studies that identify implementation-oriented features rarely considered teachers' perceptions, recognising

these features can also motivate teachers to participate in similar TPD in the future (Karabenick & Conley, 2011; Krille, 2020). This phenomenon aligns with the concept of EVT as applied in the present study, which proposes that the value teachers perceive in a TPD program is a result of its distinctive features (Eccles & Wigfield, 1995). Teachers' perceptions of value of a TPD program, in turn, determine the success of the program (Dennis & Hemmings, 2019; Didion et al., 2019; Fishman et al., 2003; Lee, 2015).

TPD studies relevant to identifying the implementation-oriented features have been criticised as “problematic” and less rigorous (Asterhan & Lefstein, 2024, p 16). These TPD studies often focus on process-product logic, which results in a list of features that are too descriptive (Opfer & Pedder, 2011). In the absence of theoretical frameworks, these studies may not be able to explain why any given feature should matter. Instead, they often report the feature merely based on positive outcomes of TPD that it happens to coincide with (Kennedy, 2016b; Opfer & Pedder, 2011; Sztajn et al., 2011).

A similar problem appears in the studies focusing on the TPD features that are motivation-oriented. While motivation theories such as EVT, self-efficacy theory, and the education participation model for adult learners (Boshier, 1977) are mentioned in these studies (see Karabenick & Conley, 2011; Richter et al., 2019; Richter et al., 2025; Rutherford et al., 2017), the theoretical basis for individual features is missing. To address this gap and provide a coherent theoretical basis for these features, the present study mapped these seventeen features that may positively influence the success of TPD onto the three positive domains of value in EVT (Eccles et al., 1983). In addition, four features identified as barriers to teachers' engagement in TPD were mapped onto the negative value domain within the EVT, the cost domain, as discussed in the following section.

### **3.3.3 Aligning the Critical Features of Successful TPD with the EVT**

Expectancy-Value Theory (EVT) was initially applied in educational research to investigate children's motivations and behaviours for engaging with specific subjects, such as mathematics or science (Eccles et al., 1983; Eccles & Wigfield, 1995). Watt and Richardson (2007) later extended the theory to explain the motivations of pre-service teachers in pursuing a teaching degree. Some researchers have also explored teachers' perceptions of TPD through the lens of EVT (e.g. Karabenick & Colney, 2011; Osman & Warner, 2020), and several assessment instruments have been developed through these studies. Nevertheless, there remains a need for a more comprehensive framework that explicitly connects EVT with the specific features of successful TPD to measure the value of TPD from the perspective of teachers.

According to EVT teachers' evaluations, TPD programs can be conceptualised through four distinct value domains: attainment value, intrinsic value, utility value and cost (Eccles et al., 1983; Eccles & Wigfield, 2020). Drawing on insights from the existing literature, the following section discusses the alignment between the key value domains of EVT and features of successful TPD. A summary is provided in Table 3.1.

#### **Attainment Value**

Attainment value refers to the perceived importance of a task based on individuals' demands and identity. Eccles and Wigfield (1995) associate attainment value with the worthiness of course participation and the significance of mastering taught skills, highlighting its relevance to learners' sense of self and academic aspirations. Watt and Richardson (2007) define attainment value as "personal utility

value”, which encompasses the personal benefits that individuals expect to receive as a teacher—e.g., income stability, career progression and job security.

The extent of attainment value is determined by relevance to teachers’ teaching philosophy, personal identity as an educator and career demands (Eccles et al., 1983; Eccles & Wigfield, 2020; Osman & Warner, 2020). Based on this conceptualisation, attainment value aligns with features detailed above such as (1) focus on specific content, knowledge and skills; (2) recognition of the experience and prior knowledge of teachers; (3) provision of feedback, assessment and reflection; and (4) provision of career advancements. These features may be appropriately classified within attainment value.

### **Intrinsic Value**

Intrinsic value refers to the enjoyment that individuals receive from engaging in an activity. The extent of this domain of value is usually related to inherent personal interest (Eccles & Wigfield, 1995). In the early educational research about EVT, researchers usually directly asked how much participants were “interested in” or “liked” a task. Responses were taken as a measure of the extent of intrinsic value (see Eccles & Wigfield, 1995; Watt & Richardson, 2007). However, factors that influence teachers’ enjoyment in a TPD program for ICT integration into teaching are more complex than factors involved with general TPD programs. Teachers have expressed enjoying building connections with other teachers and learning new skills actively (Emo, 2015). They expect to have a proper instructor who can deliver course content collaboratively so that they can interact with their peers (Bayer, 2014) and have hands-on practice opportunities that they can discuss together (Chen, 2020).

Accordingly, of the seventeen successful features identified earlier (Section 3.3.2), those that (5) Target active learning, (6) Provide well-qualified instructors, (7) Encourage collaborative learning, (8) Target novelty, and (9) Provide opportunities for hands-on learning can be categorised as having intrinsic value.

### **Utility Value**

Utility value refers to the perceived usefulness of a task towards participants' short-term and long-term goals. For example, in Eccles and Wigfield's (1995) study, the utility value of studying mathematics was determined in terms of its relevance to learners' post-graduation and future career goals (i.e. long-term goals), as well as its application in daily life outside of school (i.e. short-term goals). Watt and Richardson (2007) further refined utility value as "social utility value" (p. 172). In their research, social contribution, social equity, support for students' future and opportunities to work with children were the indicators of utility value in pursuing a teaching degree.

In the context of TPD programs for ICT integration into teaching, utility value is captured by the benefits to teachers' classroom management and instructional practices, as well as the enhancement of student learning (Gaines et al., 2019; Osman & Warner, 2020). Accordingly, features that best align with this domain are: (10) Helps with students' development; (11) Aligns with current demands and visions; (12) Provides convincing exemplary material; (13) Provides follow-up support; (14) Provides contents, ideas and materials that are relatively easy to implement in class; (15) Makes teaching materials introduced in the sessions easy to access; and (16) Provides teaching materials.

## **Cost**

Cost generally, reflects the negative perception associated with engaging in a task, including the investment of effort and emotional resources, as well as the loss of opportunity for forgoing alternative activities (Eccles et al., 1983; Eccles & Wigfield, 1995). In Watt and Richardson's (2007) study, the cost domain is conceptualised as task demand, which links to negative perceptions of choosing to be a teacher, including the burden of a heavy workload, emotional strain, intensive labour and the intellectual requirement of being an expert in a specific subject.

Previous studies have identified several features of TPD as barriers that may hinder teachers' engagement and participation in TPD programs (e.g. Fang et al., 2021; Krille, 2020; OECD, 2019; Rana & Sharma, 2022). These barriers are consistent with EVT's definition of cost and may be appropriately categorised within this domain. Accordingly, drawing on evidence presented in previous studies, this study identifies four features that impact the cost of participation: time-consuming, financially expensive, tedious procedures to implement and stressful to learn.

### **(18) Time-consuming**

Time constraints are widely recognised as a significant barrier to teacher engagement in TPD (Fang et al., 2021; Krille, 2020; OECD, 2019). The 2018 Teaching and Learning International Survey (TALIS 2018) report conducted by the OECD (2019) highlighted that conflicts between the timing of TPD courses, teachers' work schedules and the timing for teacher being with their families, were among the primary reasons for discontinuing participation. Similar to this finding, Krille's (2020)

systematic review found that rescheduling classes to accommodate TPD sessions is particularly challenging for teachers, given their existing heavy workload in schools.

Furthermore, teachers expressed feelings of guilt when asking colleagues to help rearrange class schedules, which further reduced their motivation to participate in TPD (Krille, 2020). The issue of scheduling conflicts between TPD sessions and teachers' personal schedules is globally relevant. Fang et al. (2021) investigated supports and barriers to TPD participation among teachers in Australia and China. They found that in both contexts, scheduling conflicts between TPD and work were one of the main obstacles to teacher participation in TPD.

#### (19) Financial Expense

Expensive attendance fees can deter teachers from engaging in TPD (Fang, et al., 2021; OECD, 2019; Rana & Sharma, 2022). According to the TALIS 2018 report by the OECD (2019), excessive cost was ranked as the third most significant barrier to TPD participation. This barrier is particularly pronounced in systems where teachers must rely on school funding to attend paid programs. Fang et al. (2021) revealed that Australian teachers expressed difficulty in participating in TPD as school budgets for attending TPD programs are limited. In contrast, most teachers in Shanghai did not perceive cost as an obstacle, as their schools provided both scheduled time and salary support for teacher attending TPD programs.

#### (20) Tedious Procedures to Implement

The lessons of TPD courses are not always easy to implement, especially in the context of TPD for ICT integration into teaching. Ramos-Pla et al. (2021) examined Catalan university lecturers' perceptions of online TPD courses for ICT

integration into teaching which were undertaken during the COVID-19 pandemic. Their findings revealed that participating teachers felt overwhelmed by the complexity of setting up ICT tools and reported a lack of adequate time to transfer what they had learned into practice. Such frustrating experiences with TPD for ICT integration into teaching decrease teachers' motivation to continue engaging in similar programs (Osman & Warner, 2020; Ramos-Pla, et al., 2021). This decrease in motivation may further undermine the success of the implementation of a TPD program (Osman & Warner, 2020).

(21) Stressful to Learn

The stress, anxiety and frustration that teachers perceive during TPD might decrease teachers' motivation to engage in or implement learning in classes (Osman & Warner, 2020; Philipsen et al., 2019). Teachers might also encounter some technical difficulties while participating in a TPD for ICT integration into teaching which increase their stress. For example, in a study conducted by Philipsen and his team (2019), all teachers expressed stress and frustration while participating in a TPD for ICT integration into teaching. The teachers pointed out that a delay in functioning ICT tools triggered stress during the course, which may have decreased their motivation to participate in similar TPD in the future.

At this stage of the study, a total of twenty features have been categorised into four value domains derived from the EVT: four within Attainment Value, five within Intrinsic Value, seven within Utility Value and four within Cost. Due to differing perceptions between researchers and teachers there is one additional feature that is difficult to categorise within any domains of value: (17) Carried out over a sustained period, Although previous studies

have found that long-term and sustained TPD activities are more effective for teachers than short-term and one-off TPD activities (Bates & Morgan, 2018; Bayar, 2014; Hodkinson & Hodkinson, 2005), teachers may have negative perceptions of the time costs (Chang et al., 2022; Karabenick & Conley, 2011; Krille, 2020). It is difficult to assign this feature to a specific EVT domain. Its categorisation within the VT construct will be further explored in the subsequent phase of this study, which will seek participants' views and suggestions to inform its theoretical placement.

**Table 3.1***Draft of the Value of TPD (VT) construct*

<b>Construct</b>	<b>Domains (types of value)</b>	<b>Features</b>
The Value of TPD	Attainment Value	(1) Focuses on specific content, knowledge and skills (2) Recognises the experience and prior knowledge of teachers (3) Provides feedback, assessment and reflection (4) Provides career advancement
	Intrinsic Value	(5) Targets active learning (6) Provides well-qualified instructors (7) Encourages collaborative learning (8) Targets novelty (9) Provides opportunities for hands-on learning
	Utility Value	(10) Helps with students' development (11) Aligns with current demands and visions (12) Provides convincing exemplary material (13) Provides follow-up support (14) Provides contents, ideas and materials that are relatively easy to implement in class (15) Makes teaching materials introduced in the sessions easy to access (16) Provides teaching material
	Cost	(18) Time-consuming (19) High financial expense (20) Tedious procedures to implement (21) Stressful to learn
	Uncategorised*	(17) Carried out over a sustained period

\*The corresponding domain of value for this feature was discussed in the next research stage, focus group discussions.

In the present study, the twenty-one features shown in Table 3.1 were operationalised through twenty-nine indicators to bridge the VT construct and the specific descriptions of VT items for the later scale development (see Table 3.2). Indicators were labelled according to the location of their corresponding features within the VT construct. For example, Indicator A1 (Focuses on specific content, knowledge and skills) was labelled based on Feature 1

(Focuses on specific content, knowledge and skills) and positioned within the domain of attainment value.

Some indicators were subsumed under a single feature. These include Indicator A3 (Provides peer feedback and assessment opportunities), A4 (Provides instructor's feedback and assessment opportunities) and A5 (Provides self-reflection opportunities), all of which were aligned with Feature 3 (Provides feedback, assessment and reflection). Each indicator represents distinct mechanisms through which feedback, assessment and reflection are delivered during TPD addressed in the previous studies, including feedback and assessment among peers (Bates & Morgan, 2018; Buchner & Hofmann, 2022; de Vries et al., 2013), expert-leading feedback and assessment (Bates & Morgan, 2018) and self-reflection (Bates & Morgan, 2018; de Vries et al., 2013).

Similarly, Indicator I3 (Provides opportunities for collaborative learning with peers), I4 (Provides opportunities for cross-discipline collaborative learning) and I5 (Provides opportunities for collaborative learning with teachers outside of schools) were mapped to Feature 7 (Encourages collaborative learning). This mapping reflects different forms of collaborative learning in TPD identified in the literature, including with peers (Darling-Hammond et al., 2017; de Vries et al., 2013; Lu, 2021; Njiku et al., 2021), cross-discipline (Naylor & Gibbs, 2018) and with teachers from different schools (Bustamante, 2020).

In addition, Indicator U2 (Aligns with schools' needs), U3 (Aligns with schools' curriculum plan) and U4 (Aligns with teachers' needs) were categorised under Feature 11 (Aligns with current demands and visions). This categorisation was according to different sources from which such demands and visions were produced, including demands at the school level (Alemdag et al., 2020), the professional demands of teachers (Alemdag et al., 2020; Bayar, 2014) and schools' curriculum plans and directions (Cirocki & Farrell, 2019).

Feature 13 (Provides follow-up support) and Feature 16 (Provides teaching materials) were each represented by two indicators. Indicator U6 (Provides follow-up classroom observations and feedback) and U7 (Provides follow-up advisory service) were related to Feature 13, reflecting two forms of follow-up support provided by TPD programs that were addressed in the literature: classroom observations and feedback (Lu, 2021) and advisory service (Lu, 2021; Rana et al., 2022). Finally, Indicator U10 (Provides teaching materials/equipment from the program organisers) and U11 (Provides teaching materials/equipment from the schools) were aligned with Feature 16, to identify different sources of providers for teaching materials/equipment related to TPD, including resources provided by program organisers (Naylor & Gibbs, 2018; Sáez-López et al., 2020), and those supplied by schools (Herranen et al., 2021).

**Table 3.2***Draft of the Value of TPD (VT) construct and the corresponding indicators*

Construct	Domains (types of value)	Features	Corresponding Indicators
The Value of TPD	Attainment Value	(1) Focuses on specific content, knowledge and skills	A1. Focuses on specific content, knowledge and skills
		(2) Recognises the experience and prior knowledge of teachers	A2. Recognises the experience and prior knowledge of teachers
		(3). Provides feedback, assessment and reflection	A3. Provides peer feedback and assessment opportunities A4. Provides instructor's feedback and assessment opportunities A5. Provides self-reflection opportunities
		(4) Provides career advancement	A6. Provides career advancement
	Intrinsic Value	(5) Targets active learning	I1. Targets active learning
		(6) Provides well-qualified instructors	I2. Provides well-qualified instructors
		(7) Encourages collaborative learning	I3. Provides opportunities for collaborative learning with peers I4. Provides opportunities for cross-discipline collaborative learning
			I5. Provides opportunities for collaborative learning with teachers outside of schools
		(8) Targets novelty	I6. Targets novelty
		(9) Provides opportunities for hands-on learning	I7. Provides opportunities for hands-on learning
Utility Value	(10) Helps with students' development	U1. Helps with students' development	

Table 3.2—Continued

Construct	Domains (types of value)	Features	Corresponding Indicators
The Value of TPD (continued with the previous page)	Utility Value (continued with the previous page)	(11) Aligns with current demands and visions	U2. Aligns with schools' needs U3. Aligns with schools' curriculum plan U4. Aligns with teachers' needs
		(12) Provides convincing exemplary material	U5. Provides convincing exemplary material
		(13) Provides follow-up support	U6. Provides follow-up classroom observations and feedback U7. Provides follow-up advisory service
		(14) Provides contents, ideas and materials that are relatively easy to implement in class	U8. Provides contents, ideas and materials that are relatively easy to implement in class
		(15) Makes teaching materials introduced in the sessions easy to access	U9. Makes teaching materials introduced in the sessions easy to access
		(16) Provides teaching materials	U10. Provides teaching materials/equipment from the program organisers U11. Provides teaching materials/equipment from the schools
	Cost	(18) Time-consuming	C1. Is time-consuming
		(19) High financial expense	C2. Requires high financial expense
		(20) Tedious procedures to implement	C3. Has tedious procedures to implement
		(21) Stressful to learn	C4. Is stressful to learn
Uncategorised*	(17) Carried out over a sustained period	Uncategorised. Carried out over a sustained period	

\* The corresponding domain of value for this feature is discussed in the next research stage, focus group discussions (Chapter 5, Section 5.2).

The next section discusses the relationship between the TPACK-core in TPACK framework and TPD for ICT integration into teaching based on previous literature.

### **3.4 TPACK-core as Evidence for the Success of TPD for ICT Integration into Teaching**

Mishra and Koehler (2006) developed the Technological Pedagogical and Content Knowledge (TPACK) framework in response to the limitations of traditional tool-based TPD. Since the development of this framework, teachers' TPACK has been recognised as essential evidence of the relative success of TPD programs for ICT integration into teaching. Based on previous studies, the relationship between TPD and the TPACK framework can be categorised into two main types. The first type involves TPD programs that are explicitly designed around the TPACK framework (e.g., Bustamante, 2020; Chaipidech et al., 2021; Koh et al., 2016), where the framework is used as a foundation for program design. In this type, the domains of the TPACK framework are translated into course structures and designs. For example, Chaipidech and his team (2021) conducted a two-year TPD program aimed at enhancing science teachers' overall TPACK level in Thailand. The program comprised four workshops, with the TPACK framework and andragogy theory forming the core of the training. In addition, a personalised learning application grounded in the TPACK framework was developed to assist teachers' learning throughout the workshops. Teachers' overall TPACK level was assessed upon the completion of each workshop. Another example of a TPD program designed around the TPACK framework is found in Bustamante's (2020) study. This fifteen-week online TPD program for Spanish teachers explicitly targeted each domain of the TPACK framework, such as Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) through their weekly modules.

The second type includes TPD where teachers' TPACK is used as evidence to evaluate implementation of a program for ICT integration into teaching (e.g., Lai et al., 2021; Mahmoudi et al., 2021; Nazari et al., 2019). The TPACK framework is not considered during the design stage of the TPD program. Instead, it is treated as a critical indicator to determine

whether the TPD program was effective or to identify areas where teachers still require development. For example, in Mahmoudi et al.'s (2021) study, a TPD program originally intended to enhance EFL teachers' language proficiency, subject knowledge, and teaching skills was evaluated for its impact on the teachers' overall TPACK level. Although the analysis of the TPACK questionnaire showed a positive and statistically significant result regarding the program, participating teachers reported dissatisfaction with the program. They felt it failed to address their needs and perceptions, which may ultimately deter successful implementation of what they learned in the classroom in the future.

It is worth noting that, regardless of the focus of each study, teachers' level of overall TPACK is frequently regarded as evidence of the success of TPD programs for ICT integration into teaching (e.g., Chaipidech et al., 2021; Koh et al., 2016; Mahmoudi et al., 2021). However, as discussed previously (see Chapter 2, Section 2.4.1), the design of TPACK questionnaires used in many of these studies is often problematic due to the compounded nature and inconsistent definitions of the domains within the TPACK framework per se. Furthermore, the results from these questionnaires often fail to capture the contextual differences of individual TPD programs. To address these limitations, the present study explicitly focuses on the TPACK-core domain within the TPACK framework. It develops a theoretical construct for the improvement of the TPACK-core via the TPD Experience (ITTE) scale and incorporates the context of the TPD program for ICT integration in its measurement scale.

### **3.4.1 Developing the Draft Items for the ITTE Scale**

Given the vast number of questionnaire scales developed since the introduction of the TPACK framework (Lu, 2024; Scott, 2021), it is not only feasible but judicious to select

items from various TPACK questionnaire scales and modify their content without having to develop entire new questionnaires (Gehlbach & Brinkworth, 2011; Prasojo et al., 2020; Wu & Wang, 2015).

Scott's (2021) review of 233 TPACK research studies between 2006 and 2020 provided the pool of potential items for the ITTE survey. The review identified five potential questionnaires that were most frequently adopted across these studies, including those developed by Schmidt et al. (2009), the research group led by Chai and Koh (2010–2019), Sahin (2011), Yurdakul et al. (2012), and the research group with Archambault and Crippen (2006-2011). Lu (2024) extended Scott's (2021) review to include studies published between 2020 and up to and including 2023 and similarly found that the TPACK questionnaires developed by Schmidt et al. (2009), Yurdakul et al. (2012), Sahin (2011), and Chai et al. (2011) were widely adopted in 353 relevant studies.

It is noted that rather than adhering to the original seven-domain TPACK framework proposed by Mishra and Koehler (2006) and adopted by most studies, the TPACK questionnaire developed by Yurdakul et al. (2012) was based on an extended TPACK framework proposed by the authors and involves four factors: design, exertion, ethics, and proficiency. Items from Yurdakul et al.'s (2012) scale were therefore excluded from this study. Instead, items from the TPACK questionnaires developed by Schmidt et al. (2009), Sahin (2011), Chai et al. (2011), and Archambault and Crippen (2009) were selected as references for drafting the items of the ITTE scale. The description of the draft items for the ITTE scale and the referenced studies is presented in Table 3.3.

The 47-item TPACK questionnaire developed by Schmidt et al. (2009) was originally designed for pre-service teachers in the United States explicitly within the disciplines of

mathematics, social studies, science and literacy. This questionnaire has been widely applied by other TPACK studies across Asia, the United States, and Turkey, with the focus on both in-service and pre-service teachers across all the educational sectors. Eight items from this questionnaire which relate to the TPACK-core framework, were selected as the basis for drafting the items of the ITTE scale.

Sahin (2011) developed another 47-item TPACK questionnaire similar to Schmidt et al. (2009)'s, which focused on pre-service teachers in Turkey. The majority of the studies that applied this questionnaire were conducted in Turkey and included research on in-service and pre-service teachers. Five items from Sahin's TPACK questionnaire align with the TPACK-core domain and were selected as the basis of the draft items for this study's ITTE scale.

Chai and Koh's research team have conducted a series of studies on TPACK. In Chai et al. (2011) they introduced a 36-item TPACK questionnaire specifically for pre-service teachers in Singapore across both primary and secondary education. Their TPACK questionnaire has since been widely applied in research involving in-service teachers across Asia, including in Singapore, China, and Taiwan. Five items from Chai et al.'s (2011) questionnaire that measure the TPACK-core domains were chosen in the present study for drafting the items of the ITTE scale.

Finally, Archambault and Crippen (2009) designed a 24-item TPACK questionnaire aimed at assessing the TPACK of K-12 online teachers across twenty-five states in the United States. Given its specific focus on online teaching, this survey has been used in other studies involving in-service teachers engaging in distance education.

Four items from the TPACK-core domain were selected to support the development of the ITTE measurement scale in the present study. The wording of the various items was

modified to align with the need to produce a unified scale. For example, the original item from Schmidt et al.'s (2009) questionnaire stated, "I can teach lessons that appropriately combine literacy, technologies, and teaching approaches." (p. 135), was modified to: "This TPD program enhanced my capability of using a variety of technologies that allow students to participate actively."

Furthermore, as this present study was conducted in Taiwan, the selection of draft items for the ITTE scale considered the relevance of item descriptions to the Curriculum Guidelines of 12-year Basic Education issued by the Ministry of Education in Taiwan (MOET, 2021). Overall, twenty draft items for the ITTE scale were generated during this stage of the study (Table 3.3). These draft items were further reviewed and examined in the subsequent phases of the study to determine whether they effectively measured an intended construct.

**Table 3.3***Draft items and reference for ITTE scale*

No.	Items	Modified from
1	This TPD program enhanced my capability of using a variety of technologies that allow students to participate actively.	Schmidt et al., (2009)
2	My capability of using a variety of tools to assist students in pursuing their own interests has been enhanced by participating this TPD program.	Schmidt et al., (2009)
3	My capability of employing technology effectively to provide vital information to students and peers has been enhanced by participating this TPD program.	Schmidt et al., (2009)
4	My capability of promoting global understanding by engaging students with diverse cultures through technology has been enhanced by participating this TPD program.	Schmidt et al., (2009)
5	This TPD program improved my understanding of choosing technology properly for enhancing the methods and ways of teaching, and students' learning.	Chai et al., (2011)
6	This TPD program reinforced my capability to teach successfully by appropriately combining the technologies, instructional content and instructional approaches.	Chai et al., (2011); Sahin (2011)
7	My capability of leading my colleagues to integrate content, pedagogy and technology knowledge has been improve after participating this TPD program.	Chai et al., (2011); Sahin (2011)
8	This TPD program reinforced my capability of using ICT tools and resources to support my own professional development and improve the process of English or mathematics teaching continuously.	Sahin (2011)
9	This TPD program improved my understanding of employing a variety of digital English or mathematics learning tools and resources when teaching.	Sahin (2011)
10	My capability of using a range of technologies to enhance students' English and mathematics knowledge has been improved by participating this TPD program.	Sahin (2011); MOET (2019) Curriculum guidelines of 12-year Basic education
11	This TPD program improved my capability of using a range of technologies to develop an environment that is suitable for students to practice English or mathematics.	Schmidt et al., (2009); MOET (2021) Curriculum guidelines of 12-year Basic education

Table 3.3 —*Continued*

No.	Items	Modified from
12	My capability of using a range of technologies to introduce different cultures and traditions in classes has been improved by participating this TPD program.	Schmidt et al., (2009); MOET (2021) Curriculum guidelines of 12-year Basic education
13	This TPD program improved my capability of using proper technologies to strengthen students' logical thinking when using English and mathematics	Schmidt et al., (2009); MOET (2021) Curriculum guidelines of 12-year Basic education
14	This TPD program enhanced my capability of appropriately combining instructional approaches, English or mathematics concept and technologies.	Schmidt et al., (2009)
15	This TPD program introduced fair access to learning tools of digital learning for me to conduct in classes.	Schmidt et al., (2009)
16	This TPD program provided information on digital learning communities that I can participate in to discover creative utilities of ICT to improve students' learning.	Schmidt et al., (2009)
17	This TPD program enhanced my skill in using technology to develop and present practical and unique content that go beyond the textbook.	Archambault & Crippen (2009)
18	My capability of adopting technology in student assessment to amend my teaching has been improved by participating this TPD program.	Archambault & Crippen (2009)
19	This TPD program enhanced my ability to predict how well students understand a specific topic via technology.	Archambault & Crippen (2009)
20	This TPD program helped me to achieve the overall requirements of English or mathematics teaching.	Archambault & Crippen (2009)

The next section discusses how students' learning achievement can be used to provide further evidence as to the relative success of a TPD program for ICT integration into teaching.

### 3.5 Student Learning Achievement

Some research has recognised that the ultimate goal of TPD is to improve students' learning achievement (Desimone, 2009; Meissel et al., 2016; Sokel, 2019). To deliver a successful TPD program for ICT integration into teaching, ensuring the positive impact of the TPD on teachers' and students' learning achievement is essential (Soebari & Aldridge, 2016).

This section discusses the definition of students' learning achievement and the application of high-stakes test results as evidence of students' learning achievement based on previous literature.

### **3.5.1 The Role of Student Learning Achievement in the Present Study**

Student learning achievement is the basis of teaching and learning. In general, it refers to the accomplishment of students on specified learning goals within educational settings such as classrooms and schools (Guskey, 2013; Zeng, 2023). The concept of student learning achievement is multifaceted, and context-bound. Linn et al. (2011) defined student learning achievement as the status of students' knowledge and skills in a specific subject at a given point in time. In contrast, student learning focuses on the growth or development of knowledge and skills over time. Guskey (2013) offers an integrative interpretation of student learning achievement. He suggests that student learning achievement can be measured from two perspectives: attainment and improvement. The attainment perspective aligns with Linn et al.'s (2011) definition, representing the level of performance at a single point in time. The improvement perspective emphasises growth from one point to another, which closely resembles Linn et al.'s (2011) concept of student learning.

The present study adopts Guskey (2013)'s interpretation of student learning achievement to capture both attainment and improvement aspects of students' learning achievement. Data on student learning achievement were derived from changes in students' test scores on a high-stakes annual attainment test administered across two consecutive years in Taiwan. It is important to note that, instead of being conceptualised as a direct impact of TPD intervention on learning growth, these data served specifically as further evidence for the plausibility of the intended use of scores on VT and ITTE scales.

Previous studies have pointed out that a successful TPD should reinforce teachers' professional knowledge and instructional skills, and ultimately, be connected to students' learning achievement (Darling-Hammond et al., 2017; Desimone, 2009; Meissel et al., 2016; Sims et al., 2021; Sokel, 2019). In line with this literature, teachers' perceptions of the value of a given TPD program for ICT integration into teaching and their perceived improvement in TPACK-core are considered critical to the success of the program. Accordingly, the present study anticipated that the students of teachers who value their TPD and perceive that they have improved in their TPACK-core as a result of participating would have relatively higher learning achievements than those whose teachers valued TPD less and did not perceive improvement in TPACK-core as strongly. Accordingly, a positive association between teachers' VT and ITTE results and aggregated students' learning achievement results would provide supportive evidence that the scales developed here function meaningfully.

The following section indicates the rationale for applying high-stakes test results as evidence of student learning achievement.

### **3.5.2 Applying High-stakes Test Results as Evidence of Student Learning Achievement**

A variety of tests are conducted in school to measure students' learning achievement, but not all of them are perceived as high stakes. Marchant et al. (2004) defined high-stakes tests as those that "carry serious consequences for students and educators" (p. 2). Consequences could include students' opportunities to pursue a higher grade, educator promotions and school funding (UNESCO, UIS glossary; Jones & Ennes, 2018). Common high-stakes tests include college entrance examinations, secondary school entrance examinations and national standardised achievement tests that are related to a school's

performance and reputation, such as the Student Academic Attainment Tests (SAAT) in Taiwan.

Most high-stakes tests are standardised achievement tests. These tests are designed to measure students' learning achievement in a specific subject at a specific grade level. They also have uniform rules for administration and scoring to ensure all test-takers receive the same instructions and conditions (Marchant et al., 2004; Sims et al., 2021). For example, the SAAT in Taiwan is an annual standardised test that aims to test English, mathematics and Chinese learning achievement across students from Year 3 to Year 8. Participating schools are required to conduct the test in a specific week of the school year.

Among all forms of test scores, results from high-stakes tests were found to provide the most rigorous evidence supporting the success of a TPD program (Sims et al., 2021). However, only a small number of studies have used high-stakes test results as evidence of TPD program efficacy. This may be due to the design of most TPD programs, which typically target at specific group of teachers, resulting in limited alignment between the content of the TPD and the high-stakes tests. Indeed, TPD programs for which studies have used high-stakes test results as evidence of success are usually implemented at the national level (e.g. Havard et al., 2018; Naba'h et al., 2009).

The present study is based on a nationwide TPD program for ICT integration into teaching. Thus, it makes sense to apply results from the SAAT as evidence of students' learning achievement in Taiwan. It is important to note, however, that the SAAT results are not regarded as definitive indicators of program success and student learning gain. Instead, these results are used as one source of evidence related to the exploration of whether teachers

who perceived greater value in the TPD program and improvement in their TPACK-core can be associated with relatively stronger patterns of student learning achievement.

To contextualise the use of SAAT and the national TPD program for ICT integration into teaching, the following section outlines three educational policies currently implemented in Taiwan.

### **3.6 An Overview of Recent Educational Policies for Primary Education in Taiwan**

This section outlines three key policies implemented in Taiwanese primary schools that are relevant to the present study. First is the *Digital Learning Enhancement Plan*, which has promoted ICT-focused TPD to enhance primary school teachers' capacity to integrate ICT into teaching since 2022. Second, the *Bilingual Nation 2030* policy highlights the importance of English language learning in Taiwan's primary schools. Finally, the SAAT, from which this study collected students' test results in 2023 and 2024 as evidence of learning achievement following their teachers' involvement in the TPD program for ICT integration into teaching, is introduced.

#### **3.6.1 Digital Learning Enhancement Plan**

Ranked ninth in the 2024 Global Digital Competitiveness Index and having achieved top three in seven indicators globally, Taiwan has established a leading position in numerous high-tech sectors. With the aim of developing its digital economy, the government has invested at least one billion Australian dollars in improving digital learning environments in schools over the last three years. At the end of 2021, the Ministry of Education in Taiwan launched the *Digital Learning Enhancement Plan* for Grade 1–12 Students, an educational action plan designed to integrate ICT effectively into education. The plan outlines five key goals: Enhance ICT teaching tools for simplifying preparation and diverse instruction; Distribute mobile devices such as digital pads to replace heavy textbooks; Support ICT

learning for teachers and students; Analyse big data to identify students' needs, improve policies and refine teaching approaches; Ensure equal learning opportunities by reducing learning gaps.

A range of policies has been implemented under this action plan, one of the most significant being the “A Tablet for Every Student” policy, which provides every schoolchild with a tablet to support classroom learning. Additionally, a new online learning platform, the Taiwan Adaptive Learning Platform (TALP), has been developed to fulfil students' individual learning needs by promoting self-regulated learning. Recognising the pivotal role of teachers in the success of these policies, a TPD program has been introduced to equip educators with the necessary knowledge and skills to integrate ICT effectively into their classrooms. This 36-hour TPD program comprises two compulsory workshops and four elective workshops. All K1-K12 teachers are required to complete the mandatory workshops by 2024. The outline of each workshop is indicated below:

- (1) A1 Digital Learning Workshop (Compulsory): A 3-hour workshop introducing TALP, mandatory for all primary and secondary school teachers, with a target of 100% completion by 2024.
- (2) A2 Digital Learning Workshop (Compulsory): A 3-hour workshop focusing on the TALP application, including platform operation and teaching model application. It is also compulsory for all primary and secondary school teachers, aiming for 100% completion by 2024.
- (3) A3 Digital Literacy Enhancement Workshop (Optional): A 3-hour session covering internet literacy, privacy protection, and information security.
- (4) B2 Technology-Assisted Self-Regulated Learning Workshop (Optional, prerequisite: A1 and A2): A 12-hour workshop that introduces self-regulated

learning, its implementation in schools, and its relationship with digital learning platforms/tools.

- (5) B2 PBL Teaching Application Workshop (Optional, prerequisite: A1 and A2): A 6-hour workshop on technology-assisted self-regulated learning theory and Project Based Learning (PBL). It also covers digital learning combined with PBL course operations, and PBL combined with technology-assisted self-regulated learning.
- (6) B3 Digital Teaching Guidelines Empowerment Workshop Optional, prerequisite: A1 and A2): A 6-hour workshop guiding teachers in understanding digital pedagogy and designing digital lessons.
- (7) B4 Digital Teaching Workshops by Subjects (Optional, prerequisite: A1 and A2): A 3-hour subject-specific workshop focusing on digital lesson design, practical implementation, and case studies.

The TPD program has been conducted for four years. However, there is still a lack of evidence to support its success. Hus (2024) argued that Taiwanese teachers' ability to integrate ICT into teaching still varies, even though most of the teachers have at least completed the six-hour compulsory TPD course. This finding highlights the need for developing relevant measurement instruments to support more rigorous and systematic empirical studies into the success of this TPD program.

### **3.6.2 Bilingual Nation 2030**

With the goal of increasing the global competitiveness of the younger generation and attracting international corporations, the *Bilingual Nation 2030* policy was launched in Taiwan in 2019 (Financial Supervisory Commission, Taiwan, 2019). This policy aims to

include English as one of the primary languages in Taiwan by 2030. The Ministry of Education in Taiwan had set up the short-term goal of at least 60% of primary and secondary schools using English only in English classes, and 14% of the schools teaching bilingually in other subjects by 2024. Furthermore, since the policy of enhancing digital learning is ongoing, teachers are encouraged to incorporate ICT into bilingual teaching and to effectively use mobile devices such as tablets to assist their teaching.

The policy aims to generally strengthen students' English proficiency. Given that most of the teachers in school have no experience in teaching English medium courses, the role of English teachers is crucial to the successful implementation of this policy.

### **3.6.3 Students' Academic Attainment Test (SAAT)**

To understand student learning achievement, and academic pathways and identify students' needs at the early stages, sixteen out of twenty-one local governments in Taiwan assigned the Educational Measurement and Adaptive Learning Centre at the National Taichung University of Education to develop and analyse assessment items from SAAT. The SAAT is implemented for Year 3 to Year 8 students annually by the participating local government, and covers subjects including English, mathematics and Chinese. The test results of Year 5 students in mathematics and English in 2023 and the Year 6 test results from the same group of students in the same subjects in 2024 are used in the present study to assess students' learning achievement. Overviews of the Year 5 test in mathematics and English in 2023 and the Year 6 test in mathematics and English in 2024 are given below.

#### **(1) Overview of Year 5 mathematics test in 2023**

This test encompassed twenty-five questions distributed in two dimensions: the "Knowledge Dimension" and the "Cognitive Dimension". The knowledge dimension consisted of four indicators: Number and Calculation, Units and Direct

Measurement, Geometry and Algebra. The cognitive dimension consisted of three indicators: Conceptual Understanding, Procedural Execution and Problem-Solving and Critical Thinking.

A total of 91,111 Year 5 students participated in the 2023 mathematics assessment. The overall average accuracy rate across all questions was 50%.

(2) Overview of Year 5 English test in 2023

This test encompassed thirty questions distributed in two dimensions: the “Listening Dimension” and the “Reading Dimension”. The listening dimension consisted of five indicators: Phonemic Discrimination in Listening, Lexical Recognition in Auditory Processing, Comprehension of Classroom Discourse, Appropriate Responses to Classroom Discourse, Listening Comprehension of Cultural and Festival-related Discourse, Orthographic. The reading dimension consisted of four indicators: Orthographic and Lexical Recognition, Syntactic and Semantic Sentence Comprehension, Interpretation of Short Texts and Visual Representations and Reading Comprehension of Cultural and Festival-related Texts.

A total of 91,102 Year 5 students participated in the 2023 English assessment. The overall average accuracy rate across all questions was 68%.

(3) Overview of Year 6 mathematics test in 2024

This test encompassed twenty-five questions distributed in two dimensions: the “Knowledge Dimension” and the “Cognitive Dimension”. The knowledge dimension consisted of three indicators: Number and Calculation, Units and the Direct Measurement and Geometry. The cognitive dimension consisted of three

indicators: Conceptual Understanding, Procedural Execution and Problem-Solving and Critical Thinking.

A total of 31,427 Year 6 students participated in the 2024 mathematics assessment. The overall average accuracy rate across all questions was 58%.

#### (4) Overview of Year 6 English test in 2024

This test encompassed thirty-five questions distributed in two dimensions: the “Listening Dimension” and the “Reading Dimension”. The listening dimension consisted of four indicators: Phonemic Discrimination in Listening, Lexical Recognition in Auditory Processing, Comprehension and Appropriate Responses to Classroom Discourse, Listening Comprehension of Cultural and Festival-related Discourse, Orthographic. The reading dimension consisted of four indicators: Orthographic and Lexical Recognition, Syntactic and Semantic Sentence Comprehension, Interpretation of Short Texts and Visual Representations and Reading Comprehension of Cultural and Festival-related Texts.

A total of 31,442 Year 6 students participated in the 2024 English assessment. The overall average accuracy rate across all questions was 74%.

The next section discusses the Rasch model and its usage in previous relevant studies using Likert-type formats.

### **3.7 The Rasch Model and its Application in Previous Relevant Studies**

The original Rasch model was formulated by George Rasch in 1960, with a focus on simple dichotomous responses to items representing a measurement instrument on a latent attribute (Rasch, 1960/1980). The dichotomous Rasch model was originally applied to dichotomously scored tests, where the items are scored as either correct or incorrect. The

Rasch model provides estimates both of student ability and item difficulty as independent parameters on a common measurement scale. A student's ability on an underlying construct can be estimated through the total number of items (i.e. raw score) answered correctly, and the item difficulty is estimated by the total number of correct responses to each item.

Equation 1 presents the formula for the dichotomous Rasch model:

$$Pr\{X_{ni} = 1\} = \frac{e^{\beta_n - \delta_i}}{1 + e^{\beta_n - \delta_i}} \quad (1)$$

The model describes the probability  $Pr\{X_{ni} = 1\}$  that a student  $n$  with ability  $\beta$  correctly answers item  $i$  with the difficulty of  $\delta$ . The model takes the logarithm  $e$  of the raw scores into log-odds units to reflect the probabilistic relationship between persons and items. This transformation places persons and items on the same metric and then enables meaningful comparisons across persons and items, facilitating the fundamental principles of invariance in the Rasch model (Andrich & Marais, 2019; Sick, 2009).

Andrich (1978) further extended this model to a polytomous structure that is specifically designed for estimating Likert-type data, namely the Rating Scale Model (RSM), which also known as the Polytomous Rasch Model (PRM). In the RSM, item difficulty is reconceptualised as the threshold of endorsement for a Likert-type response category, such as “agree” or “strongly agree”, etc., which indicates the extent to which the respondent aligns with the Likert-type statement to select a particular category (Andrich, 1978; Sick, 2009).

Equation 2 is presented below.

$$Pr\{X_{ni} = x\} = \frac{e^{-\tau_{1i} - \tau_{2i} \dots - \tau_{xi} + x(\beta_n - \delta_i)}}{\sum_{x'=0}^{m_i} e^{-\tau_{1i} - \tau_{2i} \dots - \tau_{x'i} + x'(\beta_n - \delta_i)}} \quad (2)$$

Extending the original dichotomous Rasch model, the  $Pr\{X_{ni} = x\}$  of the RSM refers to the probability that person  $n$  responds in category  $x$  on item  $i$ . The latent trait level (e.g.

attitude, ability) of person  $n$  is parameterised as  $\beta_n$  and the item difficulty is parameterised as  $\delta_i$ . In addition, a set of ordered threshold parameters ( $-\tau_{1i} - \tau_{2i} \dots - \tau_{xi}$ ) is incorporated to represent the relative difficulty of moving from one response category to the next across items using the same rating scale structure (Andrich, 1978; Andrich & Marais, 2019).

It is important to note that raw Likert-type responses are ordinal in nature, as the distance between response categories cannot be assumed to be equal a priori. However, within the RSM, thresholds following a proper order sequence are required, such that  $-\tau_{1i} - \tau_{2i} \dots - \tau_{xi}$ . This sequence is of paramount importance when trying to build measures like the scales in this study which are indexed to a developmental continuum. If the order of the thresholds is reversed, the response categories may not function as intended and will not likely represent coherent growth (Andrich & Marais, 2019).

The RSM also expects the threshold parameters to be equal across the items, meaning each item shares the same set of category boundaries. Each item is located at a single point on the latent continuum that reflects its difficulty parameter, which indicates the average level of the trait required for selection across all response categories (Krabbe, 2016). As indicated in Chapter 2, Section 2.5.5, this requirement establishes a condition for distinguishing whether Likert-type responses function at the ordinal or interval level. In Rasch analysis, ordinal level data are transformed (equating) into logits (log-odds unit) measures, where a logit represents an additive unit on the latent continuum (Linacre, 2023). Logits measures allow meaningful comparison among items with different difficulty levels. When item thresholds are ordered and align with Rasch model expectations, Rasch estimates reported on the logit scale can be interpreted as interval-level measures of a latent construct (Andrich & Marais, 2019).

In studies using Likert-type formats, the Rasch analysis helps facilitate the diagnosis and correction of disordered category thresholds and supports the development of functioning response categories. For example, Saubern et al. (2019) applied Rasch analysis to an existing TPACK survey scale to examine and refine the construct of Australian teachers' overall level of TPACK. Supported by the Rasch analysis, the authors collapsed a seven-point Likert-type questionnaire into four categories and developed a qualitative construct map that articulated what it means to have more or less overall level of TPACK.

Similarly, Singer and Teclehaimanot (2019) re-examined Archambault and Crippen's (2009) 24-item TPACK Likert-type questionnaire using Rasch analysis with a sample of 165 online K-12 teachers in the U.S. Following the identification of disordered thresholds through Rasch analysis, the original five-point Likert scale collapsed into four ordered categories to improve the precision of the measurement. Notably, the result also revealed a conflation among the seven domains of TPACK framework, providing empirical support to the argument regarding the framework's unidimensional nature, as discussed in Chapter 2, Section 2.4.1 of the present study.

The present study explicitly applies Rasch model analysis, specifically RSM, to provide evidence to support the claim that the VT and ITTE are measurement scales where the items function in accord with the requirements of the Rasch model. The results of the Rasch analysis are presented in Chapter 6.

### **3.8 Chapter Summary**

This chapter's literature review provides the conceptual and empirical foundation for this study. First, the definition of ICT and its role in education was reviewed to establish the need for structured professional development opportunities that support teachers in successfully integrating ICT into classroom practice.

Second, the definition and forms of TPD within the context of this study were discussed. Seventeen critical features of successful TPD were identified from empirical literature and expanded upon. These features were then systematically mapped onto the three positive value domains of Eccles et al.'s (1983) EVT: attainment, intrinsic, and utility. Additional features representing the cost domain were identified based on barriers that may discourage teachers from participating in a TPD program. In total, twenty-one features were mapped onto the four value domains to operationalise the construct of the Value of TPD (VT) scale.

Third, extending the discussion of the TPACK framework introduced in Chapter 2, this section explored how TPACK can serve as evidence for the success of TPD programs for ICT integration into teaching. It distinguished between two research foci: TPD programs for ICT integration into teaching designed based on a TPACK framework, and those evaluated through a TPACK framework. In response to critiques of existing measurement instruments across both strands, the present study conceptualises teachers' perceived improvement in TPACK-core as resulting from participation in a given TPD program. This understanding forms the basis for the development of the present study's Improvement of TPACK-core via TPD Experience (ITTE) scale.

Fourth, student learning achievement was introduced as key to determining the success of a TPD program and the multifaceted nature of student learning achievement was clarified. Results from a high-stakes standardised test, specifically the Student Academic Attainment Test (SAAT) administered in Taiwan, were proposed as an example representing students' learning achievement.

Fifth, three major educational policies implemented in Taiwan that pertinent to this study were outlined: *Digital Learning Enhancement Plan*, *Bilingual Nation 2030* and the Student Academic Attainment Tests (SAAT). These policies provide the contextual basis for

the study, supporting the selection of constructs and the empirical evidence used to evaluate the success of a TPD program for ICT integration into teaching conducted in Taiwan.

Finally, two members of the Rasch family of measurement models, the dichotomous Rasch model and the Rating Scale Model were introduced. The usage of Rasch model in validating and modifying Likert-type instruments from previous studies was discussed in detail.

The following chapter presents the research methodology employed to address the present study's research questions.

## Chapter 4: Methodology

### 4.1 Introduction

This chapter presents the methods used to answer the following research questions:

- (1) To what extent do mathematics and EFL primary school teachers in Taiwan value a given TPD program for ICT integration into teaching?
  - a. What are the features of TPD that teachers value?
  - b. How do these features align with the four domains of value derived from Eccles et al.'s (1983) Expectancy-Value Theory?
  - c. To what extent does the measurement scale proposed in this study reflect the intended construct of the value of the TPD?
- (2) To what extent do primary school mathematics and EFL teachers in Taiwan perceive that the given TPD program for ICT integration into teaching has improved their TPACK-core?
  - a. How do items developed from existing TPACK questionnaires align with the context of TPD for ICT integration into teaching in Taiwan?
  - b. To what extent does the measurement scale proposed in this study capture teachers' perceived improvement in TPACK-core resulting from participation in the given TPD program for ICT integration into teaching?
- (3) To what extent do Taiwanese primary school mathematics and EFL teachers' ratings of the value of the given TPD program for ICT integration into teaching and their perceived improvement of TPACK-core through participation in the program correlate with their students' learning achievement?

## 4.2 Conceptual Framework

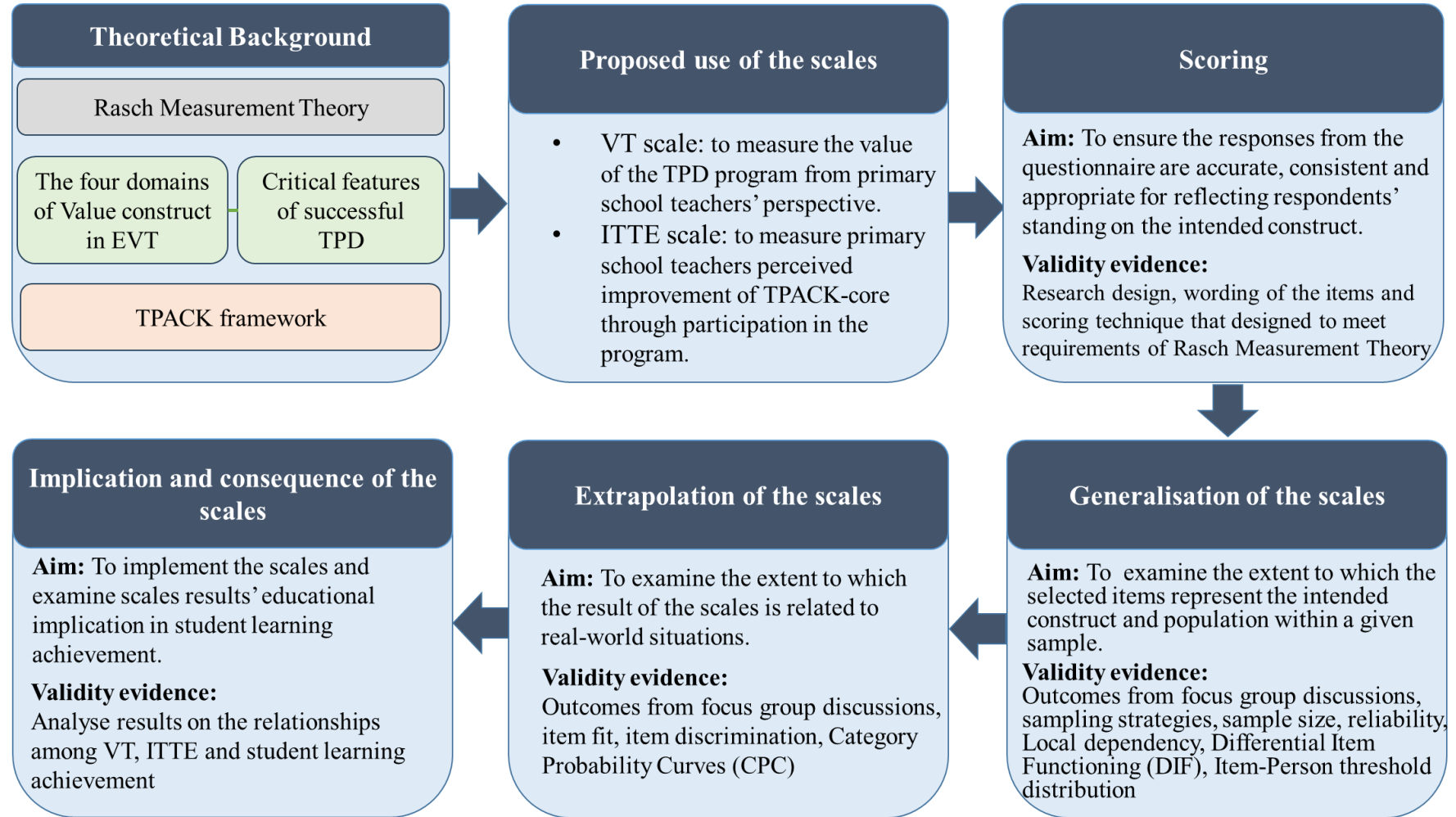
A conceptual framework is vital to this study, as it synthesises the research purposes and questions, underpinning theories, and reviewed literature to establish the theoretical rationale guiding methodological decisions (Ngulube et al., 2015). The conceptual framework of this study underpins the development and validation process for the study's two proposed measurement scales: The Value of TPD scale (VT scale) and the Improvement of TPACK via TPD Experience scale (ITTE scale).

The conceptual framework presented in Figure 4.1 is articulated across six stages: theoretical foundations, proposed use, scoring, generalisation, extrapolation and finally implications and consequences. The structure of the stages is based on Cook et al.'s (2015) evaluation process for generating evidence to contribute to Kane's (2006) argument-based validation framework (See Figure 4.1). This validation framework has been widely adopted in the United States where it is employed by the American Educational Research Association (AERA) and the National Council on Measurement in Education (NCME) as the foundation for developing standards in educational and psychological testing (AERA et al., 2014). A detailed description of these inferences is provided in Chapter 2, Section 2.6.

Each stage requires sufficient validity evidence to support or challenge assumptions (Kane, 2021). Cook et al. (2015) offer practical guidance on collecting such evidence using qualitative and quantitative approaches. Drawing on their guidance, this study outlines the purpose of each stage of inference and the corresponding forms of validity evidence gathered (see Figure 4.1).

**Figure 4.1**

*Conceptual framework for the development and validation of VT and ITTE measurement scales*



### **4.2.1 Theoretical Background**

The present study encompasses three core theoretical and methodological foundations: Expectancy-Value Theory (EVT) (Eccles et al., 1983; Eccles & Wigfield, 2020), Technological Pedagogical Content Knowledge framework (TPACK framework, Mishra & Koehler, 2006) and Rasch Measurement Theory (Rasch, 1960/1980).

As outlined in Chapter 2, Section 2.3, EVT serves as the theoretical foundation for identifying the value of TPD. This study specifically focuses on the value construct within EVT, which comprises four domains: attainment value, intrinsic value, utility value and cost. Features of successful TPD were discussed and assigned to these four domains to generate the draft construct of the VT scale. The TPACK framework underpins the construction of the ITTE scale which explicitly focuses on the TPACK-core.

Rasch Measurement Theory underpins the fundamental design principles for the development of the measurement scales. Quantitative data collected in the study were analysed using the Rasch rating scale model (RSM) to build the measurement scales (VT and ITTE) and provide evidence to support arguments for their validity.

### **4.2.2 Use of the Scales**

Establishing the proposed use of each scale is foundational to the entire scale development and validation process, as it determines the assumptions the scale must support and the type of evidence required to justify those assumptions (Cook et al., 2015; Kane, 2006). As presented in Figure 4.1, the proposed use of the VT scale is to measure the value of TPD from the perspective of primary school teachers, while the proposed use of the ITTE scale is to measure the teachers' perceived improvement in TPACK-core as a consequence of their participation in the TPD program.

### **4.2.3 Scoring**

During the scoring stage, the use of the measurement scales for producing accurate, consistent and appropriate measures of teacher perceptions of the extent of the value of TPD and the extent of perceived improvement to TPACK-core through participation in TPD for ICT integration into teaching were examined (Cook et al., 2015; Kane, 2006). The present study's presentation of research design, the wording of its indicators and the corresponding items, as well as the scoring techniques meeting the requirements of the Rasch Measurement Theory, serve as sources of validity evidence.

### **4.2.4 Generalisation of the Scale**

The generalisation stage aims to determine whether the items included in the scales adequately represent the intended constructs and the intended population (Cook et al., 2015; Kane, 2006). Validity evidence for this stage is drawn from sampling strategies, sample size and reliability, as well as analytical results from focus group discussions and Rasch analysis, including local dependency, differential item functioning (DIF) and Item-Person threshold distributions.

### **4.2.5 Extrapolation of the Scale**

During the extrapolation stage, the extent to which the scale results reflect a real-world situation is examined (Cook et al., 2015; Kane, 2006). Validity evidence is provided through the analytical results from focus group discussions and from Rasch analysis, such as item fit statistics, item discrimination, category probability curves (CPC) and threshold plot maps.

### **4.2.6 Implications and Consequences of the Scale**

Examination of implications and consequences is important for justifying the proposed use of the scale (Kane, 2006), especially regarding potential impact on students,

stakeholders and society (Cook et al., 2015). In this study, the relationships among the value of a TPD program for ICT integration into teaching, perceived improvement of TPACK-core through participating in the program and students' learning achievement are examined through the application of the VT and ITTE scales in a large-scale questionnaire survey. The findings are presented as validity evidence for the measurement scales.

The next section introduces the design of the present study and links it with the conceptual framework presented in this section.

### **4.3 Research Design**

In response to the research questions associated with the research purposes, a mixed-methods research design was applied to leverage data from both deductive and inductive approaches. The research design comprises three phases (see Figure 4.2): development, validation and implementation. Each phase contributes evidence to multiple stages of scale development and validation as outlined in the conceptual framework. Specifically, the development phase establishes the theoretical background and clarifies the proposed use of the scales. Validity evidence generated in the validation phase addresses the scoring, generalisation and extrapolation inferences of the scales. The implementation phase specifically provides evidence on the implications and consequences of implementing the scales in real-life.

As demonstrated in Chapter 2, Section 2.2, the data collection procedures within each phase were informed by the questionnaire development procedure outlined by Gehlbach and Brinkworth (2011). This resource details specific data collection steps using both deductive and inductive approaches, including literature review, focus group discussions with stakeholders and experts, as well as pretesting and pilot testing of the questionnaire. An overview of the research design, including the purposes of each data collection step corresponding to the development, validation and implementation phases of the present study,

is given in Figure 4.2. Alignments between the three phases, the data collection methods and the research questions are presented in Figure 4.3.

#### **4.3.1 The Development Phase**

This phase establishes the theoretical foundations of the VT and ITTE scales and clarifies the intended constructs and the use of the scales through an extensive literature review. As presented in Figure 4.2, this phase identified the critical features of successful TPD valued by teachers and systematically mapped these features onto the four value domains of EVT. Indicators derived from this mapping were generated to describe the construct and specify the questionnaire items developed in later stages of scale development. This phase also involved generating the preliminary items for ITTE questionnaire through a review of the assessment instruments commonly adopted in the studies related to the TPACK framework.

The outcomes of this phase address Research Question 1a: “What are the features of TPD that teachers value?” and Research Question 2a: “How do items developed from existing TPACK questionnaires align with the context of TPD for ICT integration into teaching in Taiwan?” (see Figure 4.3).

#### **4.3.2 The Validation Phase**

The validation phase provided validity evidence related to stages of scoring, generalisation and extrapolation for the development of the VT and ITTE scales, as articulated in the conceptual framework. As presented in Figure 4.2, five data collection methods are employed in this phase, including three focus group sessions, pilot testing of the questionnaire and a large-scale administration of the questionnaire. Multiple types of evidence were generated through these methods to support the validity of the two measurement scales.

The outcomes of this phase address Research Question 1b, “How do these features align with the four domains of value derived from Eccles et al.’s (1983) Expectancy-Value Theory?”,

Research Question 1c, “To what extent does the proposed measurement scale reflect the intended construct of the value of the TPD?”, and Research Question 2b “To what extent does the proposed measurement scale capture teachers’ perceived improvement in TPACK-core resulting from participation in the given TPD program for ICT integration into teaching?” (see Figure 4.3).

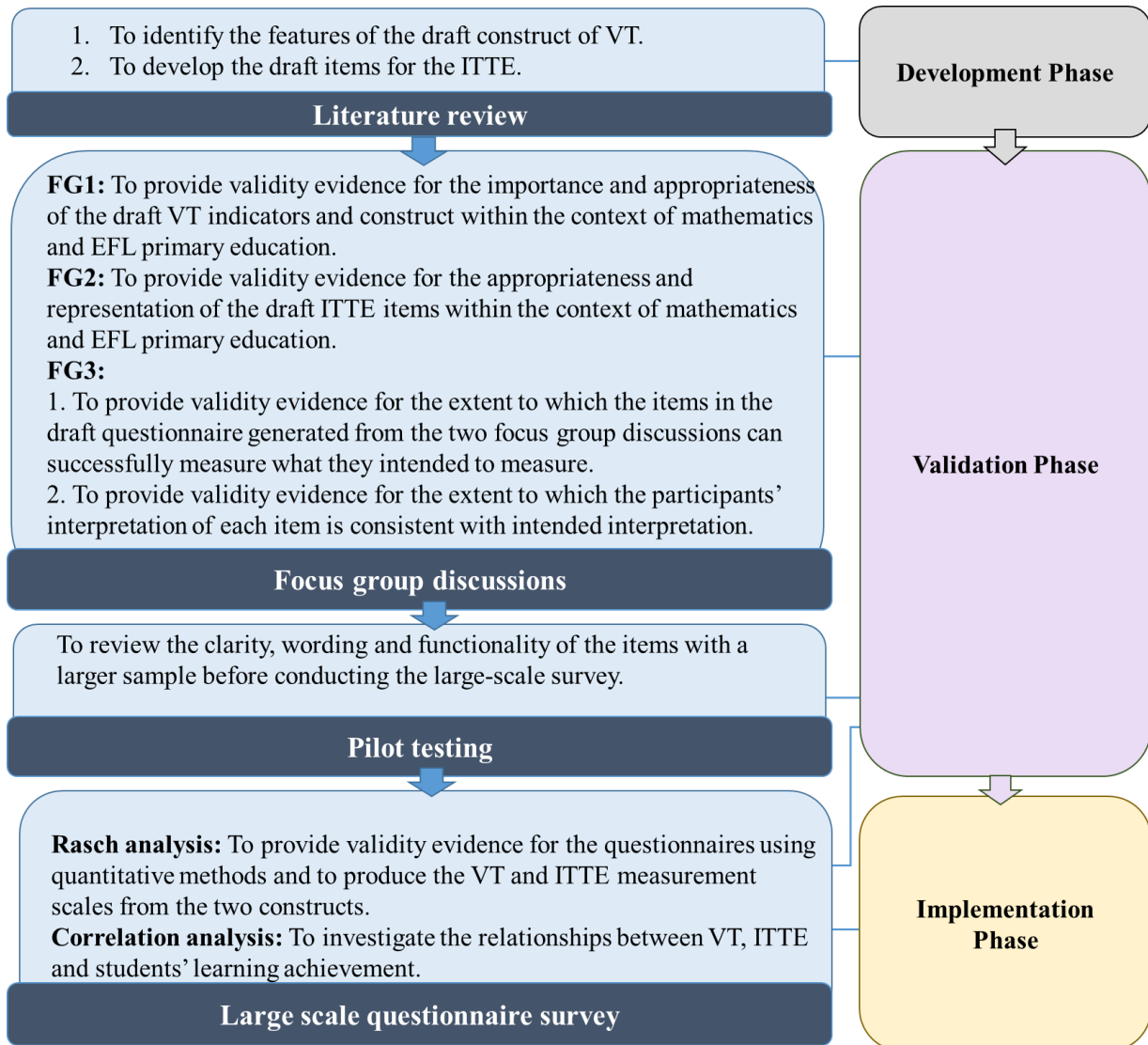
### **4.3.3 The Implication Phase**

The implication phase aimed to generate validity evidence addressing the implications and consequences of the scales. As presented in Figure 4.2, correlation analysis was applied to examine whether the VT and ITTE scales functioned as intended when applied in practice by examining how they relate to students’ learning achievement. In particular, the relationships between VT and students’ learning achievement, as well as between ITTE and students’ learning achievement, were investigated.

Findings from this phase address Research Question 3: “To what extent do Taiwanese primary school mathematics and EFL teachers’ ratings of perceived value of a given TPD program for ICT integration into teaching and perceived improvement of TPACK-core through participation correlate with their students’ learning achievement?” (see Figure 4.3).

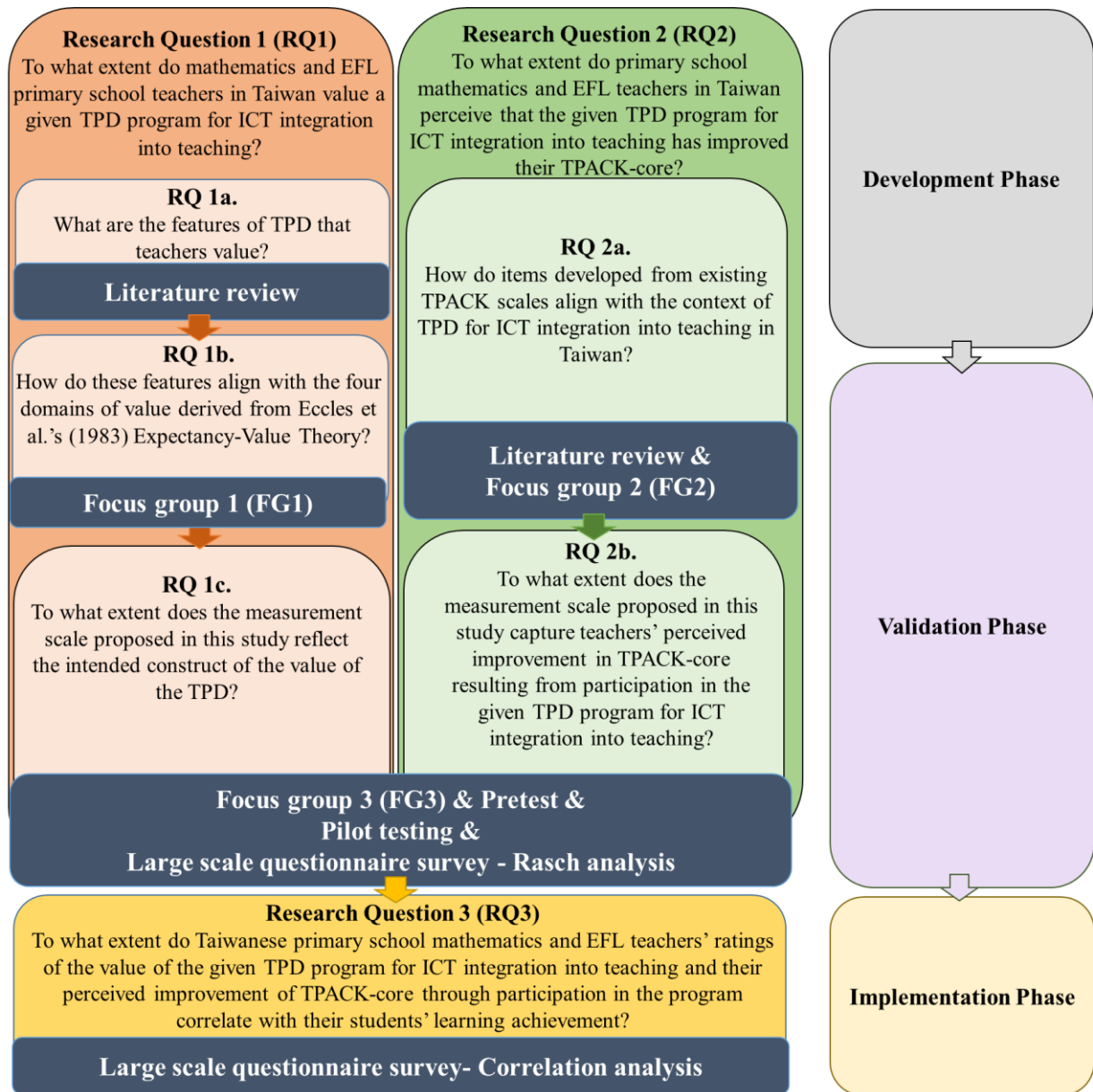
**Figure 4.2**

*Overview of research design*



**Figure 4.3**

*Research design and corresponding research questions*



#### 4.4 Data Collection Procedure and Methods

This section presents data collection procedures and methods. Data collection for the present study was carried out through focus group discussions, pilot testing and a large-scale questionnaire survey that included secondary data collected from the test score result of the Students' Academic Attainment Test (SAAT) conducted in Taiwan. As demonstrated in Chapter 3, Section 3.6, this study explicitly addresses TPD programs for ICT integration into teaching conducted across primary schools in Taiwan under the policy *Digital Learning Enhancement Plan*. The data for this study were collected from stakeholders of this program, including experts, designers and workshop lecturers involved in the TPD programs, as well as mathematics and EFL primary teachers who participated in the program. The timeline and procedures followed during each data collection method are presented in Table 4.1.

Following the literature review (see Chapter 3, Section 3.3.3), a draft construct of VT and a set of indicators corresponding to the construct were developed. Focus Group 1 (FG1) was conducted to review the draft construct and its indicators, thereby providing qualitative validity evidence for the VT construct. Based on feedback from FG1, items corresponding to the indicators were generated to form the draft VT questionnaire. These items were subsequently reviewed and pretested in Focus Group 3 (FG3).

In parallel, the draft items for the ITTE questionnaire were developed based on a review of existing related questionnaires (see Chapter 3, Section 3.4.1) and were reviewed during Focus Group 2 (FG2) to provide qualitative validity evidence for the items through the lens of in-service Taiwanese teachers. Revisions were made to the items based on FG2 feedback. The revised items were then reviewed and pretested with the VT questionnaire's items in FG3 to ensure consistency in item interpretation across both questionnaires.

After the focus group discussions, pilot testing was conducted to further examine the functionality and clarity with a larger sample base. The refined questionnaires were then administered in a large-scale questionnaire survey using online and paper-based formats.

**Table 4.1***Timeline and procedure for data collection*

<b>Duration</b>	<b>Type of data collection</b>	<b>Participants</b>	<b>Sampling</b>	<b>Procedure</b>
Two days in November 2023	Focus Group 1	6 experts and experienced in-service teachers	Purposive sampling	<ul style="list-style-type: none"> <li>• <b>Prior to the focus group</b> Sent the following documents to the participants via email.               <ol style="list-style-type: none"> <li>(1) Consent form</li> <li>(2) Discussion questions list</li> <li>(3) Importance questionnaire for draft construct and indicators of VT</li> </ol> </li> <li>• <b>During the focus group</b> The moderator guided the discussion based on FG1 discussion protocol.</li> <li>• <b>After the focus group</b> Sent transcription for double checking.</li> </ul>
Two days in November 2023	Focus Group 2	8 in-service mathematics and EFL teachers	Snowball sampling	<ul style="list-style-type: none"> <li>• <b>Prior to the focus group</b> Sent the following documents to participants via email:               <ol style="list-style-type: none"> <li>(1) Consent form</li> <li>(2) Discussion questions</li> <li>(3) Drafted items of the ITTE questionnaire</li> </ol> </li> <li>• <b>During the focus group</b> The moderator guided the discussion based on FG2 discussion protocol.</li> <li>• <b>After the focus group</b> Sent transcription for double-checking</li> </ul>

Table 4.1—*Continued*

Duration	Type of data collection	Participants	Sampling	• Procedure
One day in January 2024	Focus Group 3 & pre-testing	6 experts and experienced in-service teachers (Recall from Focus Group 1)	Purposive sampling	<ul style="list-style-type: none"> <li>• <b>Prior to the discussion</b> Sent the following documents to the participants via email:               <ol style="list-style-type: none"> <li>(1) Consent form</li> <li>(2) Discussion questions</li> <li>(3) Revised VT indicators and the corresponding items generated following FG1 discussion.</li> <li>(4) Summary of comparison between the initial draft ITTE items and revised ITTE items generated following FG2 discussion.</li> </ol> </li> <li>• <b>During the discussion</b> The moderator guided the discussion based on FG3 discussion protocol.</li> <li>• <b>After the discussion</b> Sent transcription for double-checking.</li> </ul>
Two days in June 2024	Pilot testing	16 in-service mathematic and in-service teachers	Convenience sampling	Participants were asked to fill in an online questionnaire survey and to provide feedback regarding the clarity and functionality of the items.
Two months in May and October 2024	Large-scale questionnaire survey	109 in-service teachers	Purposive sampling	Participants were asked to fill in an online questionnaire/paper questionnaire.

The following subsections discuss data collection methods.

#### **4.4.1 Focus Group Discussions**

Three rounds of focus group discussions (henceforth Focus Groups 1, 2 and 3) were conducted after the literature review to provide validity evidence for the development of the VT and ITTE scales through a deductive lens. To align with the study's focus on Taiwanese primary school teachers, the participants were required to be Taiwanese. Therefore, all focus group discussions were carried out in Mandarin. Traditional Chinese translation versions were provided along with the original English version to support the clarity of the documents. The translation procedure followed Human Ethics' Guidelines from the University of Sydney (2025). The original documents were translated by me, a native Mandarin speaker and Traditional Chinese user. These translated documents were then certified by another native Mandarin speaker and Traditional Chinese user, who is highly competent in both Mandarin and English, under the witness of a Justices of the Peace. The purposes, recruitment criteria and the procedures followed during each discussion are indicated as follows.

##### **Focus Group 1 (FG1)**

The purpose of FG1 was to collect evidence supporting the relationship between the draft construct of VT (domains and features) and the corresponding indicators of the VT scale. This study employed purposive sampling to select FG1 participants. Purposive sampling is widely used in studies with applied focus group discussions. It is a sampling technique that provides selected participants based on certain characteristics in line with research criteria (Memon et al., 2024).

Participants were recruited from the qualified lecturer list provided through the Taiwan Adaptive Learning Platform (TALP). The TALP is an official student digital learning platform developed by the Ministry of Education in Taiwan which also delivers a range of TPD programs for ICT integration into teaching nationwide.

This platform provides contact details for experienced in-service teachers who are verified as eligible designers and lecturers of these programs. To ensure participants were equipped with sufficient relevant knowledge, they were required to have the following background:

- (1) At least five years of academic experience in the field of Teacher Education or TPD.
- (2) Experience in designing TPD programs.
- (3) If possible, preferred experience in designing TPD programs related to ICT-integration into teaching.

or

- (1) Experience in designing TPD programs.
- (2) Have attended at least 54 hours of TPD programs within one year.
- (3) If possible, preferred experience in participating in or designing TPD programs related to ICT-integration into teaching.

At the close of recruitment, eight participants consented to join FG1. Of these, two participants dropped off a day before FG1 was to take place. Considering participants' differing travel distances and availabilities, the FG1 discussion was split into two groups and conducted using a hybrid format. Each group consisted of three participants. The findings of the FG1 discussion, presented in Chapter 5, Section 5.2, were synthesised using qualitative content analysis to generate evidence to support or challenge the validity of the VT scale.

The interview protocol and discussion questions for FG1 are presented in Appendix B. The questions elicit feedback on the VT construct as operationalised

through its domains and associated features, as well as the indicators corresponding to the features. Before the discussion, the participants were asked to rate the relative importance of each indicator of the draft VT by using a Likert-type format. Then during the discussion, they were asked to review and discuss the wording, translation, placement, sufficiency, importance and transferability of the draft VT construct using their experience in preparing and presenting TPD programs for ICT integration into teaching in Taiwan and their responses to the importance of the indicators.

### **Focus Group 2 (FG2)**

FG2 reviewed the draft items of the ITTE questionnaire using their knowledge of the TPD program for ICT integration into teaching. The participants in FG2 were identified by using a snowball recruitment technique. Snowball recruiting is a purposive method through which researchers start with a small group of initial participants who meet the selection criteria. These participants are then asked to recommend additional suitable participants until the targeted number of participants is reached (Parker et al., 2019). Initial participants were nominated by FG1 members. Since FG2 participants were required to be regular attendees at TPD programs for ICT integration into teaching and the individual attendance record for every TPD program is confidential under the regulations of the Ministry of Education in Taiwan, the process of using nominators was contextually suitable. Finding potential participants according to the recommendations from TPD lecturers and in-service teachers was more efficient and effective than more traditional sampling techniques. The recruitment criteria for FG2 were as follows:

- (1) Must have at least two-year teaching experience in primary schools in Taiwan.

- (2) Must have attended at least three ICT-related TPD programs within one year.
- (3) Must have a sound knowledge of TPACK framework.
  - i. The participants should know the TPACK framework and understand the meaning of each domain in the TPACK framework.
  - ii. The participants should realise TPACK-core refers to an understanding of how appropriate technologies and pedagogical techniques are effectively adopted in teaching content areas (Tondeur et al., 2017), as well as have knowledge of how proper technology helps students solve learning problems, construct their knowledge and build new teaching techniques and strengthen old ones (Koehler et al., 2017) instead of simply knowing how to adopt technologies to teaching.

Eight participants consented to take part in FG2. The FG2 discussion was conducted in a hybrid format, allowing participants to attend either face-to-face or online via a live meeting link within the same session. The eight participants were divided into two groups with four participants each to accommodate varying travel distances and availabilities participants.

The interview protocol, along with discussion questions for FG2, are presented in Appendix D. The questions were designed to seek feedback regarding the sufficiency, relevancy and appropriateness of the draft ITTE items. Qualitative content analysis was used to analyse FG2 transcripts and provide evidence to support the validity argument for the ITTE scale. The analytical results and findings of FG2 are presented in Chapter 5, Section 5.3.

Following the FG1 and FG2 discussions, draft VT and ITTE questionnaires were created based on the results and findings from discussions. The draft questionnaires were then reviewed during the FG3 discussion.

### **Focus Group (FG3)**

The purpose of FG3 was to consider the outcomes from FG1 and FG2 and further refine the questionnaires. The six participants of FG1, who served as professional lecturers and designers in TPD for ICT integration into teaching, were invited to take part in the FG3 discussion due to the difficulty of finding participants with the requisite knowledge and skills. At the end, five of the initial FG1 participants took part in FG3, with one dropping out because of illness a day before the FG3 session was to take place. Prior to the session, FG3 participants were asked to complete a draft of both of the surveys as part of the pretesting process associated with questionnaire development. During the discussion, they offered feedback regarding the wording, clarity, and functionality of the items in the VT and ITTE questionnaires. Qualitative content analysis was used to capture significant feedback as evidence to support the validity of the questionnaires. The results of FG3 are reported in Chapter 5, Section 5.4.

After modifying the draft survey questionnaires based on the outcomes of FG3, a pilot test and a large-scale questionnaire survey was implemented to collect further evidence from a quantitative perspective.

#### **4.4.2 Pilot Testing**

Pilot testing of the questionnaire was conducted before commencing a large-scale questionnaire survey. The purpose of pilot testing was to refine and modify the questionnaire and the survey procedure from a larger population perspective (Gehlbach & Brinkworth,

2011). Convenience sampling, in which participants are selected based on their availability and accessibility, was used in the pilot survey to recruit qualified participants efficiently within a short recruitment period (Onwuegbuzie & Collins, 2017). The target population for the pilot testing comprised mathematics and EFL teachers in primary schools in Taiwan, who had participated in the TPD program for ICT integration into teaching held by the Ministry of Education between July 2023 and July 2024.

The pilot questionnaire survey was presented in a five-point Likert format (rating from 1=strongly disagree to 5=strongly agree) and comprised three sections: questions for demographic information, the value of teacher professional development (VT), and those assessing the perceived improvement of the TPACK-core.

Two open-ended questions pertaining to questionnaire items and structures were added to the pilot test to collect respondents' feedback on the questionnaire:

- (1) "Please provide comments and suggestions regarding the items in the questionnaire."
- (2) "Please provide comments and suggestions regarding the overall structure of the questionnaire."

The pilot questionnaires were originally developed in English and subsequently translated into Traditional Chinese by the researcher, as the study was conducted in Taiwan and some participants were unable to fully comprehend the survey questions in English. The survey was administered online via Microsoft Form between 4 and 6 June 2024. Twenty qualified mathematics teachers and EFL teachers agreed to participate in the pilot testing of the draft questionnaire. Sixteen completed responses were received.

Following the amendment of the draft questionnaire based on the results of pilot testing, a larger-scale questionnaire survey was then conducted.

#### **4.4.3 Large-scale Questionnaire Survey and the Collection of Students' Learning Achievement Data**

As indicated in Section 4.3, the purpose of this large-scale questionnaire survey was to collect quantitative data to support arguments for validity of the questionnaires developed in the earlier phases of this study and to produce two measurement scales, one for VT and the other for ITTE. Through the lens of a TPD program for ICT integration into teaching conducted in Taiwan, it also sought to implement the study's two measurement scales by examining the relationship between mathematics and EFL teachers' perceptions of the VT and students' learning achievement. In addition, it investigated the relationship between teachers' perceived ITTE and their students' learning achievement. Test data were collected from standardised tests in English and mathematics as measures of the learning achievement of students across two consecutive years.

Data for the change in students' mathematics and English learning achievement were collected through the mathematics and English test score results from the SAAT conducted by the MOET (see Section 3.6). The test results of Year 5 students in mathematics and English in 2023 and the mathematics and English test results of Year 6 in 2024 from the same group of students were collected and subtracted to approximate the extent of change in students' learning achievement that had taken place over the year in which the teachers had completed their mandatory TPD program for ICT integration into teaching. To de-identify individual students' personal information, only the classes' test score results (i.e. the mean score results of students' test result in the class) were collected. The selection criteria for teachers participating in this questionnaire survey were as follows:

(1) They must have participated in the MOET's professional development programs from July 2023 to July 2024.

(2) They must have taught Year 5 English or mathematics before July 2023 and have been expected to teach Year 6 English or mathematics to the same group of students the next school year.

Purposive sampling was applied to identify potential participants. This type of sampling is suitable for the large-scale questionnaire survey conducted in this study, as only some primary school teachers in Taiwan met the required criteria: not all had taught the required year level and subject within the specific timeframe, and not all completed the required TPD by the end of this period.

As with the survey for pilot testing, the original English questionnaire was translated into Traditional Chinese by the researcher to enable Taiwanese participants to fully comprehend the survey questions. This large-scale questionnaire survey was administered to 127 qualified mathematics and EFL primary school teachers in Taiwan between the 15 May 2024 to 17 October 2023. Paper and online Microsoft form versions of the survey were made available to accommodate teachers' preferences. A total of 109 valid responses were obtained: a response rate of 86%. Analytical results, including the demographic information of participating teachers are presented in Chapter 6.

The next section discusses the analytical methods applied in the study.

## **4.5 Analytical Procedures and Methods**

### **4.5.1 Focus Group Discussions**

Qualitative Content Analysis (QCA) uses both inductive and deductive approaches (Elo & Kyngäs, 2008; Schreier, 2013). The collection and analysis of qualitative data typically align with the inductive approach, whereby measures are neither standardised nor pre-structured; this is in contrast to the deductive characteristics associated with quantitative data (Schreier, 2013). The QCA was deliberately applied inductively to produce outcomes

from the focus group discussions. These outcomes provided a source of validity evidence regarding the VT and ITTE scales.

Each focus group discussion served different purposes in generating validity evidence and addressing the research questions. For example, the purpose of FG1 was to refine the indicators and construct of the VT scale through a critical review of the draft VT construct and associated domains. Accordingly, transcripts from each focus group discussion were analysed using QCA and aligned with the specific purpose of each session. Transcribed data were analysed through the three-step general procedure of inductive QCA outlined by Elo and Kyngäs (2008), namely preparation, organising and reporting. Details of these procedures are outlined here.

### **Preparation**

At the beginning step of QCA, meaningful words, sentences and themes (i.e. units) in relation to the research questions and purposes of each focus group were identified from the transcripts (Elo & Kyngäs, 2008; Schreier, 2013; Vears & Gillam, 2022). This step involved a repeat reading of transcripts and relevant material to capture the whole picture of the coding frame. In the present study, transcript data for each focus group discussion were initially categorised according to the discussion questions outlined in Appendices 1, 3 and 4. The original transcripts of the focus groups were collected in Mandarin and were translated into English.

### **Organising**

The next step involved open coding of meaningful units from transcribed data and classifying relevant units under broader and higher-order categories (Elo & Kyngäs, 2008). The grouping of the codes and the naming of the higher-order categories was undertaken carefully to ensure that groupings captured insights on

describing a phenomenon (Elo & Kyngäs, 2008; Erlingsson & Brysiewicz, 2017). The labels of categories were designed to be concise and aligned with the research purposes (Erlingsson & Brysiewicz, 2017).

In this study, the labelling of coding categories was linked directly to the purposes and questions guiding the study, the conceptual framework, and the specific purposes of each focus group discussion. For example, the term “Sufficiency” was used as a category label in the FG1 transcripts to reflect the purpose of the FG1 discussion, which is outlined in Chapter 4, Figure 4.2, “To provide validity evidence for the importance and appropriateness of the draft VT indicators and construct within the context of mathematics and EFL primary education”. (p. 106).

## **Reporting**

At this step, the analytic decisions, analytical process, and the results are systematically presented (Elo & Kyngäs, 2008). A concise, well-organised and high-level interpretation of findings is essential to ensure trustworthiness (Erlingsson & Brysiewicz, 2017; Vears & Gillam, 2022). In this study, the analysis results are outlined in Chapter 5, while the in-depth discussion of these findings, and integrated topics in conjunction with the results from other steps of the study are presented in Chapters 7, respectively.

### **4.5.2 Pilot Testing**

Data collected from the pilot testing in this study were used to identify problematic wording, structures, or procedures on a larger sample of participants before conducting the large-scale questionnaire survey (Creswell & Clark, 2018; Kishore et al., 2021; van Teijlingen & Hundley, 2001). As the pilot testing included two additional open-ended questions on feedback on the survey items and overall structure, its analysis was conducted in Microsoft

Excel to integrate both numerical and textual responses. The quantitative responses were examined using descriptive statistics (e.g., item means, standard deviations and response distributions) to detect the extreme skewness and inconsistent response distributions. The two open-ended questions were analysed using a directed content analysis approach. Responses were coded to identify issues such as ambiguous wording, item redundancy, and a less-intuitive survey structure.

The analysis results of pilot testing are presented in Chapter 6, Section 6.2. Revisions undertaken based on the pilot testing results had improved the content clarity and usability of the questionnaire before its implementation in the main large-scale questionnaire survey (Creswell & Clark, 2018).

#### **4.5.3 Large-scale Questionnaire Survey**

After the raw data were cleaned, three types of quantitative analysis were conducted. First, descriptive analyses were undertaken to calculate the item means and standard deviations of the scales by using IBM SPSS software (Version 29, 2024). Second, a Rasch analysis was performed using the RUMM2030+ package (2025) to evaluate the extent to which the scales functioned as measures with items that conform to the requirements of the model (Rasch, 1960, 1980). Finally, a correlation analysis was conducted using IBM SPSS software (Version 29, 2024) to investigate the relationships between VT, ITTE and student learning achievement.

##### **RSM Analysis**

This study applies Rasch theory to determine the extent to which the VT and ITTE scales function as intended (Rasch, 1960). As the format of the scale in this study followed items of a Five-point Likert Rating format, the Rating Scale Model (Andrich, 1978, Andrich & Marais, 2019) was used.

Rating Scale Model is appropriate if the data fits the model. If they do not fit then this would weaken the proposed arguments for the validity of the measurement scale validity (Kane, 2021). The implementation of Rasch analysis in this study consisted of eight steps: Calculate item locations and teacher measures, examine scale fit to Rasch model, check scale reliability, analyse individual item and person fit, assess local dependency, examine differential item functioning (DIF), target the scale, evaluate response structure. A summary of the procedure of Rasch analysis is presented in Figure 4.4.

### ***Step 1. Calculate item locations and teacher measures for the scales***

The first step of the Rasch analysis was to calculate item locations (difficulties) and teacher measures (teacher locations). In this step, the ordinal Likert-type questionnaire responses were modelled to estimate interval-level measures (logits), thereby placing teachers and items on the same latent continuum (scale). This step is the foundation of the entire Rasch analysis. The subsequent steps are the validation process to determine whether the scale functions as intended and adequately represents the underlying construct, guided by the five requirements of Rasch Measurement Theory. These calculations can be done automatically by RUMM2030+ software, after inserting the questionnaire responses and items formats.

### ***Step 2. Examine Scale Fit to Rasch Model***

The second step is to examine the fit between the data and the model (i.e. data-model fit) to ascertain the extent to which the scale aligned with the expectations of Rasch model. This fit can be examined through the distribution of standardised residuals, which present the difference between the actual observed score and the expected score value in the Rasch model. Results showing approximately 5% or fewer

of all the responses with  $\geq 2$  standardized residuals and about 1 % or fewer of all responses with  $\geq 3$  standardized residuals were considered to give satisfactory fit to the model (Linacre, 2023). In RUMM2030+ software, the fit of the data to the scale was presented in a Summary Statistics panel, which displayed the result of Chi-square statistics, item and person residual statistics and reliability statistics.

### ***Step 3. Check Scale Reliability***

The internal consistency reliability of the scales was examined using the person separation index (PSI) and Cronbach's alpha. A value of over 0.7 on Cronbach's alpha is considered an acceptable value to support the reliability of a scale (Andrich & Marais, 2019).

### ***Step 4. Analyse Individual Item and Person Fit***

This step aimed to examine differences between observed responses and those expected under the Rasch model by applying Item-Person fit residual statistics. Specifically, it examined the extent to which an individual item and person's response pattern align with the expectation of the underlying latent construct (e.g. the value of TPD) (Bond et al., 2020). Acceptable fit was indicated by a non-significant chi-result result ( $p > 0.05$ ) and z-standardized fit residual statistics within  $\pm 2.5$ .

### ***Step 5. Assess Local Dependency***

Local independence is one of the fundamental requirements of the Rasch model, which means that responses to individual items should be statistically independent after controlling for the latent construct (e.g. the value of TPD). The residual correlation coefficients of the items were used to determine local dependence. However, there is no specific cut-off value for indicating independence based on the literature (Christensen et al., 2017). The value of 0.3 has been commonly used by

researchers (e.g. La Porta et al., 2011; Røe et al., 2014), but critical values of 0.1, 0.2, 0.5 and 0.7 were also found in use (e.g. Davidson et al., 2004; González-de Paz et al., 2015; Marais & Andrich, 2008; Yen, 1993).

Christensen et al. (2017) conducted a study to identify the cut-off value for confirming local dependency but found that the value of residual correlation was significantly impacted by sample size and the number of the items. For example, with polytomous items, a sample size below 200 could result in a larger residual correlation coefficient, while the coefficient shrank closer to zero when the sample size grew to 1000.

#### ***Step 6. Examine Differential Item Functioning (DIF)***

DIF refers to the presence of differences in how the items function across different participant backgrounds in groups. Within Rasch Measurement Theory, items are expected to function equivalently across relevant subgroups of teachers, such as subject of teaching and years of teaching experience, to support the requirement of measurement invariance. This invariance is a prerequisite for the generalisability of the VT and ITTE scales, as it ensures that measures have the same meaning across different groups of teachers. Thus, the DIF of a scale needs to be examined when there are expectations that items function differently across different participant backgrounds in groups. The results of the Analysis of Variance (ANOVA) of group, a statistically significant main effect of interaction ( $p < 0.05$ ), were taken as evidence of DIF (Andrich & Marais, 2019).

In the present study, items in the VT scale were designed to measure teachers' perceptions on the value of the TPD program, and to be broadly applicable to teachers from different backgrounds. The theoretical basis of the ITTE scale (the TPACK

framework) has been predominantly applied in science-related education studies (Tseng et al., 2020). Extending its application to language education, as in this study, may raise the possibility that some items could function differently across different subjects. Therefore, there is a need to examine the DIF by teaching subjects to provide evidence of the generalisability of ITTE scales beyond education studies focused on the science-related domain.

DIF across teachers with different lengths of teaching experience was also examined for the ITTE scale. This decision was based on prior evidence indicating significant differences between novice and experienced teachers' perceived TPACK-core levels following their participation in a TPD workshop for ICT integration into teaching (Nazzari et al., 2019). Such findings suggest that teaching experience may influence teachers' learning process and perceived improvement in TPACK-core.

Accordingly, DIF analysis was conducted to evaluate whether ITTE items maintain measurement invariance across difference lengths of teaching experience.

### ***Step 7. Targeting of the Scale***

A well-targeted scale presents a distribution of item difficulties that closely aligns with the distribution of person abilities. The targeting of the scale was visualised using the Person-Item Distribution Map on Rumm2030+ which presented the distribution of person abilities and item difficulties.

### ***Step 8. Evaluation of the Response Structure***

The response structure was visualised using the Category Probability Curves (CPC) on Rumm2030+. These were expected to cover the full range of respondent abilities. For example, when examining the VT scale, it was expected that each item on CPC would successfully capture the full range of the value of TPD in order, ranging from “strongly disagree” to “strongly agree”.

**Figure 4.4**

*Flow chart for Rasch analysis procedure*

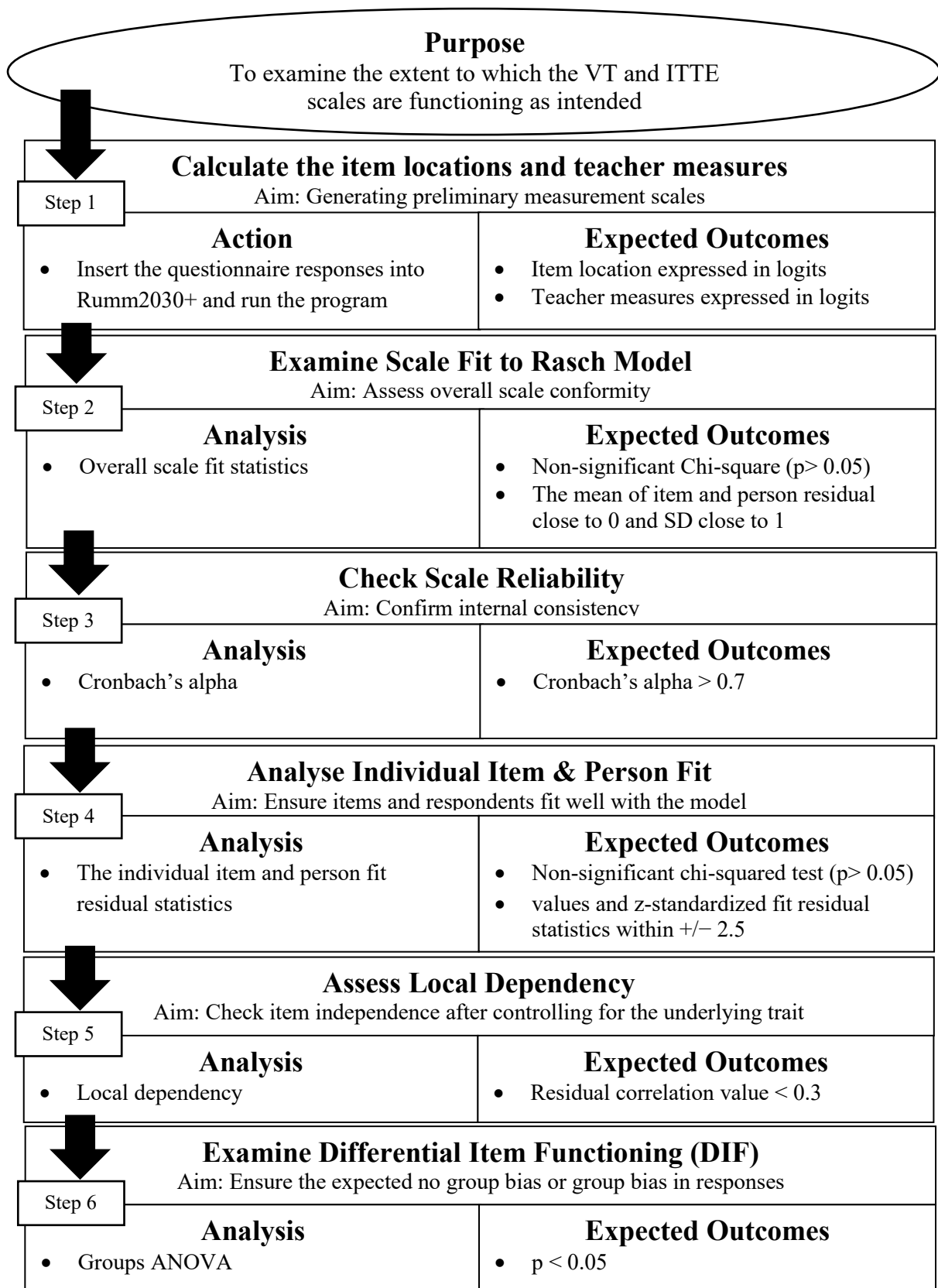
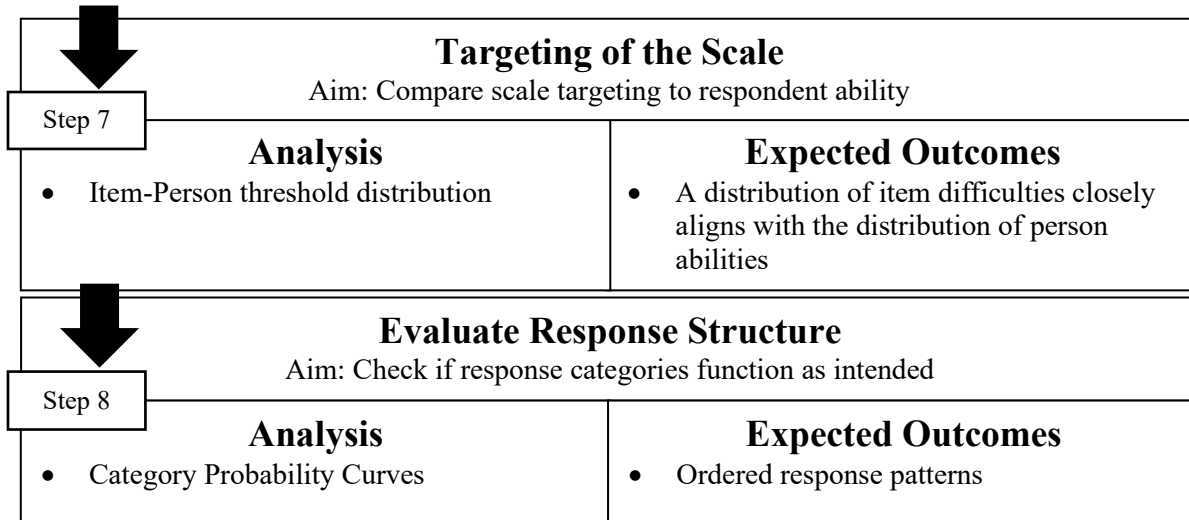


Figure 4.4 —Continued



### Correlation Analysis

Correlation analysis was used to answer Research Question 3, which represents the implementation phase of the two developed measurement scales: the VT scale and the ITTE scale. As outlined in Chapter 3, Section 3.5.1, the correlation analysis conducted in this study is explicitly exploratory in nature, aiming to examine the extent to which the VT and ITTE scales function as intended when applied in practice by exploring their associations with an external variable, students' learning achievement, without the intention of serving as an evaluation analysis for a program's success. Specifically, this analysis investigates two relationships: the first is between teacher perceptions of the value of a TPD program for ICT integration into teaching and students' learning achievement, and the second is between teachers' perceived improvement in TPACK-core following participation and students' learning achievement.

This analytical method measures the strength of the linear relationship between pairs of variables, such as the VT and students' learning achievement, as well as the ITTE and students' learning achievement. Pearson's correlation coefficient

analysis was applied to investigate these relationships, with the analyses conducted using IBM SPSS software (Version 29, 2024). It is important to note that the variables analysed using Pearson's correlation coefficient are required to be measured on an interval or ratio scale (Field, 2024). However, the five-point Likert rating scale applied in the large-scale questionnaire survey of this study is usually regarded as providing ordinal data (Bishop & Herron, 2015). Therefore, prior to conducting the correlation analysis, the data were transformed from ordinal to interval-level data (logits) using the Rasch model.

The data reflecting students' learning achievement were derived from the standardised z-score differences of the same group of students across two consecutive years of Student Academic Attainment Test (SAAT) results. Since the administration of the two tests may differ in difficulty and score distribution, the raw scores from each year of tests were transformed into standardised z-scores. This standardisation places both years on the same metric to provide a standardised indicator of students' learning achievement (Andrade, 2021; Klein, 2014).

As the national-level standard deviation of the students' SAAT score results were not available, the present study focused on the mean score and standard deviation of the SAAT results collected in the present sample. Thus, the formula of the standardised z score applied in this study is presented below, where  $x$  is student SAAT score,  $\bar{x}$  is the mean of student test score results collected in this study, and  $S$  is the standard deviation of the student test scores collected in this study.

$$z = \frac{x - \bar{x}}{S} \quad (3)$$

Students' learning achievement was calculated by taking the difference between standardised z-scores across the two consecutive years. The formula applied

in this study is presented below, where  $z_1$  is the z-score for 2023 SAAT,  $z_2$  is the z-score for the 2024 SAAT,  $x_1$  is the student 2023 SAAT score,  $\bar{x}_1$  is the mean of student test score results in that year,  $x_2$  is the student 2024 SAAT score,  $\bar{x}_2$  is the mean of student test score results in that year,  $S_1$  is the standard deviation of the students test scores in 2023 SAAT and  $S_2$  is the standard deviation of the student test scores in 2024 SAAT.

$$z_1 - z_2 = \frac{x_1 - \bar{x}_1}{S_1} - \frac{x_2 - \bar{x}_2}{S_2} \quad (4)$$

#### **4.6 Ethical Considerations**

The present study did not violate participants' human rights or any social science research ethics. Approval for commencing the data collection was granted by the Human Research Ethics Committee (HREC) at the University of Sydney with Protocol Number 2023/HE000499 (Appendix I). All processes for data collection, analysis and reporting strictly followed the research proposal approved by HREC.

Prior to data collection, the researchers sought the consent of participants in both focus groups and the large-scale questionnaire survey and clearly informed them regarding the purpose, information and procedures of the study by providing them with a Participant Information Statement (PIS) and Participant Consent Form (PCF). Before commencing the investigation, participants were required to sign and return the PCF. All participants had the authority to drop out before or during the investigation.

All data collected were treated with the strictest confidentiality and anonymity. Identifying information was removed and participants were assigned coded identifiers. Participants in the focus group discussions were coded with letters of the English alphabet corresponding to their focus group (e.g. F1). For example, participant A in the first focus group was identified as A\_F1. Questionnaire responses were coded numerically following the

order of the response. For example, the first returned response was coded as 1. As a result, no personal information can be identified from the study.

All research materials, including audio-recording and transcripts of the focus group discussions, as well as the responses to pilot testing and the large-scale questionnaire survey, were stored on the University of Sydney's Research Data Store (RDS). Access to these materials is restricted to the research team only. No research materials were saved on the personal devices of the researcher.

#### **4.7 Chapter Summary**

This chapter outlined the conceptual framework, research design, data collection and analysis procedures of this study, all of which are aligned with the study's research purposes and questions. First, the conceptual framework was grounded in Expectancy-Value Theory, the TPACK framework and Rasch Measurement Theory, and was structured using Kane's (2006) argument-based validation framework. Second, the chapter introduced the three research phases designed to address the research questions: development, validation and implementation. Third, it detailed three types of data collected, along with respective collection methods and procedures: focus group discussions, pilot testing and a large-scale questionnaire survey combined with secondary student achievement data. Fourth, the analytical methods and procedures applied to the data were discussed to present the systematic procedure of obtaining validity evidence supporting the findings of the study. Finally, the ethical considerations of the study were outlined. The next chapter presents the findings of the focus group discussions.

## **Chapter 5: Validation Analysis: Focus Group Discussions**

### **5.1 Introduction**

This chapter presents the results and findings from three separate focus group meetings as evidence supporting the validity of this study's Value of TPD (VT) and the Improvement of TPACK-core via TPD Experience (ITTE) scales.

Participants' responses to the interview questions were categorised into discussion topics according to relevance to the content. Direct statements were quoted to support validity arguments for the initial prototypes of the measurement scales. The findings address Research Questions 1 (RQ1) and 2 (RQ2, See Chapter 4, Section 4.3). The findings of each focus group discussion are presented in the following sections.

### **5.2 Focus Group 1 Discussion**

Focus Group 1 (FG1) participants were six experts and experienced primary school teachers who have engaged in designing and lecturing TPD programs for ICT integration into teaching. They were requested to provide comments on the draft VT construct developed during this study's literature review. Each participant received a list of discussion questions and was presented with the draft VT construct, including the indicators identified from the literature review and their corresponding domains of value as derived from Eccles et al.'s (1983) Expectancy-Value Theory (EVT).

In addition, they were provided with a questionnaire using a three-point rating format to rate the importance of each indicator (see Appendix C). The purpose of administering the questionnaire was to gather information on how FG1 participants perceived the relative importance of each indicator, which corresponds to the VT features, in assessing the value of a TPD for ICT integration into teaching. This information provided empirical evidence to support the inclusion of the VT features and the corresponding indicators identified during the literature review.

As presented in Chapter 4, Section 4.3, the findings of FG1 discussions specifically address the first two sub-research questions of RQ1, including RQ1a and RQ1b. The discussion questions (Appendix B) focused on wording, translation, placement, sufficiency, importance and transferability. These focal points were further categorised into three major topics, aligned with Kane's (2006) argument-based framework, as the evidence for the scoring, generalisation and extrapolation of inferences of the VT construct.

### **5.2.1 Evidence for the Scoring of Draft VT Construct**

Two key themes emerged under this topic: wording and translation. A summary of the modifications used in scoring the VT construct are presented in Table 5.1.

**Table 5.1***Modifications to the VT construct for Scoring*

Key themes	Initial descriptions of features	Initial descriptions of corresponding indicators	Modifications based on participants' comments
Wording	(2) Recognises the experience and prior knowledge of teachers	A2. Recognise the experience and prior knowledge of teachers	Indicator A3 "Provides customised content based on teachers need" and A4 "Provides a variety of courses for teachers to choose" were added under this feature.
	(6) Provides well-qualified instructors	I2. Provides well-qualified instructors	The word "instructors" was replaced with the word "educators" in both Feature 6 and Indicator I2.
	(18) Time-consuming	C1. Is time-consuming	The original indicator was replaced with three indicators for specifying different types of time costs: C1. Takes time to rearrange the class timetable C2. Takes time in the process of training C3. Takes time to work on the follow-up tasks
	(17) Carried out over a sustained period	Uncategorised. Carried out over a sustained period	Replace "Sustained Duration" with "Recurrent Training".
Translation	x	Cost domain The Chinese descriptions of indicators	Remain the same Added an explicit "target" to each feature and indicator and rephrased the descriptions of indicators to begin with an action "verb".
	(12) Provides convincing exemplary material	U5. Provision of convincing exemplary material	The Chinese version of this feature and the corresponding indicator were amended to avoid confusion with other indicators.

## **Wording**

Although the selection and presentation of terminologies (wording) in the VT construct were initially based on previous studies, participants in FG1 pointed out that some terminologies used in the construct might not align with the context of TPD in Taiwan. For instance, the naming of Feature 17 (Carried out over a sustained period) was drawn from Bates and Morgan (2018) and Bayar (2014), who suggested that sustained TPD courses are more effective than one-off workshops. However, participant F\_1 noted that this type of sustained and long-term TPD is more commonly referred to as “Recurrent training”:

We usually say it’s... continuous recurrent... recurrent... training, just like that.

Teachers will be clearer because usually, we have a program, and after the program is executed, it's a one-time thing, or...

Participant F\_1 further clarified the distinction between multi-day TPD courses and the continuous, sustained TPD courses referred to in the present study:

Three days refers to completing a three-day course, but if it's continuous, usually, we'll have this so-called “Recurrent” and then come back after a while to renew the new knowledge.

Another case is the use of the term “instructors” in Feature 6 corresponded to indicator I2 (Provides well-qualified instructors). This was originally derived from Bates and Morgan’s (2018) study, where it was used to describe the instructor who delivers TPD content during workshops. However, before the discussion, a participant argued that on the importance questionnaire, “educator” might be a more appropriate term than the original term “instructor”. Participants A\_1, B\_1, and C\_1 agreed with this suggestion during the discussion. Participant A\_1 explicitly stated that the term “instructor” might cause misunderstanding, and that “educator” is a more precise term in the TPD context in Taiwan:

I agree because when I provide instructor feedback, there may be a misunderstanding. I'm unsure about the target. But if we should say "provide educators", then I can more clearly relate it to the fact that when I'm learning, the instructions provided by the educators can genuinely enhance my achievement value. It's about providing feedback from the edu... to provide feedback from the educat(or)...

As VT construct and corresponding VT scale were developed through the lens of primary school teachers in Taiwan, it is necessary to ensure that the terminology is aligned with the Taiwanese context (Shaffer & Postlethwaite, 2012). Accordingly, the initial wording of Feature 17, which corresponded to indicator I2 (Provides well-qualified instructors), was changed to "Provides well-qualified educators".

In addition to revising the selection of terminologies, participants pointed out that the description of some features and indicators required further clarification and should include more indicators to suit different contexts. Participant F\_1 argued that Feature 18 corresponded to Indicator C1 (Is time-consuming), needs to be clarified regarding the type of tasks, such as "subsequent tasks" or the duration of the workshops. In the relevant literature, the time cost from participating in a TPD is commonly regarded as the need to reschedule classes with colleagues (Krille, 2020) or conflicts between the timing of the TPD and teachers' daily scheduled commitments (Fang et al., 2021; OECD, 2019). Following Participant F\_1's suggestion, Indicator C1 (Is time-consuming) was restructured as follows: C1 (Takes time to rearrange the class timetable), C2 (Takes time in the process of training), and C3 (Takes time to work on the follow-up tasks).

For Feature 2 (Recognise the experience and prior knowledge of teachers) corresponded to Indicator A2, Participant A\_1 suggested adding another indicator with the intention of providing customised content for teachers based on their needs, due to the

diversity of teachers' learning backgrounds in ICT. She further explained that some teachers are "novices", and some are "experienced", and their needs for TPD content for ICT integration into teaching are different. This suggested change aligns with Nazari et al.'s (2019) research, which states that the design of TPD programs for ICT integration into teaching should be tailored to the needs of experienced teachers and novice teachers. Accordingly, this change was made.

Participant D\_1 pointed out that the indicators within the attainment, intrinsic and utility value were described positively, whereas the cost domain indicators were framed negatively. This inconsistency could confuse the questionnaire respondents, especially if the items were also presented as negative statements. Thus, Participant D\_1 suggested considering the description of the cost domain in positive wording. He gave an example that Indicator C1 (Is time-consuming) and its corresponding item can be rephrased in a positive statement by "emphasising the meaningfulness of time spent, even though it's time-consuming".

From a theoretical perspective, however, the cost domain within EVT is explicitly defined as the negative perceptions or barriers associated with undertaking a task, which may decrease the overall perceived value of the task (Eccles et al., 1983). In the present study, the indicators of the cost domain were derived from empirically identified barriers that may discourage teachers from participating in TPD for ICT integration into teaching. There was an argument advanced within the FG1 that rewording these indicators positively could potentially lose the original meaning of the VT construct. Furthermore, the inclusion of negatively worded (reverse-scored) items can help detect whether respondents read the questions carefully and may reduce response bias (Paulhus, 1991).

Nonetheless, participants in FG1 indicated that mixing positive and negative descriptions on the items within the VT scale could lead to confusion among respondents and thereby decrease the reliability of the measures. Their concerns echo arguments made in previous studies (e.g. Suárez-Álvarez et al., 2018; Swain et al., 2008; Vigil-Colet et al., 2020), which suggests that mixing positively and negatively worded items in Likert-type formats may, in fact, reduce reliability due to respondents' misinterpretation of the negatively framed items.

Accordingly, the negatively worded statements describing the indicators in the cost domain were retained to preserve their original theoretical meanings. However, the VT questionnaire items generated following the FG1 discussion and corresponding to these indicators were phrased positively to enhance clarity and reduce potential response errors. For example, the item corresponding to Indicator C2 (Takes time in the process of training) was phrased as "The time spent on the training is efficient."

## **Translation**

The quality of translation is crucial in ensuring consistency in meaning between the original English and translated Chinese versions of the VT construct (Benlidayi & Gupta, 2024; Sha & Immerwahr, 2018). Participants noted several grammatical issues with the Chinese version of the VT construct. For example, Participant E\_1 agreed to the concise wording of the English version yet noted that more detailed elaboration in the Chinese version of the VT construct was needed to meet Chinese conventions.

Participant A\_1 also argued that the Chinese description of the draft VT construct was not aligned with the Chinese writing logic. They emphasised that in Chinese, a "target" is required when constructing a Chinese sentence, such as "providing opportunities for learners

to learn actively” or “providing appropriate opportunities for learners to conduct collaborative learning”.

Participant D\_1 suggested starting every sentence with a “verb” to better align with the Chinese conventions, illustrating this with the example: “This course should stimulate learning and encourage members to learn actively”. Participant D\_1 further addressed the use of the term “material” in Feature12 corresponded to Indicator U3 (Provision of convincing exemplary material) might cause confusion for Chinese speakers since the term “material” is used synonymously in other places in the construct, such as Feature 14 (Provides teaching materials), yet the meaning of “material” in Feature 14 was different. According to FG1’s feedback, the Chinese version of the VT construct and the indicators were revised, and the revision was agreed upon by the FG1 participants.

### **5.2.2 Evidence for the Generalisation of the VT Construct**

Participants’ comments supporting the extent to which the draft indicators of the VT construct represent the intended VT construct in the context of Taiwan (generalisation) are presented next. Two key themes evolved: placement and sufficiency. A summary of the modifications made to the VT construct, which improved the evidence supporting the generalisation inference of the VT features and their corresponding indicators, is presented in Table 5.2.

**Table 5.2***Modifications to the VT construct for Generalisation*

Key themes	Initial descriptions of feature	Initial descriptions of corresponding indicators	Modifications based on participants' comments
Placement	(6) Provides well-qualified instructors	I2. Provides well-qualified instructors	This feature was recategorized as one of the indicators in Feature 11 (Aligns with current demands and visions) in the utility value domain, following Indicator U2 (Aligns with schools' needs).
	(11) Aligns with current demands and visions	U4. Aligns with teachers' needs	Indicator U4 (Aligns with teachers' needs) was recategorized as one of the features in the attainment value domain. Three indicators corresponding to this feature were added: A2. Recognises the experience and prior knowledge of teachers. A3. Provides customised content based on teachers' needs. A4. Provides various courses for teachers to choose from.
	(13) Provides follow-up support	U6. Provides follow-up classroom observations and feedback U7. Provides follow-up advisory service	Two indicators, "Provides recurrent training" and "Provides follow-up course design and suggestions" were added to correspond with Feature 13, and the order of the indicators was changed as follows: U6. Recurrent training U7. Provides follow-up advisory service
	Uncategorised	Carried out over a sustained period	U8. Provides follow-up course design and suggestions U9. Provides follow-up classroom observations and feedback

Table 5.2—Continued

Key themes	Initial descriptions of feature	Initial descriptions of corresponding indicators	Modifications based on participants' comments
(continue) Placement	(16). Provides teaching materials	U10. Provides teaching materials/equipment from the program organisers U11. Provides teaching materials/equipment from the schools	Deleted “equipment” in Indicator U10 (Provides teaching materials/equipment from the program organisers) (reordered as U12), and separated the original Indicator U11 into two indicators, U13 and U14. The reordered and revised indicators for this feature are shown as follows: U12 Provides teaching materials from the program organisers U13 Provides teaching materials from the schools U14 Provides teaching equipment from the schools
	(4) Provides career advancement	A6. Provides career advancement	Feature 4 (Provides career advancement) was recategorized into the utility value domain, and the corresponding indicator was reordered as Indicator U15 (Provides career advancement).
Sufficiency	(13) Provides follow-up support	U7. Provides follow-up advisory service	The description of Indicator U7 has been amended as: U7. Provides follow-up advisory service on hands-on instructions

## Placement

The initial placement of the indicators within each value domain (attainment, intrinsic, utility and cost) was based on the existing literature. Participant A\_1 argued that Feature 6 (Provides well-qualified instructors) is less aligned with the intrinsic value domain; rather, it should be placed under the utility value domain. Participant C\_1 agreed with this suggestion and went further by saying that Feature 6 should be one of the indicators for Feature 11 (Aligns with current demands and visions) in the utility value domain. The participant further stressed that the order of indicators for Feature 11 should start with “Aligns with the school’s need” as teachers often prioritise attending TPD aligned with their school’s vision.

Participant A\_1 also noted that the description of Indicator U4 (Aligns with teachers' needs) is too ambiguous and not aligned with the utility value domain. Instead, the intentions of teachers attending TPD workshops for ICT integration into teaching are often related to their needs in "teaching" or "professional growth" and are thus more aligned with the definition of attainment value domain. The participants then agreed that this indicator should be regarded as one of the feature of attainment value domain, labelled as Feature 2 (Aligns with teachers' needs), with three indicators: A2 (Recognises the experience and prior knowledge of teachers), A3 (Provides customised content based on teachers' needs) and A4 (Provides a variety of courses for teachers to choose).

Participant C\_1 suggested moving Feature 7 (Provides hands-on learning opportunities) in the intrinsic value domain to load onto Feature 11 (Provides follow-up support), as she was aware that, after the workshop ended, many teachers contacted her seeking hands-on advice related to course design. Participant B\_1 seconded this suggestion. Participants captured these suggestions and came to a conclusion the following indicators more comprehensively reflected Feature 11 and should be re-ordered in the following way to reflect the typical procedure of follow-up support in TPD programs: U6 (Provides follow-up advisory service on hands-on instructions), U7 (Provides follow-up with course design and suggestions), and finally, U8 (Provides follow-up classroom observations and feedback).

Feature 17 (carried out over a sustained period) was initially uncategorised into any domains of value due to divergent opinions in the literature (see Section 3.3.2). While studies have shown that long-term TPD is more efficient than a one-shot TPD, extended TPD activities might discourage teachers from continued participation. During the discussion, participants confirmed the indicators' importance to the success of a TPD program for ICT integration into teaching.

...because the purpose of training is, of course, for...sustained training activities, hoping that this thing can be carried out in the long term and its effects can generate good... sustained activities in the school or within a group, or good, effective activities. (Participant F\_1).

The participants subsequently suggested aligning it with the domain of utility and making it an indicator of Feature 11 (Provision of follow-up supports), to comprehend the procedure of “follow-up supports”. Accordingly, the suggested change was made, and the order of indicators for Feature 11 was adjusted as Indicators U6 (Carried out over a sustained period, i.e. Recurrent training), U7 (Provides follow-up advisory service on hands-on instructions), U8 (provides follow-up course design and suggestion), and finally, U9 (provides follow-up classroom observations and feedback).

In addition, Participant A\_1 argued that Indicator U12 (Provides teaching materials/equipment from the program organisers) was not aligned with what the participants considered to be reality, as most of the TPD for ICT integration into teaching workshops were held at schools, thus the program organisers were not responsible for the provision of equipment. Consequently, participants suggested an alternative to U12 (Provides teaching materials for the program organisers). Participant A\_1 then suggested separating “teaching materials” and “equipment” as the schools may provide only one of these supports.

Finally, Participant D\_1 pointed out that Feature 4 (Provides career advancement) for attainment value domain might be better aligned with the utility rather than the attainment value domain, as teachers’ careers are more focused on teaching. The advancement of a teacher’s career can therefore be regarded as the enhancement of their long-term and overall teaching quality.

FG1 participants agreed to all the suggested changes regarding the placement of the indicators to enhance their alignment with the corresponding domains of value. As these

suggested changes were based on participants' professional knowledge in TPD for ICT integration into teaching in Taiwan and their experiences in designing and implementing the TPD programs for ICT integration into teaching, the changes were incorporated into the amended version of the TPD construct. However, it is worth noting that some of these suggested changes were not entirely consistent with the findings in previous literature. For example, "career advancement" is normally regarded as part of the attainment value domain in previous studies (e.g. Osman & Warner, 2020), whereas FG1 participants in the present study perceived it as more relevant to the utility domain of value. The comparisons between outcomes of FG1 discussions and previous studies are further discussed in Chapter 7, Section 7.2.2.

### **Sufficiency**

Domains of VT, including the attainment value domain, intrinsic value domain and utility value domain, were mentioned and discussed. Participant D\_1 noted that the description of the attainment value domain could be enhanced by specifying learning content, including content knowledge (CK) and pedagogical content knowledge (PCK). These are the current foci of the mathematics and English curricula in Taiwanese primary schools. This suggestion arose during the discussion of Indicator A1 (Focuses on specific content, knowledge and skills). Participant D\_1 considered the phrase "specific content" too broad and suggested specifying the "practical implementation (of the TPD)" in Indicator A1, noting that the General Guidelines of the 12-Year Basic Education Curriculum in Taiwan emphasise the enhancement of teacher and student literacies.

As there were hundreds of learning outcomes specified the Curriculum Guidelines of the 12-Year Basic Education for mathematics (2018) and English (2018), detailing each within the description of Indicator A1 would be unnecessarily redundant. Therefore, the

description of Indicator A1 (Focuses on specific content, knowledge and skills) was retained without modification. Furthermore, the emphasis on “practical implementation” suggested by Participant D\_1 was already captured by Indicators U4 (Provides follow-up support) and U5 (Provide contents, ideas and materials that are relatively easy to implement in class) in the utility value domain.

Participant E\_1 recommended including the indicator related to the provision of using digital teaching platforms in the intrinsic value domain. He observed that some platforms, such as Cool English, were favoured by teachers during TPD workshops for ICT integration into teaching, as they could be easily implemented in the classroom and allowed teachers to capture students’ responses instantly. However, as the ICT teaching materials introduced across different workshops within a TPD program for ICT integration into teaching are varied, placing special focus on digital platforms might undermine the value of other workshops that introduce different types of teaching materials.

This concept was captured in Feature 14 (Provide contents, ideas and materials that are relatively easy to implement in class) with a corresponding indicator U8 and Feature 15 (Makes teaching materials introduced in the sessions easy to access) with a corresponding indicator U9, both of which reflect a broader conception of teaching materials, inclusive of digital teaching platforms. Therefore, the description of the intrinsic value domain remained the same.

Participant C\_1 suggested that “assisting teachers with hands-on assistance or course design” should be added to the description of Feature 11 (Provides follow-up supports) in the utility value domain, as many teachers reported difficulties in transforming material learnt in TPD into practice after the program was completed. During the subsequent discussion,

participants reached a consensus to incorporate this focus into its corresponding Indicator U7 as “Follow-up advisory service on hands-on instructions”.

### **5.2.3 Evidence for the Extrapolation of the VT Construct**

Extrapolation of the VT construct considered FG1 participants’ feedback regarding whether the design of the VT construct reflects real-life situations. As all FG1 participants had previously lectured, designed and engaged in the TPD for ICT integration into teaching, the participants were asked to rate each indicator using a three-point formatted questionnaire: “relatively important”, “desirable” and “inapplicable” based on their authentic professional experience (Appendix C). The purpose of administering the questionnaire was to gather information on how FG1 participants perceived the relative importance of each indicator, corresponding to the VT features, in assessing the value of a TPD for ICT integration into teaching.

Based on the distribution of participant ratings on each indicator, indicators were classified into three levels: high importance, moderate importance, and relatively low importance (Table 5.3). Indicators were classified as high importance when all FG1 participants rated them as “relatively important”. Indicators were classified as of moderate importance when they were rated as “relatively important” by most of the participants, and none of the FG1 participants rated the indicators as “inapplicable”. The remaining indicators were classified as relatively low importance.

Feedback from the participants regarding the survey results was then analysed. Two key themes were generated in this topic: importance and transferability. It is important to note that all indicators discussed in this section remained in their initial locations (loadings onto the domains) and wordings, as the coding of topics in this focus group did not follow a chronological sequence.

**Table 5.3***FG1 participants' rating of indicator importance within the VT construct*

Importance level	Number of FG1 participants' rating			Indicators
	Relatively important	Desirable	Inapplicable	
High importance	6	0	0	A1, A2, A4, A5, I1, I2, I6, I7, U1, U2, U3, U4, U5, U7, U8, U9, C1, C2, C3, C4
Moderate importance	4	2	0	A3, I3, I4, I5, U4, U6, U11
Relatively low importance	3	2	1	U10

**Importance**

In the discussion, the participants provided feedback regarding the survey results (see Table 5.3) on the importance and how they linked the VT construct with their experience when answering the survey questions. Although the questionnaire results suggested that some indicators were considered relatively less important than others, during the discussion, participants confirmed that all indicators in the VT construct were important and should be retained with minor adjustments.

Participant A\_1 noted that “(I) haven’t thought before” about the inclusion of the cost domain, but it is “necessary”, as the indicators in this domain could influence the value that teachers perceive they gain from participation in a TPD program for ICT integration into teaching. Participant A\_1 further explained how a negative value could affect the outcomes of TPD:

Because, um...under the circumstance of the low willingness of teachers to participate in trainings, take the currency of us as example, we are required to (participate in) A1, A2 workshops due to the development of technology and digital industries, but the teachers might respond it with negative attitude. It would affect the development of

professional developments negatively. But with this framework, you include it, and it informs teachers that growth comes with a cost. I think it's a good idea.

The Indicator U10 (Provides teaching materials/equipment from the program organisers) was rated as the least important indicator in the survey results. Participant A\_1 and Participant E\_1 explained that teachers today are encouraged to bring their own digital devices when participating in TPD for ICT integration into teaching, as the equipment provided on-site may not be aligned with teachers' regular usage and could further affect their learning. The provision of teaching equipment by the workshop organisers was therefore considered less important. In contrast, Participant A\_1 emphasised that the provision of teaching materials and equipment from the schools is crucial for the successful implementation of a TPD. They stated, "It is the responsibility of the school to provide teaching materials and equipment when I'm implementing what I've learned or developed professionally". In this case, "teaching equipment" was removed from the description of Indicator U10, which was rephrased as "Provides teaching materials from the program organisers".

### **Transferability**

During the discussion, Participant B\_1 raised concerns as to whether the present study was tied to Taiwan's digital enhancement policy, noting that once the policy cycle ends, the study could appear limited in scope. Participant B\_1 then suggested expanding the focus to encompass diverse TPD for ICT integration into teaching and long-term TPD pathways, as countries and cities are promoting various TPD for ICT integration into teaching opportunities. Participant F\_1 argued that the VT construct is not limited to being associated with a particular TPD for ICT integration into teaching, which is the focus of the present study. Instead, the VT construct is applicable to other TPD with different foci, requiring only

minor adjustments to the descriptions of the VT questionnaire's items developed following the FG1 discussion.

#### **5.2.4 Summary**

Participants highlighted the wording and translation issues of the VT construct. To be aligned with the common usage in Taiwan, the term “carried out over a sustained period” was replaced by “recurrent training” and “instructors” was replaced with “educators”.

Furthermore, the description of Indicator C1 (It's time-consuming) corresponds to Feature 19, which was regarded as ambiguous. Accordingly, this indicator was replaced with three indicators (C1, C2, C3) to specify the meaning of the feature. Grammatical and writing conventions issues in the translated Chinese version of VT were also raised, which resulted in adjustments in the final version of the questionnaire.

The placement and sufficiency of the VT construct were discussed under the topic of generalisation. FG1 participants suggested relocating “Provides well-qualified instructors” from the intrinsic value domain to the utility value domain. The relocated feature and corresponding indicator are Feature 9 (Aligns with current demands and visions) and Indicator U3. The order of Feature 9's indicators was further adjusted to better reflect perceived school needs. Furthermore, Indicator (Aligns with teachers' needs), which originally was one of the indicators in Feature 9, was upgraded as Feature 2, located within the attainment value domain. Three indicators corresponding to Feature 2 were subsequently generated. The terms “teaching materials” and “teaching equipment”, previously presented together in the utility value domain, were separated. In addition, the previously uncategorised indicator “recurrent training” was included in the utility value domain as part of follow-up support and “provides career advancement” was shifted from the attainment value domain to load onto the utility value domain.

Participants debated whether existing domains and indicators were sufficient to capture an intended VT construct. Although suggestions on specifying learning content in the attainment value domain and digital platforms in the intrinsic value domain were raised, they were eventually not adopted because of potential redundancy and a focus on an overly narrow scope.

The FG1 also examined whether the VT reflected real-life practice and primary school teachers' perceptions (related to extrapolation). Participants argued that most indicators were considered relatively important. In particular, the cost domain was regarded as necessary for reflecting teachers' negative perceptions toward TPD. The provision of teaching equipment from program organisers (Indicator U10, reordered as U12 in FG1 discussion) was regarded as least important by the participants, as teachers nowadays were expected to bring their own devices to the TPD venue. Finally, participants commented on the transferability of the VT construct. Although one participant indicated some concern regarding the limited scope of the framework, others confirmed its transferability to different types and national contexts of TPD for ICT integration into teaching, with minor modifications to the description of the generated questionnaire.

As outlined in Kane's argument-based validation framework (2006), evidence for the inferences drawn about VT for TPD depends on scoring, generalisation and extrapolation of the construct. Based on the FG1 discussion, an amended VT construct is presented in Table 5.4 in order to enhance the resulting evidence of its validity. The next section discusses the analytical results and findings from the second focus group (FG2) discussion.

**Table 5.4***Amended VT construct*

Domain	Features	Indicators
Attainment Value	(1) Focuses on specific content, knowledge and skills	A1. Focuses on specific content, knowledge and skills
	(2) Aligns with teachers' needs	A2. Recognises the experience and prior knowledge of teachers A3. Provides customised content based on teachers' needs. A4. Provides various of courses for teachers to choose.
	(3) Provides feedback, assessment and reflection	A5. Provides peer feedback and assessment opportunities A6. Provides educator's feedback and assessment opportunities A7. Provides self-reflection opportunities
Intrinsic Value	(4) Targets active learning	I1. Targets active learning
	(5) Encourages collaborative learning	I2. Provides opportunities for collaborative learning with peers I3. Provides opportunities for cross-discipline collaborative learning I4. Provides opportunities for collaborative learning with teachers outside of schools
	(6) Targets novelty	I5. Targets novelty
	(7) Provides hands-on learning opportunities	I6. Provides hands-on learning opportunities
Utility Value	(8) Helps with students' development	U1. Helps with students' development
	(9) Aligns with current demands and visions	U2. Aligns with schools' needs U3. Provides proper educators U4. Aligns with schools' curriculum plan
	(10) Provides convincing exemplary material	U5. Provides convincing exemplary material

Table 5.4—Continued

Domain	Features	Indicators
Utility Value (continued with previous page)	(11) Provides follow-up supports	U6. Provides recurrent training U7. Provides follow-up advisory service on hands-on instructions U8. Provides follow-up course design and suggestion U9. Provides follow-up classroom observations and feedback
	(12) Is easy to imply in class	U10. Is easy to imply in class
	(13) Teaching materials introduced are easy to be accessed	U11. Teaching materials introduced are easy to be accessed
	(14). Provides teaching materials	U12. Provides teaching materials by the program organisers
	(15). Provides career advancement	U13. Provides teaching materials by the schools U14. Provides teaching equipment by the schools U15. Provides career advancement
Cost Value	(16). Is time-consuming	C1. Takes time to rearrange the class timetable C2. Takes time in the process of training C3. Takes time to work on the follow-up tasks
	(17). Requires high financial expense	C4. Requires high financial expense
	(18). Has tedious procedures to implement	C5. Has tedious procedures to implement
	(19). Is stressful to learn	C6. Is stressful to learn

### **5.3 Focus Group 2 Discussion**

The participants in FG2 comprised eight experienced primary school teachers who had attended several TPD for ICT integration into teaching workshops in the last year. They were asked to provide feedback on the draft items in the ITTE questionnaire as part of the evidence to determine whether the existing items reflect the intention of assessing teachers' ITTE. The findings of FG2 provided evidence for the alignment of the draft items identified in the literature review with the context of TPD for ICT integration into teaching in Taiwan (RQ2a).

FG2 revolved around two discussion questions (see Appendix D). First, participants were requested to indicate which of the TPD for ICT integration into teaching they perceived as successfully improving their TPACK-core. Second, participants were asked to provide feedback on the items comprising the draft ITTE questionnaire. Four key foci were developed based on their feedback: wording, translation, placement and sufficiency. These were then categorised into two topics as the evidence for the scoring inference and generalisation inference of the ITTE construct associated with Kane's (2006) argument-based validation framework.

Overall, three topics evolved from the result of the FG2 discussion: observation of TPACK-core improvements through TPD for ICT integration into teaching, evidence for the scoring of the ITTE questionnaire, and evidence for the generalisation of the ITTE results. The findings of each topic are presented in the following sections.

#### **5.3.1 Observation of TPACK-core Improvements through TPD for ICT Integration into Teaching**

During the first part of the discussion, participants shared their experiences in TPD for ICT integration into teaching and reflected on how these experiences contributed to the improvement of their TPACK-core. They noted that the growth of TPACK-core during the

TPD occurred when they realised better instructional strategies with ICT on the same teaching content. As Participant G\_2 stated:

They can explain the same unit, but with different routes and guidance, as well as incorporating more scientific methods, saying, "If we were teaching online today, we might use ... to better teach fractions." We can realise that teaching with this software can make it look easier (Participant G\_2).

Adding to this, Participant G\_2 shared an example of a TPD for ICT integration into teaching workshop that focused on physical education, which changed his negative impression of teaching physical education with ICT:

We initially found it challenging to incorporate technology into PE classes. However, due to the professionalism of our school's PE teachers, they shared instances where they successfully integrated technology (Participant G\_2).

Participant F\_2 noticed the improvement in TPACK-core when teachers discovered new ways of using technological tools through peer sharing in a TPD:

In terms of being beneficial, each person uses a technology product differently, with different areas of expertise. Through sharing by other teachers, you discover that a technology product has usage methods you couldn't imagine or hadn't specifically explored. People tend to stay in their comfort zones. (Participant F-2).

Participant C\_2 observed that, although they had already been using some technological tools in Mathematics classes, participation in the advanced TPD for ICT integration into teaching increased their certainty in understanding this concept of ICT integration into classrooms. Notably, they emphasised that the genuine growth in TPACK-core occurred only after repeatedly and successfully implementing what was learnt from TPD in their classroom:

During the workshops, I could identify, "Hey, I can use this feature for that purpose." I do feel that I have grown, but it's only after using it and feeling comfortable that I truly sense significant growth in this area. (Participant A-2).

### 5.3.2 Evidence for the Scoring of the ITTE Construct

Participants discussed whether the ITTE questionnaire was able to be interpreted correctly and consistently by the Taiwanese teachers (scoring). Two themes emerged: wording and translation. A summary detailing suggested modifications is presented in Table 5.5.

**Table 5.5**

*Modifications to the ITTE scale for Scoring*

Initial item number	Suggested modification	Items after modification
Item 1,3,5,6,8,9,10,11, 16,17, and 19	Replace the term “technologies” with “technological tools”	All “technologies” statements were replaced with “technological tools”.
Item 1	Replace the phrase “allow pupils to participate actively” with “stimulate students’ motivation”	The TPD program enhanced my ability to use a variety of technological tools that stimulate students’ motivation.
Item 6	Replace the phrase “teach successfully” with “teach effectively”	The TPD program reinforced my capability to teach effectively by appropriately combining the technological tools, English content and instructional approaches.
Item 16	Remove the term “digital learning communities” and revise the sentence to provide a clearer description	The TPD program inspired me to find innovative technological tools to improve students’ learning.
Item 17	Replace “unique content” with “innovative content”	The TPD program enhanced my skill in using technological tools to better develop and present practical and innovative content that goes beyond the current textbook.

## **Wording**

Items in the ITTE questionnaire were adapted from the existing TPACK questionnaires (see Section 3.4.1). However, participants pointed out that some terminology was confusing and inappropriate for Taiwan's primary education. They argued that the use of the term "technologies" could cause misunderstanding among teachers, as "technologies" is used in education to refer both to a subject and a type of teaching tools. They suggested replacing it with the more precise term "technological tools". Participant E\_2 further warned that the phrase "teach successfully" in Item 6 might lead to negative responses, given that the definition of successful teaching remains controversial among teachers. Some teachers insisted their teaching should not be evaluated in terms of success or failure. Instead, the term "teach effectively" was considered more appropriate.

Participants also noted several structural issues in the item descriptions. For example, Participant G\_2 argued that the meaning of Item 1, "This TPD program enhanced my capability of using a variety of technologies that allow pupils to participate actively." was unclear as it encompassed distinct ideas: "enhance my capability of using a variety of technologies" and "allow pupils to participate actively". As she explained:

If today I use this ability, but the students are not enthusiastic, or I won't use this ability, but the students can actively participate. It becomes like having two answers.

Participant G\_2 further suggested replacing the phrase "allow pupils to participate actively" with "stimulate students' motivation" to improve the meaning of the item.

Other participants agreed with the modification suggestion for Item 1. Accordingly, the description of Item 1 was revised to "The TPD program enhanced my capability of using a variety of technological tools that stimulate students' motivation."

Participant E\_2 and G-2 noted that the inclusion of “digital learning communities” in Item 16, “This TPD programme provided information on digital learning communities that I can participate in to discover creative utilities of ICT to improve pupils’ learning.”, could create unnecessary issues that might complicate the item. They warned that some teachers might disagree with the item simply because of a lack of experience with such communities. Participant H\_2 also shared a negative experience with such digital learning communities that provided basic content which the young teachers already know. As the result, she indicated that might disagree with this item simply based on this negative experience rather than her perceived experience in the TPD program. The participants unanimously agreed to remove the focus on digital learning communities, and revised Item 16 as follows: “This TPD program inspires me to find innovative technological tools to improve students’ learning”.

### **Translation**

Both the original English and translated Chinese versions of the ITTE questionnaire were presented to the participants of FG2. Participant E\_2 argued that the phrase “unique content” used in Item 17 could cause misunderstanding in a Chinese language context. This is because in Chinese it may be interpreted as being different from others, and you shouldn't say that others can't provide such content. Several replacement phrases were recommended, such as “innovative”, “special” or “different”. Ultimately, FG2 participants agreed that “innovative content” more accurately captured the intended meaning.

### **5.3.3 Evidence for the Generalisation of the ITTE**

The outcomes from the FG2 discussion support the extent to which the draft ITTE questionnaire reflects the intended ITTE from a Taiwanese perspective (Generalisability). Two key themes emerged during the discussion: placement and sufficiency of the ITTE construct. It is worth noting that even though the participants suggested minor modifications

to some of the items, there was consensus that the items were a good reflection of the underlying construct.

### **Placement**

The items in the ITTE originated in a broader scope, emphasising the use of a variety of technological tools to enhance teaching and students' learning, but moving to a narrower scope of focusing on the application of proper technological tools for specific teaching topics. Participant A\_2 argued that while the ITTE construct was intended to be unidimensional, the items could also represent different aspects of the construct. They suggested reordering some of the items within their categories such as “teacher instruction”, “teaching assessment” and the “content demonstration”. In contrast, Participant G\_2 considered the existing order of the items acceptable and noted that the progression from broader to narrower contexts was clearly distinguishable. Eventually, FG2 agreed to retain the order of the items, as the existing design was acknowledged by the participants and aligned with the requirements of unidimensionality of the ITTE construct.

### **Sufficiency**

During the discussion, participants were asked if there were any items that were not consistent with the Taiwanese context and therefore required elimination or modification. Participant G\_2 argued that the global understanding, culture and traditional foci reflected in Items 4 and 12 have a relatively limited scope when compared to the other items. A proposal was advanced that these two items should be eliminated. Participant F\_2 supported this perspective and noted that although the new national curriculum (i.e., Curriculum of 12-Year Basic Education) incorporated the multicultural concepts embodied in the items, the expected learning outcomes in Taiwan's primary schools placed minimal importance on this aspect of the curriculum. An example was provided in relation to the subject of English:

Because for students, when I attend an English class, what I want to improve is my English, whether it's grammar, vocabulary, or sentence structures. But they won't think that if I come to an English class today and the teacher uses a lot of technology to teach, it's to make me aware of different cultures. (Participant F\_2)

Furthermore, Participant G\_2 raised a concern that Item 20 appeared “redundant”, arguing that the earlier items had already covered aspects that Item 20 addresses. This implied that respondents who strongly agreed with the previous items would also strongly agree with Item 20, and vice-versa, which could challenge the requirement of independence. Other participants supported this concern and suggested that the item should be eliminated.

#### **5.3.4 Summary**

The FG2 discussion provided evidence for refining and validating the ITTE construct while highlighting its strengths in concept and items requiring further modification. First, participants asserted that TPD for ICT integration into teaching have a meaningful contribution to the growth of TPACK-core, especially through the extension of the existing teaching strategies and successful classroom implementation. This affirmation offered preliminary support for the extrapolation inference of the ITTE scale. Second, the discussion topic in relation to scoring inference is presented. Participants raised concerns regarding the wording and translation of several draft items. Such as the use of “technologies” and “teach successfully” were considered potentially misinterpreted in Taiwan’s education context. Alternative phrasings, including “technological tools” and “teach effectively”, were suggested.

The final discussion topic provided evidence supporting the claim that the ITTE questionnaire is capturing the construct. Although overall placement of the items was regarded as coherent and consistent, structural critiques were provided to reveal less relevant

foci and redundancy within certain items, particularly those addressing multicultural and global understanding, including Items 4, 6, and 20. Thus, these items were suggested to be eliminated.

Based on FG2 discussions, the descriptions of ITTE items were amended, and three out of twenty items were eliminated as presented in Appendix G. The comparison between the initial and the amended ITTE items, together with the suggested changes from the FG2 participants (summarised in Appendix G) were then reviewed by the FG3 participants for further refinement and for expert justification of the proposed elimination of the items.

The next section discusses the results and findings from the FG3 discussion.

#### **5.4 Focus Group 3 Discussion**

FG3 participants were invited to provide feedback on the draft VT and ITTE questionnaires developed further after changes were made following the outcomes of FG1 and FG2 discussions. The FG3 participants were the same group as the FG1 participants, selected for their professional background in designing and delivering TPD programs for ICT integration into teaching.

Prior to the discussion, participants were provided with the discussion questions, a draft of the VT questionnaire, which was generated from the revised VT construct that reflects the outcomes from the FG1 discussion (Appendix F), and a summarised amendment of the ITTE items based on the outcomes from the FG2 discussion (Appendix G). The participants were requested to answer the draft questionnaires as the pretesting process for the development of the measurement scales. The results from this discussion were structured according to the questions used in this session. As indicated in Appendix E, the discussion questions comprised two parts: feedback on the items comprising the VT questionnaire and on the items of the ITTE questionnaire.

The first part of the discussion aimed to determine whether the VT items reflected the intended construct. Two key themes arose in the discussion: wording and translation. In the second part of the discussion, participants were requested to provide feedback on the ITTE items from their perspective as TPD for ICT integration into teaching designers and experts.

Overall, three topics were generated based on the results of the FG3 discussion: feedback on the draft VT items and feedback on the ITTE items. The results of each topic are indicated in the following sections.

#### **5.4.1 Feedback on the Draft VT Items**

FG1 provided some evidence that supported the argument that the structure of the VT construct was appropriate and was consistent with the real-life situation (extrapolation) of the Taiwanese education (generalisation) context. In FG3, the participants were asked to review the wording and translation of the VT items that had been developed through a review of the literature and refined by FG1 to assess the features of the VT. The modifications based on the FG3 discussions are presented in Table 5.6.

**Table 5.6***Summary of the modification of the VT questionnaire from FG3*

Key themes	Initial descriptions	Modifications
Wording	1. The design of the TPD program focused on specific content, knowledge, and skills.	1. The TPD program focused on one or more of the following: specific content, specific knowledge or specific skills.
	3. The TPD program provided customised content based on my needs.	3. The TPD program provided training in content based on my needs.
Translation	12. The content of the TPD program was novel and different from the previous program I attended.	The Chinese version of Items 12, 15 and 21 were modified based on the suggestions of FG3.
	15. The TPD program fit with my school's needs.	
	21. The TPD program provided services of follow-up course design and suggestion.	

**Wording**

Each item in the VT was aligned directly through common wording with the associated feature. For example, the description of Item 1 “The design of the TPD program focused on specific content, knowledge” was linked with indicator A1 (Focus on specific content, knowledge and skills). However, participant B\_3 argued that this item should be divided into separate items: such as “learning specific subject content”, “subject teaching knowledge related to pedagogical content knowledge (PCK)”, and “computer information technology skills”. Participant C\_3 added that the focus of teaching content on mathematics and English was distinct, which should also be taken into consideration in this item.

On the other hand, Participant A\_3 noted that three items could be used to provide information regarding this indicator. However, this could lead to confusion because some TPD for ICT integration into teaching focused on theoretical or knowledge-based aspects without addressing skills. They argued this could result in a tendency to select negative

categories (e.g. disagree or strongly disagree), even when the workshop still retains significant value. Participant A\_3 illustrated this with an example:

If it is divided into three parts, the teacher in today's workshop might think that in this class, I only learned a concept. For example, in the A1 course of the digital improvement program, it only emphasises some parts of the self-directed learning theory. Perhaps some content introduced in the class might involve skills that could be covered on YouTube. Teachers might persist in checking, "Today, I only had more knowledge and less content," and this might be a bit...

The participants concluded that Item 1 should be retained as it is and an on-balanced judgement made when responding.

Participant D\_3 argued that the Indicator A3 (Provides customised content based on teachers' need), based on their experience was not very likely to occur as very few TPD program provide training content customised to the needs of the trainees. Participant C\_3 agreed and added that the term "customised" appeared, when translated, to be more like "commercial". They further suggested removing the term "customised" and revising the corresponding item to be "This teacher professional development workshop provides training content based on my needs.". Item 3 was accordingly adjusted to align with the original meaning of its corresponding indicator.

## **Translation**

As the respondents to the questionnaire may not fully understand the English description, a Chinese translation accompanied each item. It was noted that the term used in Item 12, "創新 (novelty)", aligned with feature I3 "Targets novelty" appeared unclear in the Chinese version. It was therefore replaced by the term "新穎(novelty)". Participants agreed to the change, as it aligned more with the structure of the Chinese sentence in that item.

Participant B\_3 noted that some problematic wording appeared in the Chinese description of Items 15 and 21, where the use of prepositions “of (的)” and “and (及)” seemed to obscure the intended meaning of the indicators. Participant B\_3 also suggested that the term “services (協助)” was redundant and argued for its removal. These refinements were accepted by all the participants and the Chinese features and associated items 12, 15, and 21 were amended.

#### **5.4.2 Feedback on the Draft ITTE Items**

Participant A\_3 suggested that the term “related” should be omitted from Item 5 to make it clearer. Participant E\_3 supported this suggestion and further proposed replacing “enhance” with “contribute” to avoid repetition. A revised Item 5 was then proposed and accepted by the participants: “The TPD program contributed to my choice of appropriate technological tools to improve teaching methods and student learning ability”.

Participant A\_3 suggested a more positive wording could be used for Item 14. She suggested that “enhance students’ development” was better than “improve students’ development”. The participants discussed this and eventually arrived at the following wording for Item 14 “The TPD program inspires me to find innovative technology tools to enhance students’ development.”. Finally, FG3 participants affirmed the FG2’s suggested change on the term “unique” in Item 17 with “innovative”. No further amendments were recommended.

As indicated in the findings of the FG2 discussion (see Section 5.2), Items 4, 12, and 20 in the ITTE questionnaire were eliminated by FG2 participants due to their narrow scope and redundancy. FG3 agreed with the redundancy of Item 20, whereas they debated FG2’s decisions to remove Items 4 and 12.

Participants B\_3 and E\_3 argued that “global understanding” and “cross-cultural interaction” that were originally included in Items 4 and 12 were closely tied to English learning, as they could enhance students’ oral communication skills, even though they agreed they were less relevant to mathematics. Participant B\_3 illustrated this point for English as follows:

For example, I am currently taking English classes, communicating online with some foreigners. When you learn English, you are also learning language expression skills.

Participant C\_3 then suggested that in some special contexts, such as mathematics classes designed around Problem-Based Learning (PBL), the items could have meanings. Participant A\_3 added that, since PBL was one of the crucial pedagogical approaches emphasised in the *Digital Learning Enhancement Plan*, the applicability of Items 4 and 12 for mathematics teachers could be argued to be not only acceptable, but necessary.

Participant A\_3 then concluded that the applicability of these two items depends largely on teachers’ background and school contexts. For teachers and schools involved in international or bilingual education, the concept of global understanding and cross-cultural understanding represented by Item 4 could be meaningful in classes, whereas in other contexts it would be less applicable. Participant A\_3 also suggested retaining Item 12, as it focused on cross-cultural and traditional understanding within the national context. She illustrated this with an ICT-focused PBL plan currently implemented in her school:

This item reminds me of a PBL plan that our school is conducting. Regarding the social studies, math, and language. Sitting together to do a PBL course, of course, the design is in... whether to introduce different cultures, of course, whether this culture crosses international cultures, or... what we are doing now is a traditional school in Beitun District, Taichung City. Whether there are different cultures, or if children extend to the

outside, outside, it means that foreign cultures similar to ours may be brought in, possibly (Participant A\_3).

On reflection, Items 4 and 12 were originally included because they were in Taiwan's national curriculum guidelines (MOET, 2021), which identified multicultural and global understanding as critical literacies that K1-12 students should develop. However, as participants of FG3 argued, in practice, although culture and global understanding can be addressed in mathematics and English classrooms, these concepts are not central to the integration of ICT into classrooms and require certain contexts to achieve them. The participants suggested collecting more empirical evidence to determine whether these two items should be included against the advice of the participants in FG2.

This consideration was carried forward to the pilot testing and the large-scale questionnaire survey where teachers' responses to the questionnaire were applied to further justify the relevance and importance of these two items in the ITTE scale.

#### **5.4.3 Summary**

The focus group discussions sought evidence from the experts' perspectives for producing evidence that the draft questionnaires that evolved from the FG1 and FG2 discussions were in fact fit-for-purpose. Given that the participants across all three focus groups were Chinese speakers, the English version of the questionnaires was edited by native English speakers following the completion of FG3. Furthermore, the analytical results of the three focus group discussions were reviewed and discussed by my supervisory team. As result, the order of items in the ITTE questionnaire was adjusted: Items 4 and 12 of the ITTE questionnaire were moved to the last two questions, which is Items 18 and 19, and the numbering of the remaining items was adjusted accordingly. The final VT questionnaire comprised thirty items, and the ITTE questionnaire comprised 19 items (see Appendix H).

While they were two separate questionnaires, they were provided to respondents in one administration.

## **5.5 Chapter Summary**

Chapter 5 presented some evidence regarding the validity of the analysis of VT and ITTE constructs and questionnaires through three rounds of focus group discussions. Each focus group provided validity evidence aligned with discussion questions and Kane's (2006) argument-based validation framework, with a particular focus on scoring, generalisation and extrapolation inferences.

FG1 focused explicitly on the VT construct. Participants identified several wording and translation issues of the construct with suggested alternatives, which reinforce the accuracy, consistency and appropriateness of the responses for the corresponding scale. Furthermore, they proposed structural modifications, including the adjustments to the placement and extended description of the indicators, to increase the relevance of the indicators with the intended construct. Finally, the FG1 participants distinguished the importance and transferability of the indicators based on their experience in TPD for ICT integration into teaching. Their insights offered validity evidence for the relevance of the VT questionnaire and associated construct to real-life TPD contexts.

Shifting the attention to the ITTE construct, FG2 participants first reflected on their experience in TPD for ICT integration into teaching and how this contributed to improvements in their TPACK-core. Their successful improvement experience of TPACK-core through the participations in different forms of TPD provides preliminary empirical evidence supporting the linkages between the TPD and TPACK-core. Meanwhile, participants identified problematic wording and translations and proposed alternatives, such as the replacement of "technologies" with "technological tools", to ensure the accurate

interpretation of the questionnaires by the respondents. The participants debated the relatively redundant and limited focus of certain items, with the final decision to eliminate three items. These suggested revisions enhanced the clarity, consistency and contextual fit of the items to the intended ITTE construct.

FG3 participants provided insights on the developed VT and ITTE questionnaires based on the results of FG1 and FG2. For VT items, they refined problematic wording and translations to improve clarity and accuracy of the scoring. For the ITTE items, they argued for the possible re-inclusion of the items eliminated in FG2, which focused on multicultural and global understanding. Although they acknowledged their importance in English classrooms and certain pedagogical contexts, they questioned items' centrality to ICT integration. Notably, their conclusion was to gather further empirical evidence on the appropriateness of these items.

Overall, this chapter presents the findings of the focus group discussions, which provide validity evidence for the required revisions to the VT and ITTE questionnaires from qualitative perspectives. The next chapter discusses the analytical findings from pilot testing and a large-scale questionnaire survey, providing validity evidence for the revisions to the two questionnaires from a quantitative perspective. Data from the large-scale questionnaire survey were analysed using the Rasch model to determine whether the measurement scales can result from such revisions.

## **Chapter 6: Validation Analysis: Questionnaire Survey**

### **6.1 Introduction**

This chapter presents the results for the pilot testing and large-scale questionnaire survey. These results provide deductive evidence supporting the validity of the scales developed in the present study: the Value of TPD (VT) and the Improvement of TPACK-core via TPD Experience (ITTE) scales. It begins by presenting the results of pilot testing, including respondents' demographic statistics and qualitative feedback. Following that, the results of large-scale questionnaire survey based on three quantitative analyses were introduced, including demographic statistics, Rasch analysis and correlation analysis. The results presented in this chapter address research questions 1 and 2 using Rasch Measurement Theory (Rasch 1960/1980) and Kane's (2006) argument-based validation framework.

### **6.2 Results of Pilot Testing**

As outlined in Chapter 4, Section 4.4.2, the purpose of conducting the pilot testing was to examine the clarity, wording and functionality of the questionnaire items with a larger group of respondents than the focus group discussions. Sixteen participants were involved in this round of pilot testing. It is noted that, given the small sample size (making the results less precise), the inclusion or elimination of items should not be decided entirely on the basis of these statistical results obtained during this pilot testing (Hertzog, 2008). The reliability of the questionnaire was further examined in the subsequent large-scale questionnaire survey of the study to obtain more stable and precise estimates (Bujang & Baharum, 2018).

#### **6.2.1 Demographics of Pilot Testing Respondents**

Participant demographic characteristics are presented in Table 6.1. The majority of participants in the pilot study were female (69%), aged between 26 and 35 years (75%), taught mathematics in school, had fewer than five years of teaching experience (56%) and

had attended four to six hours of ICT-focused TPD program during the current school year (44%).

**Table 6.1**

*Participant characteristics for pilot testing*

Demographics	Frequency	
	N	%
<b>Gender</b>		
Male	5	31%
Female	11	69%
<b>Age</b>		
26 to 35 years old	12	75%
36 to 45 years old	3	19%
46 to 55 years old	1	6%
56 and above	0	0
<b>Teaching subject</b>		
English	3	19%
Mathematics	13	81%
<b>Hours of participation in the given TPD program within this school year</b>		
1 to 3 hours	5	31%
4 to 6 hours	7	44%
7 hours and above	4	25%
<b>Teaching seniority</b>		
5 years and below	9	56%
6 to 10 years	6	38%
11 to 15 years	1	6%
16 to 20 years	0	0%
21 years and more	0	0%

### 6.2.2 Quantitative responses

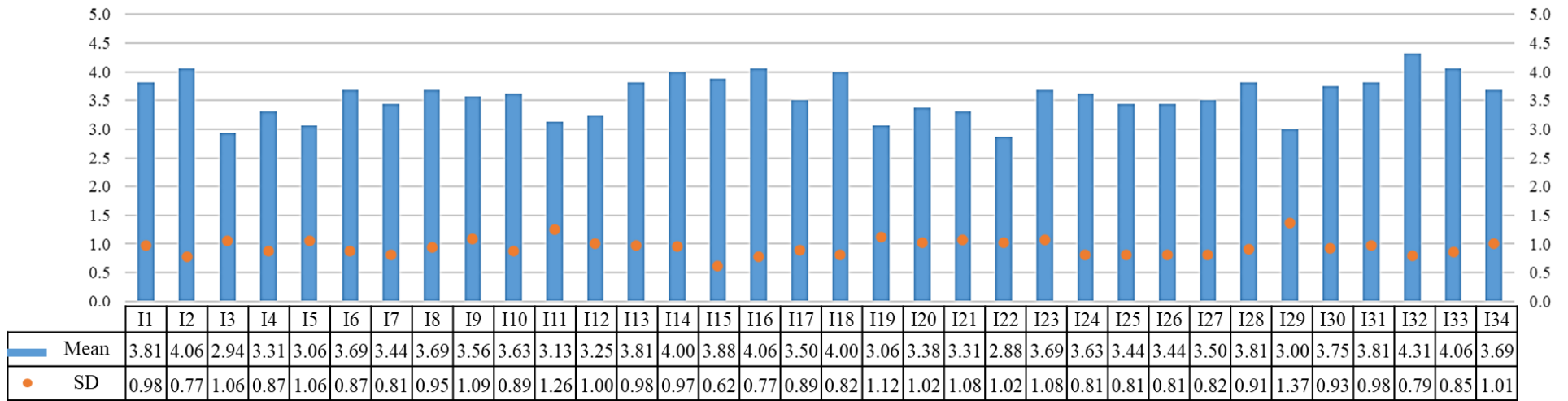
Figure 6.1 presents the mean and standard deviation scores for the items in the VT questionnaire obtained from the pilot testing. Overall, the mean score of the items from the VT questionnaire for the pilot testing ranged from 2.9 to 4.3 (out of 5), and the standard deviation ranged from 0.8 to 1.4. The lowest mean scores (the hardest items) were Items 3, 22 and 29, with means of 2.9, 2.9 and 3.0, respectively. Items 11, 19, and 29 demonstrated the highest standard deviations with the values of 1.3, 1.1, and 1.4, respectively.

Item 29, “It was easy for me to rearrange my classes’ timetable to attend the TPD program.” was the most difficult item in that it had presented a relatively high standard deviation, which potentially could imply participants’ different reactions to the statement represented by the items, or their different interpretations of the descriptions of the items. This item corresponds to Indicator C1 (Takes time to rearrange the class timetable) within the cost domain. Initially, the inclusion of this indicator was suggested by FG1 participants to clarify different types of time-related costs involved in participating in the TPD (see Section 5.2.1). Although the pilot testing result indicates teachers had differing opinions and a relatively low level of agreement for this item, given the small sample size in the pilot testing research (N = 16), Item 29 was retained. Further examination of the functioning of this item was achieved using Rasch analysis in the following large-scale questionnaire survey.

**Figure 6.1**

*Pilot testing results from the VT questionnaire*

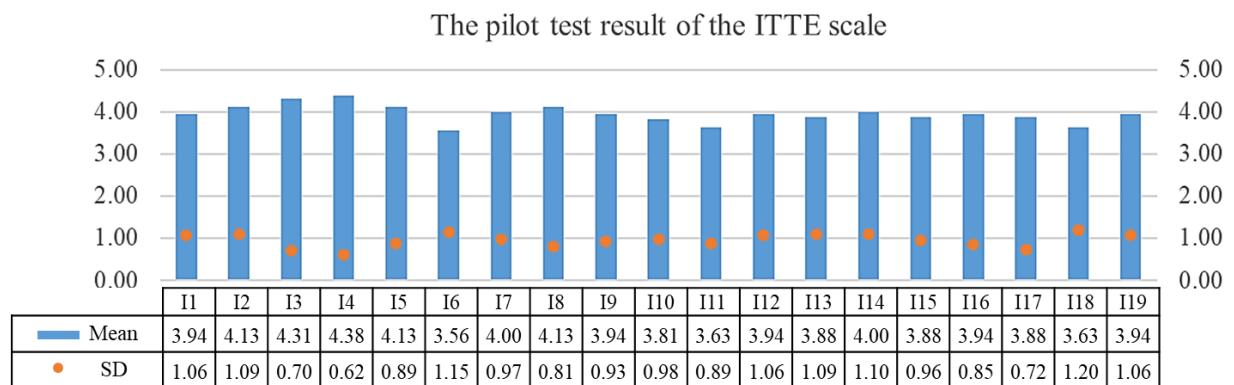
The pilot test result of the VT questionnaire



The mean and standard deviations of the items of the ITTE questionnaire are presented in Figure 6.2. Overall, the mean score of the ITTE items ranged between 3.56 and 4.31, while the standard deviations ranged from 0.7 to 1.2. The most difficult item for the participants to agree with was Item 6, “Participation in the TPD program: enhanced my capacity to lead my colleagues in integrating content, pedagogical and technological knowledge.” with a result of 3.56. Meanwhile, Item 18 “Participation in the TPD program enhanced my capacity to increase global understanding by students from diverse cultures through technologies.”, demonstrated the highest standard deviation, with the result of 1.2.

**Figure 6.2**

*Pilot testing result from the ITTE questionnaire*



### 6.2.2 Qualitative Feedback

During the pilot testing, participants were invited to provide feedback on both the individual items and the overall structure of the questionnaire survey, including demographic questions of both the VT and ITTE questionnaires. Three participants offered feedback.

One participant provided positive feedback on the number of items, noting that the number of items in the VT and ITTE questionnaires was “appropriate” and “did not place pressure on respondents.” Another participant highlighted the ambiguity of certain Chinese translations, which they felt could cause confusion. He further noted the term “teaching

seniority” in Q4 of the demographic section was normally regarded as the number of years a teacher has taught at a particular school, whereas “teaching experience” better captures a teacher’s total years of teaching. Finally, two participants expressed difficulty recalling details of earlier items while responding to the questionnaires, as related questions were not clustered together in the online interface.

Overall, the result of the pilot testing provided preliminary evidence regarding the clarity and feasibility of the questionnaire items, as well as insights into how primary mathematics and EFL teachers in Taiwan interpreted the item wording. In response to the result from the pilot testing, before the commencement of the large-scale questionnaire survey, the wording of Q4 “Teaching seniority” was modified to “teaching experience” to more accurately reflect length of teacher teaching practice. In addition, the Chinese version of the questionnaire was refined again to be more aligned with teachers’ common usage of terms. To solve the problem of recalling the related questions on the online questionnaire, the design of the online questionnaire was reconfigured so that related items clustered together in the questionnaire.

### **6.3 Results of the Large-scale Questionnaire Survey**

This section presents the results from the large-scale questionnaire survey. As outlined in Chapter 4, Section 4.5.3, the findings of the large-scale questionnaire survey address the research questions from an inductive perspective. First, the demographic statistics of the questionnaire respondents are reported. Then Rasch analysis results are presented to answer Research questions 1 and 2 from a quantitative perspective. Finally, the results of correlation analysis are outlined to answer research question 3 (RQ3). The findings of each analysis are provided in the following subsections.

### 6.3.1 Demographics of Large-scale Questionnaire Survey Respondents

Five demographics items were included in the large-scale questionnaire survey to capture information about the respondents: gender, age, teaching subject, hours of participation in ICT-focused TPD program within the current school year and years of teaching experience.

The information regarding characteristics of the respondents is presented in Table 6.2. Of the 127 questionnaires distributed to primary school teachers who met the selection criteria, 109 were returned. This gave an 85.6% response rate. Over half of the respondents were female (66%). Just under half of all respondents were between the ages of forty-six and fifty-five (43%).

More than half of the teachers taught mathematics (74%). This distribution was not intentionally designed; however, it is consistent with national patterns, as the number of primary mathematics teachers in Taiwan is much larger than that of English teachers (National Centre for Education Statistics, 2025). It should be noted that the current study did not employ sampling approaches to balance the subject proportions between mathematics and English teachers. Instead, a purposive sampling approach was used in the questionnaire survey to identify and recruit participants who met the inclusion criteria (see Chapter 4, Section 4.4.3).

Relatively large proportion had attended no more than three hours of TPD in the last school year (44%). Although the teachers were required to complete at least two compulsory workshops of three hours each in the program before 2024, this finding is not unexpected, as some teachers might have already attended workshops in previous years before this study was commenced. Finally, the demographic results show that 39% of teachers had more than twenty-one years of teaching experience. This links with the age distribution of respondents,

most of whom were aged forty-six or older. Teachers in Taiwan normally obtain their teaching certificate between the ages of twenty and thirty.

**Table 6.2**

*Demographic information of respondents*

Demographics	Frequency	
	N	%
<b>Gender</b>		
Male	37	34%
Female	72	66%
Missing data	0	0%
<b>Age</b>		
26 to 35 years old	3	3%
36 to 45 years old	14	13%
46 to 55 years old	47	43%
56 and above	35	32%
Missing data	0	0%
<b>Teaching subject</b>		
English	28	26%
Mathematics	81	74%
Missing data	0	0%
<b>Hours of participation in the given TPD program within this school year</b>		
1 to 3 hours	48	44%
4 to 6 hours	38	35%
7 hours and above	21	19%
Missing data	2	2%
<b>Teaching experience</b>		
5 years and below	12	11%
6 to 10 years	18	17%
11 to 15 years	19	17%
16 to 20 years	17	16%
21 years and more	42	39%
Missing data	1	1%

### 6.3.2 Rasch Analysis

The Rasch analysis in this study was performed using the RUMM2030+ package (Andrich et al., 2010). The Rating Scale Model (RSM) was applied to analyse the data. The following sections present the results for the VT and ITTE scales. For each scale, the Rasch results are presented in two stages: Stage 1 presents the results based on the initial set of

items and teachers (respondents), and Stage 2 presents the refined results after removing any items that were not functioning in accord with the expectations of the Rasch Theory (referred to as misfitting items).

### **Stage 1 of the Rasch Analysis of the VT Questionnaire**

Of the 109 responses returned, 107 teachers completed all the 34-items comprising the VT questionnaire. The summary results for the fit of the data to the Rasch model (model fit), overall item and teacher fit, as well as the reliability of the VT questionnaire is presented in Table 6.3. Individual teacher and item fit were then examined to identify items and teacher responses not in accord with the expectations of the Rasch model.

A summary of model fit for the VT questionnaire is presented in Table 6.3. The VT questionnaire did not fit the Rasch model well, as evidenced by a significant item-trait interaction ( $\chi^2=163.21$ ;  $df=68$ ;  $p<0.001$ ). While the overall fit to the Rasch Model does not meet the criterion for acceptable fit using traditional summary fit statistics, this outcome is common and can be strongly influenced by sample size and other factors (Andrich & Marais, 2019; Tesio et al., 2024). A more useful and practical indicator of fit to the model, particularly for identifying further scale refinement, is the number of items that have a poor fit to the model (Andrich & Marais, 2019; Tesio et al., 2024). As shown in the following section, only three of the thirty-four items in the VT questionnaire were considered to have fit that varied significantly from the expected value generated by the Rasch Model. The remaining thirty-one items fit the model well. In practice, this pattern represents a relatively good fit to the Rasch Model (Tesio et al., 2024). Consistent with this interpretation, the reliability results of the scale indicated high internal consistency and targeting of the items that comprise the VT questionnaire, with a Cronbach's Alpha of 0.94.

**Table 6.3***Summary model fit statistics and reliability of VT questionnaire*

Number of Items	Chi square ( $\lambda^2$ )			Item residual		Teacher residual		Reliability
	Value	DF	<i>P</i>	Mean	SD	Mean	SD	Cronbach's Alpha ( $\alpha$ )
34	163.21	68.00	***	0.29	1.64	-0.31	2.29	0.94

*Note.* SD refers to standard deviation. DF refers to degree of freedom.

The results of individual teachers fit residual revealed that two teachers had extreme scores (teachers 20 and 46 – see Appendix J-1). Extreme scores occur where all teachers selected the most positive (i.e., strongly agree) or most negative categories (i.e., strongly disagree) for given items. Both teachers selected “strongly agree” for all the items. These scores are excluded from the analysis as the extreme scores’ pattern provides no relative teacher and item interactive information (Marais & Andrich, 2008). Data from 107 teachers were retained for the following analyses.

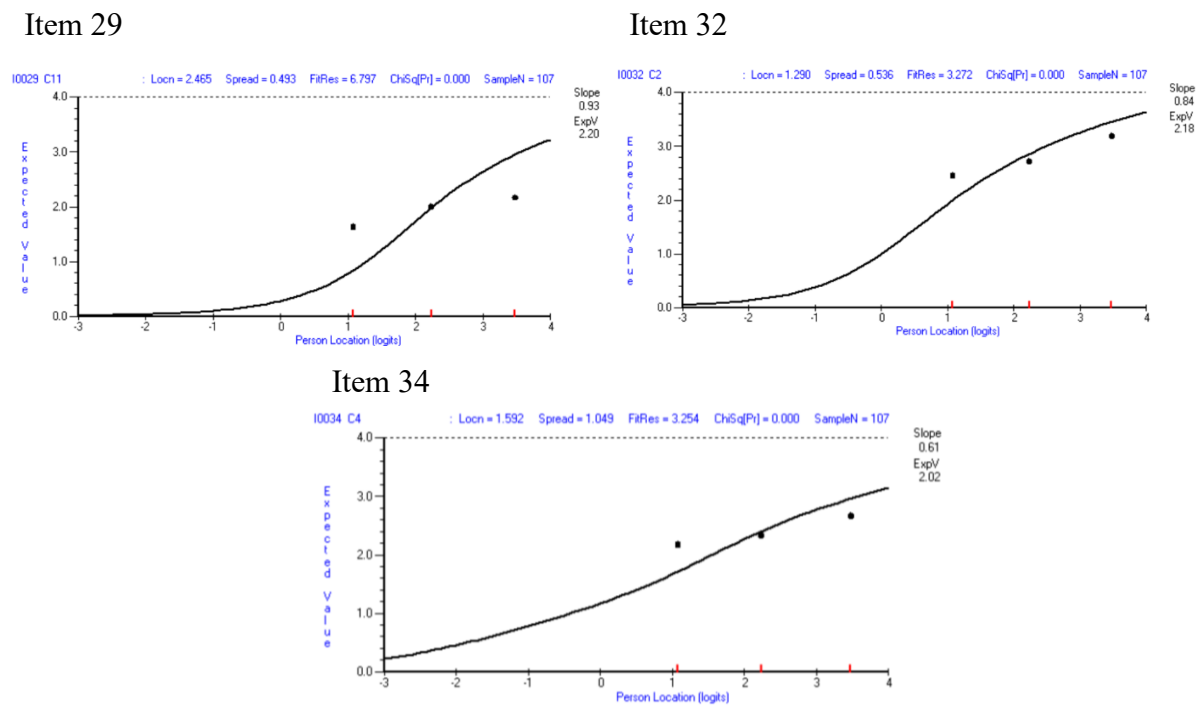
Andrich and Marais (2019) and Linacre (2023) suggest that an item fit residual value beyond  $\pm 2.5$  SD should be regarded as misfitting. Appendix J-2 shows that 3 of the 34 items, Items 29, 32, and 34, had high positive residual values of 6.80, 3.27, and 3.25, respectively. This indicates that the responses from these items varied significantly from the expected value generated by the model and that the items discriminated relatively poorly (Andrich & Marais, 2019). That is, the teachers who were in the most positive group responded less positively than predicted by the Rasch Model, and those who were less positive overall responded more positively than predicted.

The Item Characteristic Curves (ICCs) shown in Figure 6.3 illustrate the misfit that is indicative of items with positive residuals. For example, teachers with lower overall scores on the VT questionnaire (as indicated by the “dot” in the ICCs below) provided relatively higher

scores on Item 29, “It was easy for me to rearrange my classes’ timetable to attend the TPD program.” than what the model predicted. In contrast, teachers with expected higher scores in general gave relatively lower scores on Item 29 than predicted. Similar response patterns were found for Items 32, “The fees for participating in the TPD program were not too expensive.”, and Item 34, “I enjoy participating in the TPD program without too much stress.”, as shown in Figure 6.3.

**Figure 6.3**

*Item Characteristic Curves (ICC) for Items 29, 32 and 34*



It is worth noting at this stage that items which do not fit the Rasch Model were all from the “cost” domain within the VT construct (see Appendix F), as Item 29 represented Indicator C1 (takes time to rearrange the class timetable), Item 32 represented Indicator C4 (requires high financial expense), and Item 34 represented Indicator C6 (Is stressful to learn).

The misfit of items within this domain is to be expected, as the inclusion of the cost domain in the value construct has been highly debated in the Expectancy-Value Theory

(EVT) literature (as noted in Section 2.3). Unlike the other three domains in the value construct, attainment, intrinsic, and utility, the cost domain indicates a negative aspect that might contribute to a diminution in the value of the TPD. This theoretical distinction has led some researchers to argue that cost should be conceptually separated from the other three positive domains of value. (e.g., Barron & Hulleman, 2015; Jiang et al., 2018; Osman & Warner, 2020). In the earlier focus group discussions conducted in this study, the negative wording of the items in the cost domain were rephrased to positive expressions based on suggestions from participants in Focus Group 1 (FG1). This rephrasing made the wording of the items in the cost domain consistent with the wording of other items in the VT questionnaire, as explained in Section 5.2.1. Although the reworded items were reviewed and endorsed by Focus Group 3, the use of positive expressions within the items in the cost domain may have weakened the alignment between some of the items and their indicators' original negative meaning. This change may have contributed to the item misfit to the model.

Furthermore, some “cost” perceived by the teachers in attending TPD for ICT integration into teaching may not genuinely reflect the negative value of the TPD program per se. Instead, perceived costs could be related to teachers' personal experiences within their school contexts. For example, a teacher who finds it difficult to rearrange class timetables (relevant to Item 29) may attribute it to the school's policies rather than the design or implementation of the TPD program for ICT integration into teaching. Similarly, financial expenses incurred from attending the program (relevant to Item 32) may result from the school's class rearrangement fee, as most TPD programs in Taiwan do not charge a registration fee. The stress that teachers perceived from participating in the ICT-focused TPD program (relevant to Item 34) may also be due to the increased teaching load after completing the program, instead of the content of the TPD program itself. These findings indicate the cost domain items detracted from the validity of the VT questionnaire and as such, Items 29,

32, and 34 were removed from the VT items set, led to the remaining data of thirty-one items. The reduced set of data was then reanalysed using the Rasch Model in Stage 2 of the Rasch analysis to examine their fit to the model, as presented in the following section.

### Stage 2 of the Rasch Analysis of the VT Scale

The overall fit of the model, item fit and teacher fit, improved after eliminating problematic items (see Table 6.4). The reliability of the refined VT questionnaire remained very high, indicating strong internal consistency ( $\alpha=0.95$ ).

**Table 6.4**

*Summary of model fit statistics and refined VT questionnaire reliability*

Number of Items	Chi square ( $\lambda^2$ )			Item residual		Teacher residual		Reliability
	Value	DF	<i>P</i>	Mean	SD	Mean	SD	Cronbach's Alpha ( $\alpha$ )
31	77.83	62.00	0.08	0.13	1.07	-0.49	2.26	0.95

*Note.* SD refers to standard deviation. DF refers to degree of freedom.

All individual item fit residuals are within  $\pm 2.5$  SD after eliminating the problematic items, indicating all the remaining items fit the model (Appendix J-3). Individual teachers' fit residual for the refined VT item set is presented in Appendix J-4. Twenty-seven of the 107 teachers' fit residuals are beyond  $\pm 2.5$  SD, indicating inconsistent or unpredictable response patterns that do not align with the score patterns expected by the Rasch model. Given the acceptable overall model fit and the strong internal consistency of the refined VT item set, the cases of teachers' misfit are regarded as diagnostic information. The responses from these teachers are therefore retained for subsequent analyses.

The above results have indicated that the refined VT items set (thirty-one items) functions more coherently than the preliminary item set. Following that, analyses based on Steps 5 to 8 of the Rasch analysis procedure presented in the present study (see Chapter 4,

Section 4.5.3) were conducted to gether validity evidence. These analyses examined whether the VT item set meets the requirements of the Rasch model and could therefore be regarded as a measurement scale. The analytical results are presented as follows.

First, the dependency of items was examined through the statistics of items' residual correlation coefficients. The matrix of residual correlation results from the refined VT item set (thirty-one items) is presented in Appendix J-5. Most of the 961 pairs of item residuals' correlations were below 0.3, whereas fourteen pairs indicated a residual correlation greater than 0.3. As shown in Table 6.5, the correlation coefficients for seven of the fourteen pairs lay between 0.3 and 0.4 (including Items 1 and 2; Items 3 and 4; Items 6 and 7; Items 13 and 14; Items 16 and 18; Items 19 and 21; and Items 24 and 25. The other seven pairs of items' correlation coefficients were larger than 0.4.

**Table 6.5**

*Summary of item pairs with residual correlation coefficients over 0.3*

First item		Paired item		Correlation coefficients
Item number	C.I.	Item number	C.I.	
1	A1	2	A2	0.37
3	A3	4	A4	0.35
6	A6	7	A7	0.31
13	I6	14	U1	0.31
15	U2	17	U4	0.53
16	U3	18	U5	0.30
19	U6	21	U8	0.30
20	U7	21	U8	0.71
20	U8	22	U9	0.47
21	U9	22	U9	0.68
24	U11	25	U12	0.35
26	U13	27	U14	0.47
30	C2	31	C3	0.40
31	C3	33	C5	0.40

*Note.* C.I. refers to the item's corresponding indicator.

Most of the item pairs with high residual correlations are expected due to the design nature of the VT construct. Indicators behind these items were designed to represent the same feature. For example, Items 19 to 22, representing Indicators U6 (Provides recurrent training), U7 (Provides follow-up advisory service on hands-on instructions), and U8 (Provides follow-up course design and suggestion), are loaded onto Feature 11 (Provides follow-up supports), presenting residual correlation coefficients ranging from 0.30 to 0.71. High residual correlations are also observed among items loading onto the same underlying value domains. For example, the item pairs of Items 1 and 2, 3 and 4, and 6 and 7 are all loaded onto the attainment value domain in the VT construct. These items were retained in the analyses as the interdependence identified among these items was aligned with the design of the VT construct. Further research is warranted to examine whether these alliances of item residuals could affect other VT items.

The only paired items from different domains that presented a notable residual correlation are Items 13 and 14, which belong to the intrinsic and utility value domains, respectively. These residual correlations may indicate a degree of local dependency, but their correlation is only 0.31 such that, given their acceptable overall fit to the Rasch model, Items 13 and 14 were retained in the analyses.

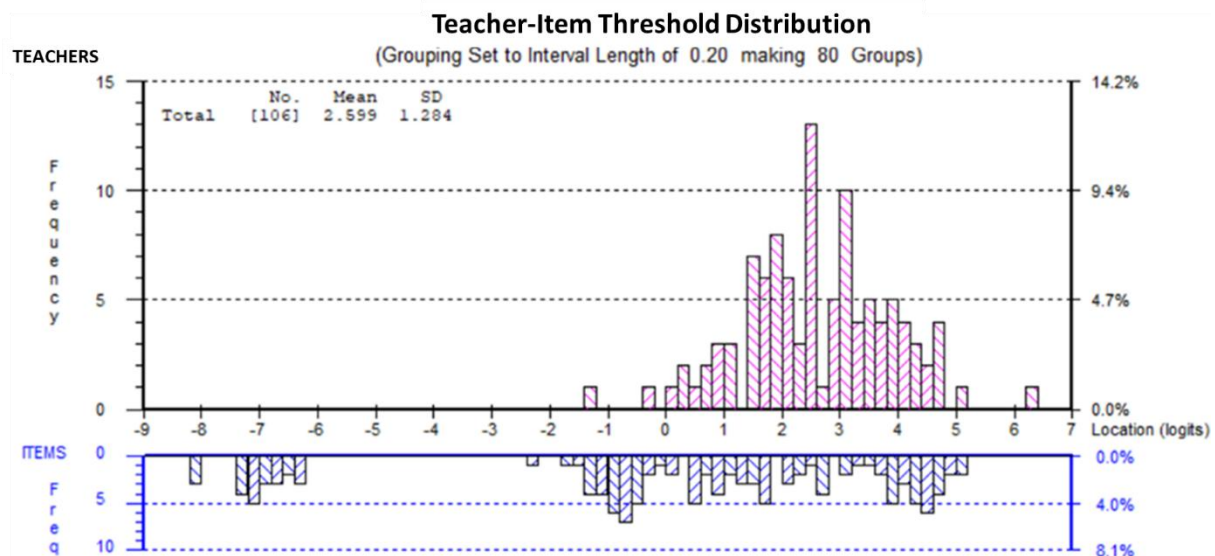
Second, the distribution for the VT items resulting from the Stage 2 analysis was presented in Figure 6.4. Teachers who scored highly on the questionnaire are located toward the right of the new continuum. The mean location of the teachers on the resulting Rasch scale was 2.6 logits (SD = 1.28 logits). Item thresholds, which demonstrate how the respondents move between responses as their perceived value of TPD increases, were distributed between -8 and +6 logits, with the majority located around -1 to 5 logits.

Several of the item thresholds appeared at the lower end of the Rasch scale (-7 to -5 logits). Most respondents were located well above these thresholds, suggesting that most

teachers found some value in the given TPD program. That is, very few indicated that they strongly disagreed with the positive statements in the VT questionnaire. This interpretation is supported by the frequencies of responses for the VT questionnaire (see Appendix J-6), which indicated that a very small proportion of teachers selected “strongly disagree” (0-2%) and “disagree” (1-14%) across the VT items. Overall, Figure 6.4 reveals that most of the thresholds are located in the same area of the scale as the respondents, which indicates that the population targeted by the questionnaire is appropriate.

**Figure 6.4**

*Teacher-Item threshold distribution for the refined VT questionnaire*



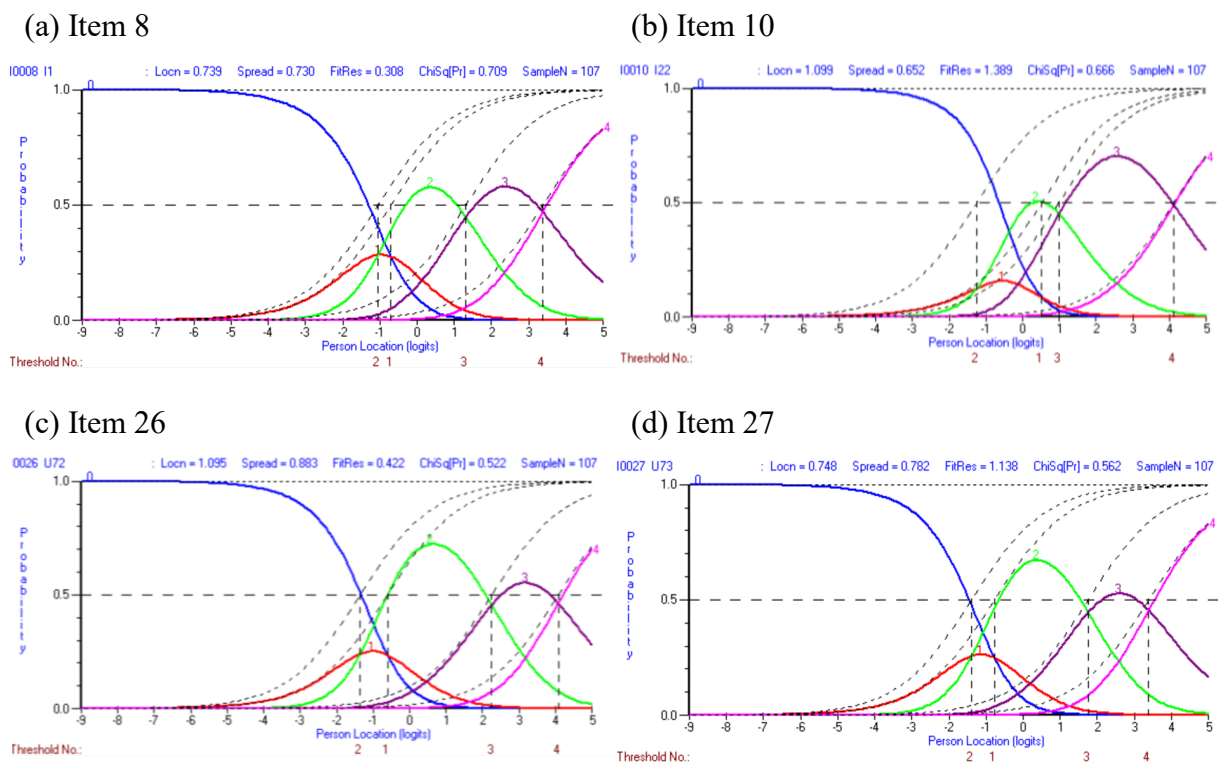
Finally, the response structure of individual items on the VT questionnaire is presented as Category Probability Curves (CPC) and revealed that disordered thresholds were observed for Items 8, 10, 26, and 27 (see Figure 6.5). According to Andrich and Marais (2019), the disorder thresholds occur when the estimated thresholds between response categories are not ordered as intended along the latent continuum. This typically indicates that a response category occupies a very narrow or no interval on the scale, which is usually due to the infrequent use of that category. In the case of the VT questionnaire, this pattern indicates that teachers located in this region of the continuum, representing the extent to which they value

the TPD program, tended to bypass the category. Instead, the teachers selected a higher or lower category when responding to the identified items.

The CPC results further show that all the disordered thresholds occurred at the first and the second thresholds. Category 1 (Strongly Disagree) was never the most likely response from any category of teachers. This pattern is consistent with the results of the person-item threshold distribution (Figure 6.4) and frequencies of the respondents (Appendix J-5) as discussed in the previous paragraph. In one sense, the pattern apparent in Table 6.5 is to be expected because the category “Strongly Disagree” would indicate that the TPD had very little or no value to the teachers attending the TPD, which would be unusual to be selected. These findings could suggest that the response category “Strongly Disagree” needs to be suppressed in future administrations of the questionnaire. Monitoring the impact of this suggestion would require the administration of a modified questionnaire to a new sample of respondents.

**Figure 6.5**

*Category Probability Curve (CPC) for items with disordered thresholds*



In summary, the two stages of Rasch analysis resulted in a refined 31-item VT set of items derived from the initial 34-item VT questionnaire. The Rasch analysis shows that the refined item set demonstrates better model fit and closer alignment with the intention of the original VT construct than the initial questionnaire. This was also supported by evidence obtained from the focus group discussions. Furthermore, the application of Rasch Measurement Theory to scale this item pool, along with elimination of non-fitting items, has transformed the ordinal Likert-type responses to the questionnaire into interval-level measures that follows fundamental measurement requirements for scale development. A raw-score-to-ability table (Appendix J-7) is developed alongside the new measurement scale, which converts the raw scores on the questionnaire into locations on the scale. The application of the raw-score-to-ability table for VT addresses RQ 1 and is discussed in the next chapter.

The next section discusses the Rasch Analysis results for the ITTE scale.

### Stage 1 of the Rasch Analysis of the ITTE Questionnaire

Of the 109 returned responses, 107 participants completed the 19-item ITTE questionnaire. A summary of model statistics, including model fit, overall item and teacher fit, and reliability, is presented in the next section of the study. This presentation is then followed by discussions of individual teacher and item fit.

A quite good fit of the ITTE data to the Rasch model is shown in Table 6.6, with a significant value of Chi square of 86.07 ( $p < 0.01$ ) on 38 degrees of freedom (DF). This fit is confirmed by examination of item misfit in that only one item did not meet model expectations. The Cronbach's Alpha results indicate excellent internal reliability of the ITTE questionnaire, with a Cronbach's Alpha value of 0.95.

**Table 6.6**

*Stage 1 summary model fit statistics and ITTE construct reliability*

Number of Items	Chi square			Item residual		Person residual		Reliability
	Value	DF	<i>p</i>	Mean	SD	Mean	SD	Cronbach's Alpha( $\alpha$ )
19	86.07	38	***	-0.26	2.20	-0.74	2.43	0.95

*Note.* SD refers to standard deviation. DF refers to degree of freedom.

As shown in Appendix K-1, four teachers were found to have extreme scores. These teachers' scores were excluded from the analysis as they provide no information regarding the interaction between item difficulty and respondents' ability (Marais & Andrich, 2008).

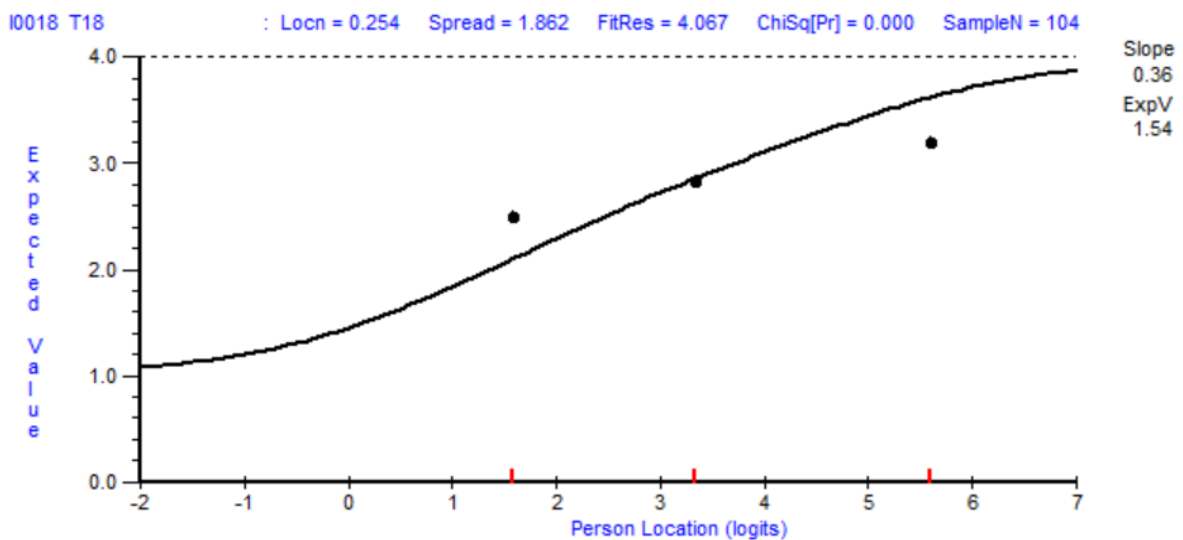
Residual values beyond  $\pm 2.5$  SD in individual item fit statistics are considered to be misfit or overfit (Andrich & Marais, 2019). In the ITTE item set, Item 18 (referred to as Item

4 in the ITTE focus group discussions) was identified as a misfitting item with a fit residual of 4.07 ( $p < 0.001$ ) (see Appendix K-2).

The ICC of Item 18 is shown in Figure 6.6. The figure indicates that teachers with lower overall scores on the ITTE questionnaire selected relatively higher scores on Item 18, “Participation in the TPD program enhanced my capacity to increase global understanding by students from diverse cultures through technologies”, than was predicted by the Rasch Model (Actual 2.5 versus Expected 1.8). Conversely, a lower-than-expected score was obtained from teachers who were regarded as higher-scoring teachers on the ITTE questionnaire (Actual 3.3 versus Expected 3.7).

**Figure 6.6**

*ICC for Item 18*



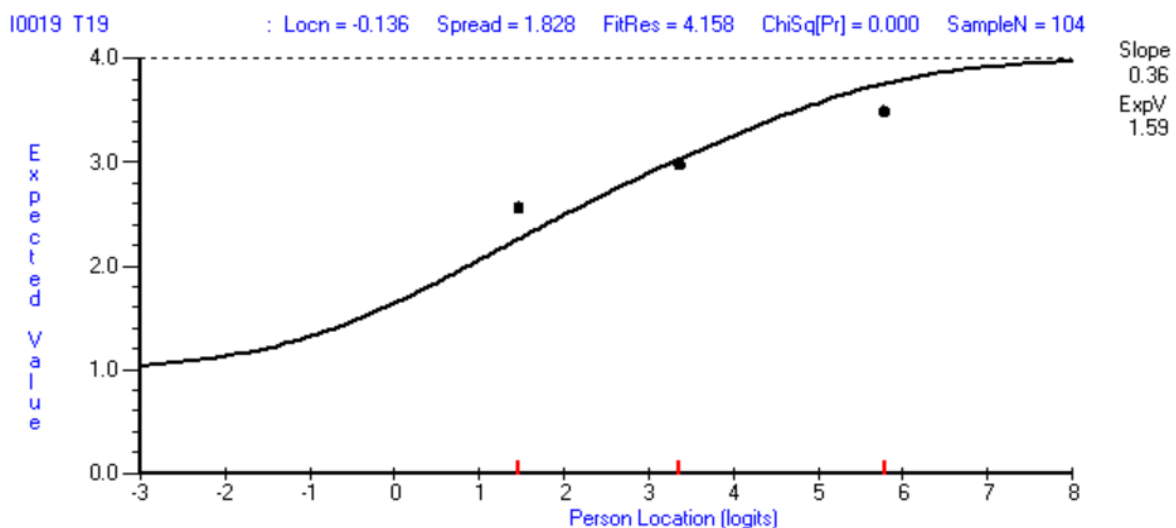
The inclusion of Item 18 was critically debated during the focus group discussions. In particular, the discussions pointed out a misalignment between the concepts of cultural and global understanding which manifested more in Item 18 than with other items which were more focused in integrating ICT into mathematics and English classrooms in Taiwan (see Chapter 5, Section 5.4). The results of the Rasch analysis at this stage confirmed the

misalignment of Item 18 with other items. Accordingly, Item 18 was excluded from the ITTE item set.

The data were then reanalysed with Item 18 eliminated from the item set. The subsequent results showed that Item 19 (referred to as Item 12 of ITTE in focus group discussions) demonstrated misfit (fit residual of 4.16,  $p < 0.001$ , see Appendix K-3). As can be seen from Figure 6.7, teachers with lower overall scores on the ITTE questionnaire selected relatively higher scores than expected by the model for Item 19, “Participation in the TPD program enhanced my capacity to use a range of technologies to introduce different cultures and traditions in classes” (Actual 2.5 versus Expected 2.1). Teachers with higher overall scores on the ITTE questionnaire performed slightly lower than what was predicted by the Rasch Model (Actual 3.5 versus Expected 3.8).

**Figure 6.7**

*ICC for Item 19 after excluding Item 18*



The misfit of Item 19 was to some extent expected as its alignment with other items had been challenged by participants during the focus group discussions. Focus Groups 2 and 3 raised concerns about the emphasis on understanding of multicultural traditions as unrelated to the current focus of ICT-integration into teaching in Taiwan (see Chapter 5, Section 5.4). It is

also worth noting that the response patterns for Items 19 and 18 were similar. Item 19 was eliminated at this stage of analysis. The remaining seventeen items were then reanalysed, as presented in the following section.

### Stage 2 of the Rasch Analysis of the ITTE Scale

The overall fit of the data to the Rasch model was acceptable with a  $\lambda^2 = 43.83$  with 34 degrees of freedom ( $p \approx 0.1$ ) (see Table 6.7). The mean and SD of the item fit residual have been improved (Mean=-0.32; SD=1.64), as well as the teacher fit residual (Mean = -0.75; SD = 2.19), while the reliability of the refined ITTE questionnaire remained the same ( $\alpha=0.95$ ).

**Table 6.7**

*Summary model fit statistics and reliability of refined ITTE questionnaire*

Number of Items	Chi square			Item residual		Person residual		Reliability
	Value	DF	<i>p</i>	Mean	SD	Mean	SD	Cronbach's Alpha( $\alpha$ )
17	43.83	34	0.12	-0.32	1.64	-0.75	2.19	0.95

*Note.* SD refers to standard deviation. DF refers to Degree of freedom.

The fit residuals for the remaining items were within  $\pm 2.5$  SD, indicating all the remaining items fit the model (Appendix K-4). Individual teachers' fit residual for the refined ITTE item set is presented in Appendix K-5. Twenty-four of the 103 teachers' fit residuals were beyond  $\pm 2.5$  SD, indicating inconsistent or unpredictable response patterns that do not align with the score patterns expected by the Rasch model. Same as the analyses for the VT scale, these misfit teachers' responses were retained and the results of teachers' fit residual on the refined ITTE questionnaire were regarded as diagnostic information linking to the subsequent analyses.

The above results have indicated that the refined ITT items set (seventeen items) functions more coherently than the preliminary item set. Following that, analyses based on Steps 5 to 8 of the Rasch analysis procedure presented in the present study (see Chapter 4, Section 4.5.3) were conducted to provide validity evidence for determining whether the refined ITTE item set meets the requirements of the Rasch model and could therefore be regarded as a measurement scale. The analytical results are presented as follows.

First, the dependency of items was examined through the statistics of items' residual correlation coefficients. The matrix of residual correlation results for the refined ITTE scale are presented in Appendix K-6. Most item pairs had residual correlations below 0.30, except for Items 10 and 11 (0.30), and Items 14 and 15 (0.31). The correlations of these two pairs were only slightly higher than other pairs, potentially owing to the small sample size of the present study. In addition, although the value of 0.3 has been widely used to determining the dependency between items, some studies had used a value of 0.5 or 0.7 for distinguishing the depended items, as there is still not a cut-off value represents an independency of the items (see discussions in Chapter 4, Section 4.5.3). Thus, Items 10, 11, 14 and 15 were retained at this stage of the analysis.

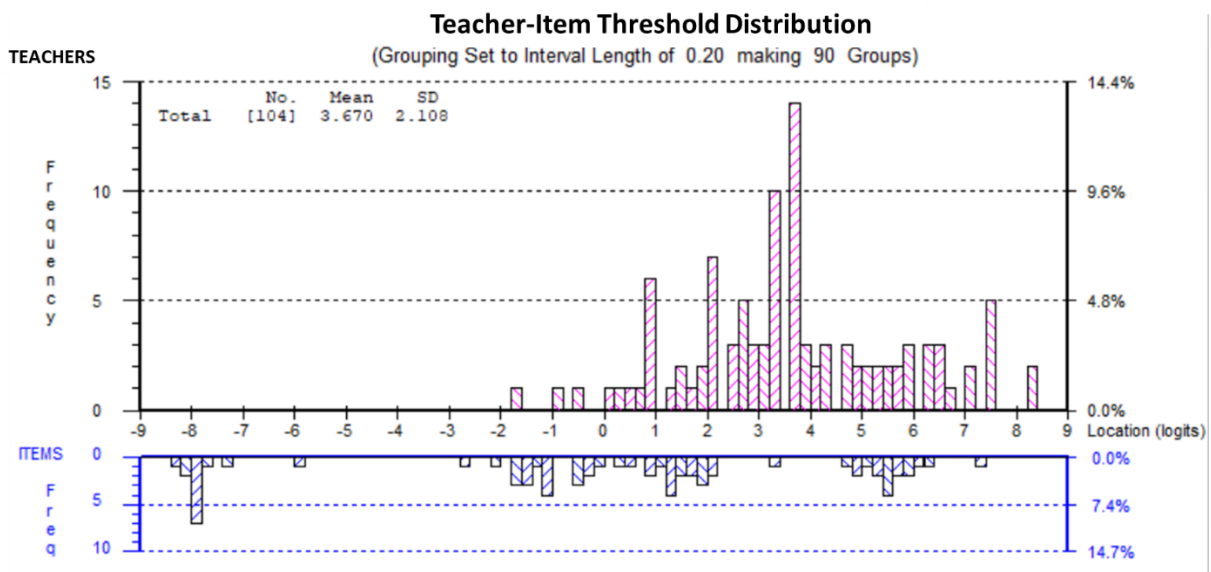
Second, Standard analysis of variance (ANOVA) was used in conjunction with the item characteristic curve (ICC) to determine whether the items comprising the refined ITTE item set function differentially across different groups of teachers grouped by teaching subjects and years of teaching experience. The ANOVA results revealed that there were no significant differences ( $p>0.05$ ) in responding to the refined ITTE item set across different teaching subjects (Appendix K-7) and years of teaching experience (Appendix K-7).

Third, the person-item distribution for the latest analysis of the refined ITTE questionnaire is presented in Figure 6.8. It shows the teacher location(measures) and item thresholds, respectively. The relative overlap of the teachers' measures and the item

thresholds (locations or difficulties) suggests that the scale is well targeted to the teachers who have responded to the questionnaire. Figure 6.8 shows that the teachers were inclined to respond positively to the items in the questionnaire, as the item thresholds were mainly distributed between -2 and 6 logits. Only a very small number of item thresholds were located at the lower end of the continuum (-9 to -6 logits), indicating that very few teachers expressed that they strongly disagree with the positive statements in the ITTE questionnaire. This interpretation is supported by the frequencies of responses results for the ITTE questionnaire (See Appendix K-8), which showed that only a small proportion of teachers selected “strongly disagree” (0-2%) and “disagree” (1-6%) across the ITTE items.

**Figure 6.8**

*Teacher-Item location distribution for the refined ITTE questionnaire*



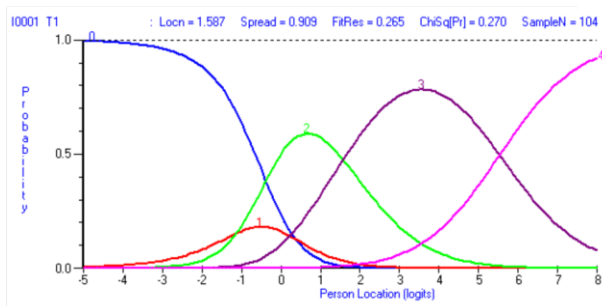
Finally, as shown by the CPC results presented in Figure 6.9, Items 1 and 15 were found to have disordered thresholds. Disordered thresholds occurred at the first and the second threshold, where Category 1 (Strongly Disagree) was completely suppressed. This indicates that the Category 1 was never the most likely response from any category of teachers. This pattern is consistent with the findings presented in Figure 6.8 and Appendix K-8 discussed in the previous paragraph. The occurrence of such disordered thresholds is

expected due to the self-assessment nature of ITTE items, in which the respondents may tend to overestimate their ability when answering self-assessment questionnaires (Karpen, 2018). These findings could suggest a possible suppression of the response category “strongly disagree” in future administrations of the questions. Administration of a modified ITTE questionnaire would be needed to monitor the impact of this suggestion.

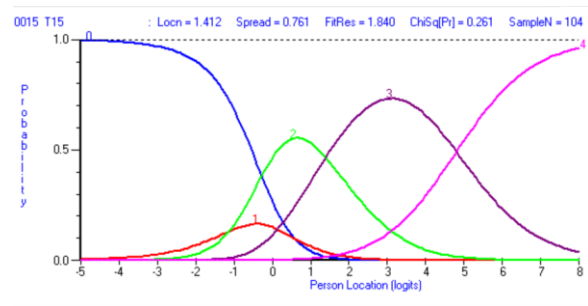
**Figure 6.9**

*CPC for disordered items*

(a) Item 1



(b) Item 15



In summary, the two stages of Rasch analysis result in a refined ITTE item set (seventeen items), which present better model fit that closer alignment with the original ITTE construct than the initial 20-item questionnaire. Evidence obtained from experts’ feedback in focus groups and the results of Rasch analysis has supported the refined item set’ validity. Through the application of Rasch Measurement Theory to scale the item pool and the elimination of non-fitting items, the ordinal Likert-type responses from the questionnaire have transformed into interval-level measures. A raw-score-to-ability table (Appendix K-10) alongside the new measurement scale, the ITTE scale, is developed, which converts the score on questionnaire into locations on the scale. The application of the raw-score-to-ability table for ITTE addresses RQ 2 and is discussed in the next chapter.

The next section addresses the results of correlation analysis.

### 6.3.3 Correlation Analysis

A Pearson correlation coefficient ( $r$ ) was generated to investigate the relationships between VT, ITTE and students' learning achievement (RQ3). This step sought proof of concept for how results from the VT and ITTE scales might be used to ascertain the extent of implication relationships between scales in educational research contexts. As outlined in Chapter 4, Section 4.4.3, respondents to the large-scale questionnaire survey were asked to provide their classes' test score results in Student Academic Attainment Tests (SAAT) from the same group of students for two successive years. The intention was to use the difference in the mean scores on the two occasions as a measure of achievement variation. Of the 109 returned questionnaires, 68 participants provided summary data on their class test scores.

Before conducting the correlation analysis, each year of the score result was transformed into a standardised  $z$  score to calculate changes in students test scores between the two consecutive years as the data of students' learning achievement. VT and ITTE measures obtained by Rasch analysis were generated for each of the 68 participants.

A Pearson's correlation coefficient ( $r$ ) above 0.40 was considered as to be relatively substantial relationship, while a value above 0.70 indicates a strong relationship (Schober et al, 2018). As presented in Table 6.8, results revealed a significant positive bivariate correlation between the VT and ITTE ( $r=0.72$ ,  $p<0.01$ ). However, no significant correlations were found between VT and students' learning achievement, or between ITTE and students' learning achievement.

**Table 6.8***Correlations between VT, ITTE and students' learning achievement*

	The improvement of students' learning achievement (z score)	VT	ITTE
The improvement of students' learning achievement (z score)	-	0.05	0.06
VT		-	0.72**
ITTE			-
Sample Number		68	
Mean	0.00	2.37	3.91
SD	0.57	1.23	1.90

Note: \*\*. Correlation is significant at the 0.01 level (2- tailed)).

The results of the correlation analysis demonstrated a lack of significant relationships between either VT or ITTE and students' learning achievement. From the perspective of Kane's (2006) argument-based validation framework, these findings do not support the expectation that the implication of the VT and ITTE scale scores could be extended directly to the expectations of students' learning achievement. However, given the small sample size conducted in this stage of analysis, these findings should be carefully interpreted. On one hand, this could suggest the appropriate use of the VT and ITTE scales in the future, which is for informing interpretations related to teachers' perceptions on TPD and their perceived growth in professional knowledge, rather than assuming the success of the program on students' learning outcomes. On the other hand, the findings have revealed the limitation of the present study and inform the need for further investigation using larger sample to confirm the implications drawn from these correlation results.

Discussions between the findings of this correlation analysis in conjunction with other studies, as well as an explanation of how they address RQ3, is present in the next chapter.

## 6.4 Chapter Summary

Chapter 6 provided the findings from the pilot testing and a large-scale questionnaire survey as further evidence regarding the validity of the VT and ITTE scales. The pilot testing results provide insight into the feasibility and clarity of the overall questionnaire from a larger group perspective. Based on pilot testing results, the Chinese translation and the wording of Q4 have been revised again and the format of the online questionnaire redesigned.

The large-scale questionnaire survey was analysed using Rasch analysis and correlation analysis. The results of the Rasch analysis suggested most of the items functioned as intended and aligned well with their respective latent constructs. Three misfitting items (Item 29, 32, and 34) in VT were identified and removed from the Rasch analysis because they did not function in accord with what was expected from the model. Information obtained from the Focus Groups also impacted the decision to remove those items from the scale. The remaining VT items presented a better fit to the model supporting the unidimensional construct of the value of TPD.

Two misfitting items (Item 18 and 19) in the ITTE were identified and removed from the Rasch analysis as a consequence of the misfit between what the Rasch Model predicted to be the response pattern and what actually occurred. The evidence supporting removing the items was first identified during the focus group sessions and the data from the analysis was then more confirmatory than exploratory. The items were both mentioned as potentially problematic items during the previous focus group discussions, and their difficulty in representing the context of TPD for ICT integration into teaching in Taiwan. The remaining ITTE items indicated a relatively good fit to the model, supporting the unidimensional construct of teachers' perceived improvement in TPACK-core resulting from participation in TPD.

The results of the correlation analysis indicated no significant relationship between the extent to which teachers value TPD and their students' learning achievement, nor between teachers' perceived improvement in TPACK-core through the participation in TPD and their students' learning achievement. These findings are reasonable given a small sample size at this stage of analysis and the multitude of contextual and instructional factors that may influence the outcome of students' learning. Detailed discussion and limitations regarding the correlation analysis conducted in the present study are presented in the next chapter.

## **Chapter 7: Discussion and Conclusion**

### **7.1 Introduction**

This chapter presents the findings of the study, addressing its three research questions linked to the development, validation, and implementation of two measurement scales: the value of TPD (VT) scale and the improvement of the TPACK-core via TPD Experience (ITTE) scale. The chapter concludes with a discussion of the study's implications and limitations, as well as suggestions for future research. This study demonstrates the process of collecting evidence under deductive and inductive approaches in order to support validity arguments for the measurement scales through the lens of Rasch Measurement Theory. The process described here can be generalised to other scale development studies in the field of education and as well as other fields such as health and marketing.

### **7.2 Research Question 1: To what extent do mathematics and EFL primary school teachers in Taiwan value a given TPD program for ICT integration into teaching?**

The measurement scales developed in this study are intended to provide evidence of the extent to which the value of a given TPD program for ICT integration into teaching through the perspectives of primary school teachers in Taiwan. This study's findings in relation to three sub-research questions included within Research Question 1 (RQ1) are discussed in the following sections and a direct answer to the overarching question presented.

#### **7.2.1 RQ1a: What are the features of TPD that teachers value?**

In this study, teachers' perceptions of the value of TPD were conceptualised within the framework of Eccles et al.'s (1983) Expectancy-Value Theory (EVT) and in relation to features of TPD identified in the previous literature as critical to the successful implementation of TPD (i.e., implementation-oriented features) or as having increased teachers' motivation through continued engagement in TPD programs (i.e., motivation-

oriented features). Overall, twenty-one features of TPD were found to be related to the value of TPD.

Among the twenty-one features, seventeen were found related positively to the value of TPD:

- (1) focus on specific content, knowledge and skills;
- (2) recognise the experience and prior knowledge of teachers;
- (3) provide feedback, assessment and reflection;
- (4) provide career advancement;
- (5) target active learning;
- (6) provide well-qualified instructors;
- (7) encourage collaborative learning;
- (8) target novelty;
- (9) provide opportunities for hands-on learning;
- (10) help with students' development;
- (11) align with current demands and visions;
- (12) provide convincing exemplary material;
- (13) provide follow-up support;
- (14) provide contents, ideas that are relatively easy to implement in class;
- (15) make teaching materials introduced in the sessions easy to access;
- (16) provide teaching materials; and,
- (17) conducted over a sustained period.

Previous studies have suggested that the absence of any positive features can weaken the effectiveness of others. For example, the feature “active learning” is closely related to other features such as “collaborative learning”, “hands-on learning” and “feedback, assessment and reflection” (Darling-Hammond et al., 2017; Huang 2021; Kimav & Kurum-

Yapicioglu, 2021). Similarly, “provide well-qualified instructors” can ensure the successful implementation of “active learning” and “focus on specific content” (Bates & Morgan, 2018). In the present study, the extent of the alignment of these features was considered by the focus group participants. During the discussion, the participants consistently stressed that all the identified features were important in evaluating the value of TPD.

Four features of TPD that potentially detract from the value (i.e. cost) were included, as EVT is a theory that governs to some degree the design and conceptualisation of this study. This resulting in a total of twenty-one features found critical to the value of TPD.

These four cost-related features are:

- (18) time-consuming
- (19) high financial expense
- (20) tedious procedures to implement
- (21) stressful to learn

Notably, Focus Group 1 (FG1) participants highlighted the importance of including the negative features (Features 18 to 21) in any questionnaire designed to determine the value of TPD for teachers. This latter opinion from the FG1 aligns with Osman and Warner’s (2020) findings, which found that teachers often mentioned negative concerns when evaluating a TPD program. These findings provide empirical justification that positive and negative features contribute towards a unidimensional measure of the value of TPD.

In order to justify the structure of VT construct, the next section provides validity evidence regarding how the twenty-one features of successful TPD align with the value domains of EVT.

### **7.2.2 RQ1b: How do these features align with the four domains of value derived from Eccles et al.'s (1983) Expectancy-Value Theory?**

According to EVT, an individual's perception of the value of a task can be assigned (loaded onto) one of four domains: attainment value, intrinsic value, utility value and cost (Eccles et al., 1983). Likewise, the twenty-one features of TPD that teachers value load onto four domains identified in Eccles et al.'s (1986) EVT. An initial alignment between these domains of value and the TPD features was established through a review of the literature and then evaluated by the FG1 participants. Overall, the FG1 participants confirmed that the twenty-one can be meaningfully mapped onto all four domains of value derived from the EVT with adjustments to features' wordings, translations, placements, and descriptions (see Chapter 5, Section 5.2).

Most of the feedback from the FG1 participants was contained within the domains of attainment and utility. For example, participants suggested moving "Align with teachers' needs" from the utility to the attainment value domain, while agreeing that "Align with school's needs" should remain in the utility value domain. This switching of "teachers' needs" to attainment value is aligned with Watt and Richardson's (2007) study, where they redefined attainment value as "personal utility value", or the personal benefits that individuals expect to receive when participating in a task.

The FG1 participants also proposed relocating "provides career advancement" from the attainment value domain to the utility value domain, as the advancement of teaching quality is the focus of teachers' careers, which is a long-term goal that is more aligned with the meaning of the utility value domain. Career advancement is generally linked with an individual's personal goals, such as personal promotion or recognition, reflecting the value of attainment (Eccles et al., 1983; Eccles & Wigfield, 2020; Osman & Warner, 2020). However, in this study, teachers interpreted career advancement from the perspective of improving

teaching quality, which aligns with the long-term purpose of enhancing teaching practice and student learning. This interpretation of career advancement is more aligned with the utility value domain, which emphasises the long-term and short-term practical benefits of participating in the TPD program, such as the enhancement of instructional practice and student learning (Gaines et al., 2019; Osman & Warner, 2020).

This study specifically focused on mathematics and EFL teachers who participated in a nationwide TPD program for ICT integration into teaching in Taiwan. The value of TPD, as a construct in this study, was therefore grounded in this particular policy and program context. However, evidence from the FG1 discussion indicates that the applicability of the VT construct may extend beyond this specific setting. Participants highlighted that similar forms of TPD for ICT integration into teaching are being implemented across different countries and educational systems (see Chapter 5, Section 5.2.3), suggesting that the VT construct can potentially be applied to other contexts. Importantly, the VT construct was conceptualised based on critical features of TPD that were theoretically and empirically identified in previous studies across diverse contexts (see Chapter 3, Section 3.3.2). As such, the construct captures the core domains of the value of TPD that are broadly relevant across contexts. With minor modifications to the wording of questionnaire items to reflect different subject and program emphases, the VT construct can be meaningfully adapted to other forms of TPD with different foci.

The next section discusses the evidence resulting from the focus group discussions and Rasch model analysis to support the development and utility of a measurement scale to measure the extent to which participants in a purposive sample of teachers from Taiwanese mathematics and EFL primary schools value TPD programs for ICT integration into teaching.

### **7.2.3 RQ 1c: To what extent does the measurement scale proposed in this study reflect the intended construct of the value of the TPD?**

Draft items for the VT scale were developed based on the study's VT construct. The evidence used to support the validity of the VT includes outcomes resulting from two focus group discussions (FG1, FG3) and the administration of a large-scale questionnaire survey analysed using the Rasch model. The Rasch model was used with the intention of building a measurement scale that could be used to answer Research Question 1c, which is a measurement question. It asks "how much" do primary mathematics and EFL teachers value TPD.

Evidence collected from focus group discussions was used to support the validity argument represented by Kane's (2006) validation framework (see Chapter 5). This evidence includes the appropriateness of the items used to capture the features aligned within each value domain. It also provides evidence of the appropriateness of the scoring of the items (scoring) and the extent to which the items represent real life situations (extrapolation). Participants in FG1 conducted a comprehensive review of each feature and corresponding indicators as well as the value domain to which they were proposed to align. They also made suggestions to better align the original features and indicators, which increased the validity of the original questionnaire of the VT construct. Participants in FG3 primarily gave suggestions on the wording and translation of the items while confirming the overall conceptual appropriateness and consistency of the VT construct and its items.

Results from the Rasch analysis also supported the outcomes from focus group discussions, indicating that both the scale and most of the items fit the Rasch model well and that there is a high degree of internal consistency (reliability). Only three items related to the cost domain, Items 29, 32, and 34, were identified as misfitting the model in relation to the construct that was defined by the rest of the items. The justification for removing these three

items from the analysis and hence the final version of the VT scale has been presented in Chapter 6, Section 6.3.2.

It is worth noting that the result from ANOVA, conducted as part of the differential item functioning analysis (DIF), shows that most of the items function well across different groups of mathematics and EFL teachers stratified by teaching subjects in responding to the VT items. This finding supports evidence for the generalisability of the VT scale across different disciplines. Even though mathematics teachers were assumed to value the TPD for ICT integration into teaching more highly than the EFL teachers, given that the literature shows their participation rates in this type of TPD are generally higher (NCTM, 1989, 2000, 2014), their responses to the VT were similar to those of the EFL teachers. This implies that the value of the TPD program for ICT integration into teaching, as assessed by the VT scale, is equally applicable and meaningful across teachers in both subjects.

Results from the Category Probability Curve (CPC) show that there were reverse thresholds for Category 1 (Strongly Disagree) responses in Items 8, “The TPD program motivated me to learn actively.”, 10, “The TPD program provided opportunities for cross-discipline collaborative learning.”, 26 “My school provided teaching materials introduced from the program.” and 27 “My school provided teaching equipment introduced from the program.”. Disagree responses were never the most likely outcome across the range of “achievement”, which means that very few teachers selected “disagree” on these items in this category. The reasons for these reversals may have been that the category descriptions were not clear because of the way the item was worded (though the focus groups had indicated that this was not an issue) or the differences were real in the sense that there was no disagreement with these items. The latter is a positive response as it interprets that the teachers generally agree the given TPD program for ICT integration into teaching matches the indicators represented by these items, which is more likely the case in the present study.

Furthermore, the high agreement between teachers on the provision of teaching materials (Item 26) and equipment (Item 27) may be due to the close relationship between the TPD program that are the focus of the present study and other digital learning enhancement policies currently conducted in Taiwan, including the provision of tablets for every primary school student and the development of a new online learning Taiwan Adaptive Learning Platform (TALP). Thus, these items were retained in the VT scale.

The results of the Rasch analysis provide further evidence that the VT scale (with misfitting items removed) is fit for purpose. It fits the Rasch model and, as such, can be used to measure the extent to which teachers perceive the value of a given TPD program on a linear and interval-level measurement scale (Andrich & Marais, 2019).

The next section interprets the results of the VT scale estimated through Rasch analysis to address the extent to which mathematics and EFL primary school teachers in Taiwan perceived the value of the given TPD program for ICT integration into teaching.

#### **7.2.4 Measurement of mathematics and EFL primary school teachers' ratings of the value of a given TPD program for ICT integration into teaching in Taiwan**

Rasch estimates reported on a logit scale can be interpreted as interval-level measures of a latent construct (Andrich & Marais, 2019). Such measures, derived from the Rasch model represent the construct as a quantitative variable that fulfils fundamental requirements of measurement, which is not available to questionnaires with the same measuring purpose analysed using Classical Test Theory (Bond et al., 2020; Tesio et al., 2024). One of these features is that subsets of the items can be used to locate the performance of teachers on the construct, and the results can be compared, so long as they are calibrated on the VT scale. It also means that items can be removed and added to the scale while still retaining the scale's

capacity to compare teachers' measures on the construct across time or administrations (Bond et al., 2020; Tesio et al., 2024).

In addressing Research Question 1, the “extent” to which teacher value a given TPD program is operationalised as teachers' measures (locations) on the latent VT continuum, as estimated by the Rasch model and indicated in logits on the scale. Accordingly, raw scores collected from the VT questionnaire were not regarded as measurements in of themselves but were estimated as individual teachers' measures on the VT scale (logits). Following the validation process through Rasch analysis, the final version of the VT scale comprised thirty-one items. As presented in Appendix J-7, the observed raw scores from the VT questionnaire were converted into interval-level teacher measures on a 31-item VT scale through Rasch model estimation implemented in RUMM2030+ (Andrich et al., 2010).

Appendix J-7 further indicates that the maximum possible raw score on the VT scale is 124, which reflects the scoring of the 31-item questionnaire, in which responses to each five-point Likert-type item are scored from 0 (Category 1 “Strongly Disagree”) to 4 (Category 5 “Strongly Agree”). The corresponding Rasch measures ranged from -10.68 to 8.20 logits, representing teachers' measures (locations) on the scale of their perceived value on the given TPD program. For example, a raw score of 88 on the VT questionnaire corresponds to a mean teacher measure of 2.66 logits, indicating that on average, teachers within this score range rated a high value on the TPD program for ICT integration into teaching.

The next section addresses the second research question regarding the extent to which the primary mathematics and EFL teachers perceive improvement of their TPACK-core as resulting from their experience in the TPD program for ICT integration into teaching.

### **7.3 Research Question 2: To what extent do primary school mathematics and EFL teachers in Taiwan perceive that the given TPD program for ICT integration into teaching has improved their TPACK-core?**

This research question is related to the second research purpose, which is to develop a measurement scale that provides evidence of the extent to which mathematics and EFL primary school teachers in Taiwan perceive improvement in their TPACK-core as resulting from their experience in a given TPD program. It is important to note that, as discussed in the previous chapters, the present study focuses on the core domain of knowledge within the TPACK framework (TPACK-core) to represent teachers' knowledge in appropriately and effectively integrating ICT into their pedagogical techniques in a specific subject content to assist student learning (Cox, 2008; Koehler et al., 2017, Tondeur et al., 2017). Accordingly, the measurement scale developed at this stage was called the improvement of TPACK-core via TPD experience (ITTE) scale. Findings of the research questions are discussed in the following sections.

#### **7.3.1 RQ 2a: How do items developed from existing TPACK questionnaires align with the context of TPD for ICT integration into teaching in Taiwan?**

The twenty initial items of ITTE were adapted and selected from existing TPACK questionnaires developed by Archambault and Crippen (2009), Chai et al. (2011), Sahin (2011), and Schmidt et al. (2009). The description of the items was modified by the researcher in alignment with the research purpose and the context of the study (see Chapter 3, Section 3.4.1). Discussions from FG2 and FG3 provide evidential arguments for alignment between the twenty items generated based on the existing TPACK questionnaire and the ITTE construct in the context of TPD for ICT integration into teaching in Taiwan.

FG2 participants pointed out that some terminology was confusing and inappropriate in the context of Taiwan's primary education. For example, in the education sector

“technologies” could refer both a subject and a type of teaching tool. The phrase “unique content” was also noted to contain negative associations when translated into Chinese. “Innovative content” was determined to be a more appropriate replacement.

These findings support Mishra and Koehler’s (2006) assertion that the TPACK framework is “context bound”. Teachers’ knowledge of TPACK-core cannot be measured meaningfully without considering the education and cultural context of the teachers. As discussed in Chapter 3, Section 3.4.1, decontextualised items from the existing TPACK questionnaires used to assess TPACK-core were often adopted across studies but can result in validity concerns through the misrepresentation of teachers’ actual knowledge (Koehler et al., 2011; Messick, 1989). Thus, this present study followed participants in the focus group discussions’ suggestion on the revisions of wording of items.

FG2 and FG3 participants debated the contextual alignment between two items and the purpose of measuring ITTE. Participants in FG2 argued that Item 18, “My capability of promoting global understanding by engaging students with diverse cultures through technology has been enhanced by participating this TPD program. and Item 19, “My capability of using a range of technologies to introduce different cultures and traditions in classes has been improved by participating this TPD program.” had a relatively narrow scope and were irrelevant to the purposes of mathematics and English teaching, as these items focused on the enhancement of knowledge on promoting global understanding, culture and diverse tradition by incorporating proper technological tools. Thus, they suggested removing the items. On the other hand, FG3 participants argued the importance of these items when delivering specific pedagogical strategies such as the problem-based learning (PBL) and cultural exchange courses in the mathematics classes in Taiwan, and suggested the items be retained.

Differences in opinions between the focus groups on the two items highlight that the items adapted from the existing TPACK questionnaire are not fully aligned with the context of TPD for ICT integration into teaching in Taiwan. Most of the items were regarded as contextually aligned with the Taiwanese context by the focus groups following minor revisions to the wording, whereas there was a lack of consensus on the contextual alignments of Items 18 and 19 among the focus groups. Given this disagreement, these two items were retained for subsequent Rasch analysis to examine their alignment with the intended ITTE construct at the measurement level. In contrast, one specific item (Item 20) was removed before conducting the Rasch analysis due to redundancy, with this removal supported by FG2 and FG3.

Evidence from the results of Rasch analysis are shown in the next section to further support the argument for the validity of the questionnaire and the construction of the measurement scale for ITTE.

### **7.3.2 RQ 2b: To what extent does the measurement scale proposed in this study capture teachers' perceived improvement in TPACK-core resulting from participation in the given TPD program for ICT integration into teaching?**

The validation process for ITTE included two focus group discussions (FG2, FG3) and questionnaire results obtained through an analysis of the responses of a sample of 107 teachers. Rasch analysis was used to examine whether ITTE items can effectively measure the intended ITTE construct within the context of the present study. Findings from FG2 and FG3 support the feasibility of most of the ITTE items in capturing the ITTE construct. The results from Rasch analysis provide further evidence that most of the items function as predicted and in accordance with the governing measurement model, with the resulting scale demonstrating high reliability (0.95). However, as presented in the previous section, Items 4 and 12 (reordered as Items 18 and 19 in the Rasch analysis) were challenged by focus group

participants due to their lack of alignment with the rest of the items and their divergence from the intended focus of the underlying construct. The results of the Rasch analysis further confirmed the misfit of these same two items relative to the rest of the scale. Accordingly, feedback from the focus group participants and results from Rasch analysis provided sufficient rational supporting the removal of these two items to improve the scales' validity. These two items were thereby removed in the final scale.

Similar to the results from the VT scale, the ANOVA results for ITTE indicate that the items functioned as expected across teachers from different subjects and years of teaching experience and thus support the generalisability of the ITTE scale among teachers from different backgrounds (mathematics and EFL). Notably, the finding that there was no significant difference in ITTE between teachers with different years of teaching experience contradicts the results of Nazzari et al.'s (2019) study. Nazzari et al.'s (2019) study identified a significant difference in novice and experienced teachers' perceptions of TPACK-core level following participation in a TPD workshop for ICT integration into teaching. This difference in findings may be attributed to the use of the TPACK questionnaire in Nazzari et al.'s (2019) study, which was adapted from an existing TPACK questionnaire decontextualised from the context of teachers' participation in the TPD for ICT integration into teaching. Nazzari et al.'s (2019) conclusions on teachers' perceived TPACK-core level could potentially have been affected by facets of teachers' pre-existing TPACK-core level before participating in the workshop. In contrast, the ITTE scale developed in the present study is specifically designed to measure teachers' perceived growth in TPACK-core resulting specifically from their participation in the TPD program for ICT integration into teaching.

Results from the Teacher-Item distribution map and CPC reveal that Items 1, "Participation in the TPD program enhanced my capacity to use a variety of technological tools to stimulate students' motivation." and Item 15, "Participation in the TPD program

enhanced my capacity to use technological tools to present practical and innovative content that goes beyond the current textbook.” were agreed upon by most of the questionnaire respondents, as the “disagree” category in CPC for these items never the most likely response from any teachers located on the measurement scale. This finding implies that teachers widely acknowledged growth in this aspect of TPACK-core as an outcome of their participation in the TPD program for ICT integration into teaching.

After the removal of misfitting items, the results of the Rasch analysis provided evidence to support the ITTE scale’s fit to the Rasch model. Therefore, the ITTE scale can be applied to measure the extent to which teachers perceive improvement in TPACK-core as the result of participation in the TPD program for ICT integration into teaching on a linear and interval-level measurement scale.

The next section interprets the results of the ITTE scale estimated through Rasch analysis to address the extent to which mathematics and EFL primary school teachers in Taiwan perceived improvement in TPACK-core as being linked to participation in a given TPD program for ICT integration into teaching.

### **7.3.3 Measurement of mathematics and EFL primary school teachers’ perceived improvement of TPACK-core through the participation in the given TPD program**

In addressing Research Question 2, the “extent” to which teachers’ perceived improvement of TPACK-core as the result of participation in the given TPD program is operationalised and represented as teachers’ measures (locations) on the latent ITTE continuum (ITTE scale). Following the validation process through Rasch analysis, the final version of the ITTE scale comprised seventeen items. As demonstrated in Appendix K-9, the observed raw scores on the ITTE questionnaire were converted into interval-level teacher measures on the 17-item ITTE scale (logit) through Rasch model estimation through the application of RUMM2030+ (Andrich et al., 2010). As demonstrated in Section 7.2.4, this

interval-level measure, derived from the Rasch model, allows the subsets of the items used to locate the performance of teachers in the ITTE construct. The scale items can be removed or added while still retaining comparability between teachers' measures on the ITTE construct across different timelines or types of administration (Bond et al., 2020; Tesio et al., 2024).

Appendix K-9 demonstrates that the maximum possible raw score on the ITTE scale is 68. This reflects the scoring of the 17-item questionnaire, in which responses to each five-point Likert-type item are scored from 0 ("strongly disagree") to 4 ("strongly agree"). The corresponding Rasch measures ranged from -10.83 to 9.07 logits, representing teachers' measures on the scale of their perceived improvement of TPACK-core via their participation in a given TPD program. For example, a raw score between 88 and 89 on the ITTE questionnaire corresponds to a mean teacher measure of 2.68 logits. Teachers within this score range, on average, perceived that they had improved their TPACK-core as a consequence of participation in TPD.

The next section addresses the third research question by examining the application of the VT and ITTE scales in real-world contexts, specifically through investigating correlation relationships among teachers' perceptions of the value of a given TPD program for ICT integration into teaching, their perceived improvement of TPACK-core through participation in the program and their students' learning achievement.

#### **7.4 Research Question 3: To what extent do Taiwanese primary school mathematics and EFL teachers' ratings of the value of the given TPD program for ICT integration into teaching and their perceived improvement of TPACK-core through participation in the program correlate with their students' learning achievement?**

This research question is related to the research purpose of using the VT and ITTE scales to address real-world issues. It shows how the measures for determining how much

teachers value a given TPD program are related to teachers' perceived improvement of their TPACK-core and their students' learning achievement. The analysis is focused on primary mathematics and EFL teachers who participated in the TPD program for ICT integration into teaching in Taiwan.

The results from correlation analysis indicate that there was no significant correlation between the extent to which mathematics and EFL valued a given TPD program for ICT integration into teaching and students' learning achievement, nor between the extent to which the teachers perceived improvement of TPACK-core through the experience in TPD for ICT integration into teaching and students' learning achievement. These results are consistent with the systematic review conducted by Suhaini et al. (2020), which presented empirical evidence from previous literature that students' learning achievement is a multifaceted outcome that is shaped by different factors, including teacher quality, school environment, students' motivation and family background.

These findings should not be interpreted as a failure of the intervention of TPD on improving students' learning achievement. Instead, these findings reflect the real-world complexity of the educational ecosystem, where the effect of TPD is typically indirect and mediated by multiple factors (Ambussaidi & Yang, 2019). In particular, teachers' instructional transformation from their professional growth to instructional practice could in turn influence students' learning achievement (Darling-Hammond et al., 2017; Desimone, 2009), and its impact could further depend on student engagement and learning behaviours in classes (Fishman et al., 2003; Gozukucuk & Gunbas, 2022). In addition, the contextual and environmental conditions, such as schools' ICT infrastructures and support (OECD, 2019), and the socio-economic status of the surrounding community (Marynowski et al., 2022),

could either enable or constrain the extent to which improvements in teachers' teaching translate into improvements in students' learning achievement (Amemasor et al., 2025).

Therefore, further studies could investigate the full mediation effects of the abovementioned factors on the relationships between VT, ITTE and students' learning achievement. Such investigations could draw more comprehensive conclusions regarding the pathways through which TPD influences teachers and students' learning outcomes. The measurement scales developed supported by validity evidence in the current study also make such research more feasible.

### **7.5 Implications of the Study**

This study provides several implications. First, this study employs Rasch Measurement Theory as an analytical framework for developing measurement scales. The application of Rasch Measurement Theory allows the examination of item relevance to an intended construct and ensures items function appropriately and consistently across respondents (Fox & Jones, 1998). The measurement scales developed in this study follow Likert-type formats. Rasch analyses allowed the examination of requirements of measurement: linearity, additivity and invariance (Bond et al., 2020, p.273) and was used to transform ordinal data into a calculatable linear, interval-level data for further empirical usages. However, most of the existing studies for developing measurement instruments in Likert-type formats are still applying the analytical methods pertinent to Classical Test Theory (CTT), for which the initial purpose of developing this theory was to evaluate the reliability and validity of test scores, rather than to achieve true measurement (Bond et al., 2020; Finch & French, 2018).

Another key implication of employing the Rasch model is that subsets of items from the VT and ITTE scales can be used to locate teachers' positions within intended construct, and the results can be meaningfully compared across contexts, groups of teachers and ways

of administration, as long as they are calibrated on the same scale. Such flexibility is not achievable when questionnaires are analysed using Classical Test Theory, where scores are tied to specific items (Bond et al., 2020; Tesio et al., 2024).

Therefore, this study serves as an exemplar of how Rasch Measurement Theory can be effectively applied to the development of educational measurement scales that apply Likert-type formats. Furthermore, the eight-step analytical procedures for Rasch analysis presented in the previous chapter can be applied in future studies to examine whether measurement instruments function as intended.

Second, while the present study specifically focused on primary mathematics and EFL teachers in Taiwan, its methodological framework can be generalised to other countries and different educational sectors. Rasch measurement theory, an argument-based validation framework (Kane, 2026) and the scale development procedure proposed by Gehlbach and Brinkworth (2011) were adapted to construct the procedure of collecting validity evidence for the development of the VT and ITTE scales. In addition to the development and validation phrases for scale development suggested from previous literature (Creswell & Plano Clark, 2018; DeVellis & Thorpe, 2021), this study incorporated an implementation phrase to demonstrate potential implications of the two scales by investigating the relationships between VT, ITTE and students' learning achievement, consistent with the validation framework proposed by Kane (2006).

Third, the development of the VT scale addresses a crucial gap in evaluating the implementation of a TPD program from the perspective of participating teachers. Teachers are the centre of TPD. However, most measurement instruments that evaluate the success of TPD implementation often focus on changes in teachers' instructions and student learning, neglecting how teachers perceive their TPD experience. Such perceptions are critical, as they

determine teachers' sustained engagement and participation in professional development (Bayar, 2014; Karabenick & Conley, 2011; Richter et al., 2025).

The development of VT scale in this study offers both theoretical and practical contributions. From a theoretical perspective, this study expanded the EVT framework from its initial focus on individual subjective motivations to a more systematic and generalisable construct based in the value of TPD as seen through the lens of teachers by linking the EVT (Eccles et al., 1983) with features that were empirically found to be critical to the success of TPD. Although the VT scale was developed under the context of TPD for ICT integration into teaching in Taiwan, the underlying construct (the value of TPD) is supported by conceptual and empirical evidence reflecting the universal value of professional development and is therefore applicable across different nations and disciplines.

From a practical perspective, the use of the VT scale can allow policy makers and TPD designers to monitor and adjust their content and deliver TPD based on teachers' feedback. TPD designers can refine program design to better align with what teachers "buy into" to further improve the overall impact of TPD on teachers' professional learning journeys.

Forth, the development of the ITTE scale addresses the notion of contextual factors in the TPACK framework. Many previous studies have applied existing TPACK questionnaires to assess the outcomes of TPD for ICT integration into teaching. These studies have been argued in the present study that they often did not consider the context of measurement adequately (e.g. Kang, 2020; Young et al., 2020, see Chapter 2, Section 2.4.1). This may result in variance between what instruments actually measure and the purpose of the measurement. The ITTE scale has been developed to resolve this validity issue in the measurement of TPACK. Evidence collected through the ITTE will be therefore more

aligned with what teachers' actually perceive in terms of growth in their knowledge and thus benefits accurate evaluation of TPD for ICT integration into teaching.

Finally, the absence of direct correlations between the VT and students' learning achievement, and between the ITTE and students' learning achievement identified in the current study could contribute to challenging the assumption that improvements in teacher quality always led to better student outcomes. Instead, it highlights the need for TPACK researchers to investigate deeper in the underlying processes of classroom implementation that could potentially mediate these relationships. The findings also point to potential mediating factors that may influence the direct effect of TPD on students, suggesting that TPD policies should address on both the quality of teacher training and those factors that may shape its impact, such as instructional practice, student's motivation and engagement, and relevant contextual factors so that the "value" of TPD could actually bring meaningful outcomes for students.

## **7.6 Limitations and Directions for Future Research**

The VT and ITTE measurement scales were developed through three methods of validation process: literature review, focus group discussions and questionnaire surveys. While the design of each method and the consequent modifications was carefully reviewed and approved by the supervisory team, certain limitations still existed which should be acknowledged before generalising from this study's findings.

First, the scope of the literature review was limited to English-dominated research databases and Taiwanese academic journals due to the researchers' language proficiency, thereby excluding relevant studies published in other languages. A more in-depth literature review, particularly encompassing research from non-English and non-Mandarin speaking regions, is recommended for future studies to obtain a more comprehensive understanding of

theoretical and empirical findings on TPD and TPD for ICT integration into teaching across diverse educational and cultural contexts.

Second, due to the complexity of the selection criteria and a short recruitment period, this study applied purposive and snowball sampling techniques to select the participants for the focus group discussions and purposive sampling for its questionnaire surveys. These non-random sampling techniques selected participants who met the study's requirements; however, the result was a relatively small sample size. In addition, two participants in Focus Group 1 decided to drop off one day before the discussion, leading to a final sample size of six in the focus group. Although the generalisability of the VT and ITTE scales was emphasised throughout the validation phase of this study, future studies can recruit a larger number of participants for the focus group discussions to obtain more diverse perspectives.

As for the questionnaire surveys, it is notable that the number of participants between mathematics and English teachers was uneven. However, as stressed in Chapter 6, Section 6.3.1, the distribution of participants across these two subjects was not intentionally controlled. Unlike other sampling techniques, such as stratified or cluster sampling, which aim to achieve representativeness of a broader population, the design of purposive sampling applied in the current study prioritised the inclusion of participants who met the study criteria. Therefore, the findings of the questionnaire survey should be interpreted as representative of the group of teachers who responded, rather than the broader population, such as all mathematics and English teachers in Taiwan.

Further research may consider applying randomised sampling techniques, such as stratified sampling and cluster sampling on the questionnaire surveys, if the aim is to achieve representativeness across a broader population. In addition, if the VT and ITTE scales are to be applied across other educational sectors and cultural contexts, additional validation

processes, including focus group discussions and questionnaire surveys under such contexts will be required.

Many teachers did not provide their students' test score results, leading to a drop in the sample size for the correlation analysis. This limitation may have contributed to the non-significant correlations found between the VT, the ITTE and students' learning achievement. These findings also point to the need to investigate potential mediating factors that may underlie these relationships. Therefore, further research could investigate the possible full mediation effects of relevant factors on the relationships between the VT, the ITTE and students' learning achievement by using a larger sample size to enhance statistical representativeness. As the use of a high-stakes test result has been recommended in previous studies for determining the outcome of a TPD program, future research may also consider alternative sources for obtaining such data, such as publicly available data sources or direct collection from students themselves, with the consent of their guardians.

Finally, the data for the value of TPD for ICT integration into teaching and the improvement of TPACK-core via the TPD experience were collected through a self-reported questionnaire survey. Teachers were requested to complete the survey based on their participation in a specific TPD program for ICT integration into teaching during that year. However, as multiple workshops within the program were held throughout the year at various locations across Taiwan, it was difficult to determine the time gap between when teachers attended the workshops and when they completed the questionnaire survey.

As such, some temporal bias may have occurred when the respondents were asked to reflect on their experiences in the programs to answer the survey questions, including hindsight biases and impact biases (Sanna et al., 2011). Hindsight biases could result in participants' overestimating their prior knowledge after completing the TPD program for ICT integration into teaching (Osman, 2017; Sanna et al., 2011). They may have believed they

“knew it all along” and therefore have selected more extreme scores on the scales. Furthermore, they may have exaggerated the impact of the TPD program for ICT integration into teaching on their performance (i.e. the impact biases, Gilbert, 2006; Samma et al., 2011). In this study, such biases may have affected the responses of the VT and ITTE scales, whereby the participants might overestimate or underestimate the value of the TPD program for ICT integration into teaching and the impact of the program on their improvement of TPACK-core.

These biases may explain some of the skewing in teachers’ responses, as most participants reported high scores on most items in the VT and ITTE scales. It is vital for researchers to consider these potential biases in future studies. For example, by controlling for the time difference in participation in the TPD program or by conducting longitudinal research to identify which aspects of the VT and ITTE scales are especially influenced by temporal biases.

## **7.7 Concluding Remarks**

The findings of this study extended the evaluation of teacher professional development (TPD) to include teacher perceptions by systematically developing two measurement scales: The Value of TPD (VT) scale and the Improvement of TPACK-core via TPD Experience (ITTE) scale. These scales are designed to assess teacher perceptions of the value of a given TPD program for ICT integration into teaching, and their perceived improvement of TPACK-core following TPD participation. This study showcases the substantial and methodological value of applying Rasch Measurement Theory as a foundation for scale development. Although the present study focused on mathematics and EFL primary school teachers in Taiwan, the VT and ITTE scales are applicable across subject areas, educational sectors and national contexts as supported by evidence from focus group participants and the results of Rasch analysis.

A critical implication of this study is its demonstration of how a Likert-type instrument can be transformed into a measurement scale through validation based on Rasch Theory. In contrast to traditional analyses grounded in Classical Test Theory, Rasch Measurement Theory enable teachers' measures to be interpreted independently from the item sets, and therefore allows further refinement, removal, or addition to the items over time while retaining the comparability of the measurement results on the two scales. This application reinforces the generalisability and long-term utility of the VT and ITTE scales for future relevant studies.

This study also presents a mixed-methods approach to the process of scale development, employing Rasch Measurement Theory and an argument-based validation framework. The process started with defining the construct and setting the validity argument through an extensive literature review. This was followed by the collection of qualitative evidence to validate the scales through focus group discussions. Then, Rasch analysis was applied to examine whether the items fit with the intended constructs from a quantitative perspective.

Finally, the scales were examined in a real-life context by investigating their relationships with other relevant variables. The non-significant relationships observed between VT, ITTE, and students' learning achievement in the current study flag a potential full mediation effect of other factors that could impact the influence of the TPD program on teachers' professional learning and students' learning achievement. Importantly, the measurement scales developed in the current study, with evidence supporting their validity, provide a more substantiated empirical foundation that makes such future investigations more feasible.

Although this study's relatively limited sample size could have introduced some bias into the results of the analysis, it is believed that the findings provide profound insights into the validation of the measurement scales, and can contribute to the evidence-based, teacher-centred evaluation of teacher professional development programs worldwide.

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### Appendix A: Summary of critical features of TPD for ICT integration into teaching and supporting literature

Features	Literature
Focuses on specific content, knowledge and skills	Bates & Morgan, 2018; Desimone, 2009; Darling-Hammond et al., 2017; Herranen et al., 2021; Krille, 2020; Rana et al., 2022; Wasserman & Migdal, 2019; Karabenick & Conley, 2011
Recognises the experience and prior knowledge of teachers	Covay Minor et al., 2016; Desimone, 2009; Lindvall, 2017; NSW Education Standards Authority, 2021
Provides feedback, assessment and reflection	Bates & Morgan, 2018; Bayar, 2014; Darling-Hammond et al., 2017; de Vries et al., 2013; Krille, 2020
Provides career advancements Targets active learning	Chang et al., 2022; Karabenick & Conley, 2011; Kao et al., 2011; Richter et al., 2019; Alemdag et al., 2020; Bates & Morgan, 2018; Bayar, 2014; Desimone, 2009; Darling-Hammond et al., 2017
Provides well-qualified instructors Encourages collaborative learning	Bates & Morgan, 2018; Bustamante, 2020; Darling-Hammond et al., 2017; de Vries S et al, 2013; Hargreaves & Fullan, 2012; Lu, 2021; Naylor & Gibbs, 2018; Njiku et al., 2021
Targets novelty	Cordingley et al., 2015; Richter et al., 2025; Naylor & Gibbs, 2018
Provides opportunities for hands-on learning	Chen, 2020; Huang, 2021; Kimav & Kürüm-Yapıcıoğlu., 2021; Sáez-López et al., 2020
Helps with students' development Aligns with current demands and visions Provides convincing exemplary material	Desimone, 2009; Gozukucuk & Gunbas, 2022; Mumcu et al., 2022; Naylor & Gibbs, 2018 Alemdag et al., 2020; Bayer, 2014; Cirocki & Farrell, 2019 Buchner & Hofmann, 2022; Getenet, 2020; Lin, 2022
Provides follow-up support	Lu, 2021; Rana et al., 2022
Provides contents, ideas and materials that are relatively easy to implement in class	Kimav & Kürüm-Yapıcıoğlu, 2021; Naylor & Gibbs, 2018
Makes teaching materials introduced in the sessions easy to access	Hu et al., Mumcu et al., 2022
Provides teaching materials	Herranen et al., 2021; Hu et al., 2021; Naylor & Gibbs, 2018; Rana et al., 2022; Sáez-López et al., 2020
Carried out over a sustained period	Bates & Morgan, 2018; Bayar, 2014; Cordingley et al., 2015; Hodkinson & Hodkinson, 2005

## Appendix B: Focus group 1 Interview Protocol

Dear participants. Thank you for participating in this interview. My name is Penny Lu, and I am a PhD candidate at the University of Sydney. I am currently working on my doctoral thesis titled “Development of Measurement Scales for Teacher Professional Development in ICT Integration: Insights into the Program Value, TPACK, and Student Learning Achievement in Primary Education”.

As mentioned in the information materials sent before the interview, the purpose of this phase of the qualitative study is to identify and validate the indicators of how teachers value their TPD for ICT integration into teaching experience. The structure of the construct is developed for Eccles’ (1983) Expectancy-Value Theory and features of successful TPD found in previous literature. Three stages of focus group interviews will be conducted for data collection.

The discussion today will be recorded. This is an anonymous interview, and your responses will remain confidential. You can stop the interview at any time and not answer the questions. This interview consists of five sections, and the overall interview will be taken around **one** hours. Please make sure to sign the consent form before the interview starts. Please feel free to ask if you have any questions regarding the form.

Please provide feedback on the VT construct that have been presented:

1. What do you think about the VT construct? Are these indicators sufficient?
2. Do you think that the VT construct fits the purpose of the present study? Please justify why.
3. Do you think that the VT construct reflects the reality of the TPD for ICT integration into teaching in Taiwan? Please justify why.
4. Would you like to modify/add any indicators that are not addressed in the VT construct?
5. Please look at the summarised results of the importance for each indicator. Are there any differences in your opinions? In which category should they be placed for the new features suggested in the last questions?

**Appendix C: Rating scale of draft construct and indicators of VT**

<b>Types of Value</b>	<b>Feature</b>	<b>Indicators</b>	<b>Relatively Important</b>	<b>Desirable</b>	<b>Inapplicable</b>
<b>Attainment Value<sup>a*</sup></b>	(1) Focuses on specific content, knowledge and skills	A1. Focuses on specific content, knowledge and skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(2) Recognises the experience and prior knowledge of teachers	A2. Recognises the experience and prior knowledge of teachers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(3). Provides feedback, assessment and reflection	A3. Provides peer feedback and assessment opportunities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		A4. Provides instructor's feedback and assessment opportunities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		A5. Provides self-reflection opportunities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(4) Provides career advancement	A6. Provides career advancement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Intrinsic Value<sup>b*</sup></b>	(5) Targets active learning	I1. Targets active learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(6) Provides well-qualified instructors	I2. Provides well-qualified instructors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(7) Encourages collaborative learning	I3. Provides opportunities for collaborative learning with peers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		I4. Provides opportunities for cross-discipline collaborative learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		I5. Provides opportunities for collaborative learning with teachers outside of schools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(8) Targets novelty	I6. Targets novelty	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(9) Provides opportunities for hands-on learning	I7. Provides opportunities for hands-on learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Utility Value<sup>c*</sup></b>	(10) Helps with students' development	U1. Helps with students' development	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(11) Aligns with current demands and visions	U2. Aligns with schools' needs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		U3. Aligns with schools' curriculum plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		U4. Aligns with teachers' needs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	(12) Provides convincing exemplary material	U5. Provides convincing exemplary material	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(13) Provides follow-up support	U6. Provides follow-up classroom observations and feedback	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		U7. Provides follow-up advisory service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(14) Provides contents, ideas and materials that are relatively easy to implement in class	U8. Provides contents, ideas and materials that are relatively easy to implement in class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(15) Makes teaching materials introduced in the sessions easy to access	U9. Makes teaching materials introduced in the sessions easy to access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(16) Provides teaching materials	U10. Provides teaching materials/equipment from the program organisers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		U11. Provides teaching materials/equipment from the schools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Cost<sup>d*</sup></b>	(18) Time-consuming	C1. Is time-consuming	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(19) High financial expense	C2. Requires high financial expense	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(20) Tedious procedures to implement	C3. Has tedious procedures to implement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	(21) Stressful to learn	C4. Is stressful to learn	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

a\* **Attainment Value:** The relevance of the TPD program for ICT integration into teaching to teachers' sense of self, identity, and core personal values

b\* **Intrinsic Value:** The enjoyment and interest that teachers obtain from the TPD program for ICT integration into teaching

c\* **Utility Value:** The usefulness of the TPD program for ICT integration into teaching for the pursuit of other short- and long-term goals

d\* **Cost:** Including effort cost—how much effort would need to be exerted to complete the TPD program for ICT integration into teaching and whether it is worth doing so, opportunity cost—how much time and ability would be taken away to complete the TPD program for ICT integration into teaching, and emotional cost—the emotional or psychological costs of pursuing the TPD program for ICT integration into teaching, particularly anticipated anxiety and the emotional and social costs of failure.

## Appendix D: Focus group 2 interview protocol

Dear participants. Thank you for participating in this interview. My name is Penny Lu, and I am a PhD candidate at the University of Sydney. I am currently working on my doctoral thesis titled “Development of Measurement Scales for Teacher Professional Development in ICT Integration: Insights into the Program Value, TPACK, and Student Learning Achievement in Primary Education”.

As mentioned in the information materials sent before the interview, the purpose of this phase of qualitative study is to identify and validate the items of teachers perceive improvement of TPACK via their TPD experience (ITTE) scale.

The discussion today will be recorded. This is an anonymous interview, and your responses will remain confidential. You can stop the interview at any time and not answer the questions. This interview consists of two parts; the first part consists of one section, and the second part consists of four sections. The overall interview will be around **one** hours. Please make sure to sign the consent form before the interview starts. Please feel free to ask if you have any questions regarding the form.

First, please recall your experiences with the the TPD programs for ICT integration into teaching in which you participated in the last 12 months, and answer the following question:

1. Have any of the TPD programs for ICT integration into teaching successfully improved your TPACK? If so, please explain how you noticed the improvement? If so, please justify how you noticed the improvement.

Second, please provide feedback on the draft ITTE scale that have been presented:

1. What are your thoughts on the draft ITTE scale? Do you find it sufficient?
2. Do the items described in the scale align with your own experiences? Are there any items you find ambiguous or controversial?
3. Are there any items on the scale that you find difficult to represent the improvement of TPACK-core?
4. Would you like to modify/add any items to this scale?

### **Appendix E: Focus group 3 interview protocol**

Dear participants. Thank you again for coming back and participating in this stage of interview. As I introduced on the first focus group interview, my name is Penny Lu, and I am a PhD candidate at the University of Sydney. I am currently working on my doctoral thesis titled “Development of Measurement Scales for Teacher Professional Development in ICT Integration: Insights into the Program Value, TPACK, and Student Learning Achievement in Primary Education”.

As mentioned in the information materials sent before the interview, the purpose of this phase of qualitative study is to validate and modify the questionnaire surveys of VT and ITTE based on your personal experience.

The discussion today will be recorded. This is an anonymous interview, and your responses will remain confidential. You can stop the interview at any time and not answer the questions. This interview consists of two part and five sections, and the overall interview will be around **one** hours. Please make sure to sign the consent form before the interview starts. Please feel free to ask if you have any questions regarding the form.

First, please provide feedback on the questionnaire for VT:

1. Are there any items described in the questionnaire that cannot fit with the specified indicators?
2. Do these items described in the scale align with your own experience? Are there any items you find ambiguous or controversial?
3. Do you think the questionnaire of VT can effectively examine teachers’ perceptions of the value of the TPD for ICT integration into teaching? Please justify why.

Second, please provide feedback on the questionnaire for ITTE:

1. What do you think about the added and eliminated items in the scale from the last focus group interview? Do they align with your own experience and perceptions?
2. Do you think the ITTE questionnaires can effectively examine primary Mathematics and EFL teachers' perceived extent of improving the TPACK via the TPD for ICT integration into teaching? Please justify why.

## Appendix F: VT indicators and corresponding items

項目 Indicators	問項 Items
A1. 專注於特定內容、知識和技能 Focus on specific content, knowledge and skills	1. 此教師專業發展研習專注於特定內容、知識和技能。 The design of the TPD program focused on specific content, knowledge, and skills.
A2. 認可教師的經驗及先備知識 Recognises the experience and prior knowledge of teachers	2. 此教師專業發展研習的內容能與我的培訓經驗和先備知識相結合。 The content of the TPD program linked with my experience in training and prior knowledge.
A3. 依教師需求提供客製化培訓內容 Provides customised content based on teachers need.	3. 此教師專業發展研習依照我的需求提供客製化培訓內容。 The TPD program provided customised content based on my needs.
A4. 提供多種不同培訓課程供選擇 Provides various of courses for teachers to choose	4. 此教師專業發展研習提供了多種不同培訓課程供我選擇。 The TPD program provided various of courses selection for me.
A5. 提供同儕回饋和互評機會 Provides peer feedback and assessment opportunities	5. 此教師專業發展研習提供了同儕回饋與互評的機會。 The TPD program provided feedback and assessment opportunities from peers.
A6. 提供授課者回饋和評量機會 Provides educator's feedback and assessment opportunities	6. 此教師專業發展研習提供了授課者回饋與評量機會。 The TPD program provided feedback and assessment opportunities from the workshops' educators.
A7. 提供自我反思機會 Provides self-reflection opportunities	7. 此教師專業發展研習有提供自我反思的機會。 The TPD program provided opportunities of self-reflection.
I1. 主動學習 Targets active learning	8. 此教師專業發展研習啟發並鼓勵了我進行主動學習。 The TPD program motivated and encouraged me to learn actively.
I2. 提供與同儕合作學習機會 Provides opportunities for collaborative learning with peers	9. 此教師專業發展研習提供了與同儕合作學習的機會。 The TPD program provided opportunities for collaborative learning with peers.
I3. 提供跨領域合作學習機會 Provides opportunities for cross-discipline collaborative learning	10. 此教師專業發展研習提供了跨領域合作學習的機會。 The TPD program provided opportunities for cross-discipline collaborative learning.
I4. 提供與校外教師合作學習機會	11. 此教師專業發展研習提供了與校外教師合作學習的機會。

Provides opportunities for collaborative learning with teachers outside of schools	The TPD program provided opportunities for collaborative learning with teachers outside of schools.
I5. 新穎 Targets novelty	12. 此教師專業發展研習的授課內容新穎，與我之前參與過的培訓研習有所不同。 The content of the TPD program was novel and different from the previous program I attended.
I6. 提供實作學習機會 Provides hands-on learning opportunities	13. 此教師專業發展研習提供了實作學習的機會。 The TPD program provided hands-on learning opportunities.
U1. 幫助學生發展 Help with students' development	14. 此教師專業發展研習有助我增進學生的發展。 The TPD program helped me to enhance students' development.
U2. 符合學校需求 Aligns with schools' needs	15. 此教師專業發展內容符合我的學校的需求。 The TPD program fit with my school's needs.
U3. 提供適當授課者 Provides proper educators	16. 我認為此教師專業發展研習裡的授課者很專業。 The TPD program provided educators that I perceived professional in the field.
U4. 符合學校課程研習 Aligns with schools' curriculum plan	17. 此教師專業發展研習內容符合我的學校的課程計畫。 The content of this TPD program fit with my school's curriculum plan.
U5. 提供可信的範例 Provides convincing exemplary material	18. 此教師專業發展研習提供可信的範例教材。 The TPD program provided convincing exemplary material.
U6. 回流訓練 Provides recurrent training	19. 此教師專業發展研習提供了回流訓練。 The TPD program provided recurrent training.
U7. 後續實作教學諮詢服務 Provides follow-up advisory service on hands-on instructions	20. 此教師專業發展研習提供後續實作教學的諮詢服務。 The TPD program provided follow-up advisory service on hands-on instructions.
U8. 後續課程設計及建議 Provides follow-up course design and suggestion	21. 此教師專業發展研習提供後續課程設計及建議的協助。 The TPD program provided services of follow-up course design and suggestion.
U9. 後續觀課及回饋 Provides follow-up classroom observations and feedback	22. 此教師專業發展研習提供後續觀課及回饋的服務。 The TPD program provided services of follow-up classroom observations and feedbacks.
U10. 易於課堂上實施 Is easy to imply in class	23. 我能容易地應用研習中所學的於課堂上。 I can easily imply what I have learnt from the TPD program in my class.

U11. 介紹的教材易取得 Teaching materials introduced are easy to be accessed	24. 我能容易地取得研習中所介紹的教材。 I can easily access the teaching material introduced from the program.
U12. 研習主辦單位教材提供 Provides teaching materials by the program organisers	25. 此研習的主辦單位提供充足的的教材。 The organisers of this TPD program provided sufficient teaching materials.
U13. 學校教材提供教材 Provides teaching materials by the schools	26. 我所任教之學校提供充足研習中所推薦的教材。 My school provided sufficient teaching materials introduced from the program.
U14. 學校提供設備 Provides teaching equipment by the schools	27. 我所任教之學校提供充足研習中所推薦的教學設備。 My school provided sufficient teaching equipment introduced from the program.
U15. 能精進職涯發展 Provides career advancement	28. 此教師專業發展研習增進我的教師職涯發展。 The TPD program strengthened my career as a teacher.
C1. 重新排課所耗費之時間 Takes time to rearrange the class timetable	29. 為了參加此教師專業發展研習，我 <u>不</u> 需要花費太多的時間在重新排課上。 It was easy for me to rearrange my classes' timetable to attend the TPD program.
C2. 受訓過程所耗費之時間 Takes time in the process of training	30. 我 <u>不</u> 認為受訓過程很耗費時間。 The time spent on the training is efficient.
C3. 執行研習派發的作業所耗費之時間 Takes time to work on the follow-up tasks	31. 我 <u>不</u> 認為做研習期間所派發之作業很耗費時間。 I can conduct the follow-up tasks from the TPD program easily.
C4. 金錢花費 Requires high financial expense	32. 參與此教師專業發展研習的費用支出很低。 The fees for participating in the TPD program were not too expensive.
C5. 執行步驟繁瑣 Has tedious procedures to implement	33. 執行教師專業發展研習所學於課堂上的步驟是簡單明瞭的。 The procedures to implement what I learnt from the TPD program were clear.
C6. 學習壓力大 Is stressful to learn	34. 我覺得參加此教師專業發展研習很輕鬆，沒有什麼壓力。 I enjoy participating in the TPD program without too much stress

**Appendix G: Comparison between initial ITTE items and amended ITTE items based on FG2 discussion**

題號 Initial No.	初始問項 Initial items	焦點小組二訪談結果 Suggestions from the FG2	修改後題號 Amended No.	修改後問項 Amended items
1	<p>此教師專業發展研習提升了我在課堂上運用各種科技的能力，並使學生能夠積極參與。</p> <p>This TPD program enhanced my capability of using a variety of technologies that allow students to participate actively.</p>	<p>1. “科技工具” 取代 “科技” 。 Replace “technologies” with “technological tools”</p> <p>2. “啟發了學生學習動機” 取代 “使學生能夠積極參與” 。 Replace “...allow students to participate actively” with “...stimulate students’ motivation</p>	1	<p>此教師專業發展研習提升了我運用各種科技工具去激勵學生學習動機的能力。</p> <p>The TPD program enhanced my capability of using a variety of technological tools that stimulate students’ motivation.</p>
2	<p>藉由參加此教師專業發展研習，我更會運用各種科技工具協助學生追求他們自己的興趣。</p> <p>My capability of using a variety of tools to assist students in pursuing their own interests has been enhanced by participating this TPD program.</p>		2	<p>參加此教師專業發展研習後，我更會運用各種科技工具去協助學生追求他們自己興趣。</p> <p>My capability of using a variety of tools to assist students in pursuing their own interests has been enhanced by participating the TPD program.</p>
3	<p>參與此教師專業發展研習後，我更會運用科技來有效地提供重要資訊給學生和同事。</p> <p>My capability of employing technology effectively to provide vital information to students and peers has been enhanced by participating this TPD program.</p>	<p>“科技工具” 取代 “科技” 。 Replace “technologies” with “technological tools”</p>	3	<p>參加此教師專業發展研習後，我更會運用科技工具來有效地提供資訊給學生與同事。</p> <p>My capability of employing technological tools effectively to provide information to students and peers has been enhanced by participating the TPD program.</p>

4	<p>藉由參加此教師專業發展研習，我更會運用科技來與不同文化的學生互動，促進全球理解。</p> <p>My capability of promoting global understanding by engaging students with diverse cultures through technology has been enhanced by participating this TPD program.</p>	<p>刪除。</p> <p>Deleted</p>		
5	<p>此教師專業發展研習精進了我有關選擇適當科技以增進教學方法和學生學習方式的知識。</p> <p>This TPD program improved my understanding of choosing technology properly for enhancing the methods and ways of teaching, and students' learning.</p>	<p>“科技工具”取代“科技”。</p> <p>Replace “technologies” with “technological tools”</p>	4	<p>此教師專業發展研習精進了我有關選擇適當科技工具以增進教學方法和學生學習方式的知識。</p> <p>The TPD program improved my understanding of choosing technological tools properly for enhancing the methods and ways of teaching, and students' learning.</p>
6	<p>此教師專業發展研習使我能更適當地將科技、教學內容與教學法結合，來成功地進行教學。</p> <p>This TPD program reinforced my capability to teach successfully by appropriately combining the technologies, instructional content and approaches.</p>	<p>1. “科技工具”取代“科技”。</p> <p>Replace “technologies” with “technological tools”</p> <p>2. “順利地...”取代“成功地...”。</p> <p>Replace “successfully” with “smoothly”</p>	5	<p>此教師專業發展研習使我能更適當地將科技、教學內容及教學法結合，來順利地進行教學。</p> <p>The TPD program reinforced my capability to teach effectively by appropriately combining the technological tools, instructional content approaches.</p>
7	<p>參與此教師專業發展研習後，我更能帶領同事整合其教學內容、教學法以及科技相關知識。</p> <p>My capability of leading my colleagues to integrate content, pedagogy and technology knowledge</p>		6	<p>參與此教師專業發展研習後，我更能帶領同事整合其教學內容、教學法與科技相關知識。</p> <p>My capability of leading my colleagues to integrate content, pedagogy and</p>

	has been improve after participating this TPD program.			technology knowledge has been improved after attending the TPD program.
8	此教師專業發展研習使我更能運用科技工具和資源來輔助自己的專業發展，持續地改進我的英語教學。 This TPD program reinforce my capability of using ICT tools and resources to support my own professional development and improve the process of teaching English or Mathematics continuously .	科技工具”取代“科技”。 Replace “ICT tools” with “technological tools”	7	此教師專業發展研習使我更能運用科技工具和資源來輔助自己的專業發展，持續地改進我的英語或數學教學。 The TPD program reinforced my capability of using technological tools and resources to support my own professional development and improve the process of teaching English or Mathematics continuously.
9	此教師專業發展研習使我更知道如何在教學時運用各種數位學習工具和資源。 This TPD program improved my understanding of employing a variety of digital learning tools and resources when teaching.	“科技工具”取代“數位學習工具”。 Replace “digital English learning tools” with “technological tools”	8	此教師專業發展研習使我更知道如何在教學時運用各種科技工具和資源。 The TPD program improved my understanding of how to employ a variety of technological tools and resources when teaching.
10	參與此教師專業發展研習後，我更能運用多種科技來提升學生英語或數學知識。 My capability of using a range of technologies to enhance students’ knowledge in English or Mathematics has been improved by participating this TPD program.	“科技工具”取代“科技”。 Replace “technologies” with “technological tools”	9	參與此教師專業發展研習後，我更能運用多種科技工具來提升學生的英語或數學知識。 My ability to use a range of technological tools to enhance students’ knowledge in English or Mathematics has been improved by participating in this TPD program.
11	此教師專業發展研習使我更能運用各種科技來打造一個適合學生練習英語或數學的環境。	“科技工具”取代“科技”。 Replace “technologies” with “technological tools”	10	此教師專業發展研習使我更能運用各種科技工具來打造一個適合學生練習英語或數學的環境。

	This TPD program improved my capability of using a range of technologies to develop an environment that is suitable for students to practice English or Mathematics			The TPD program improved my ability to use a range of technological tools to develop an environment that is suitable for students to practice English or Mathematics
12	參與此教師專業發展研習後，我更能運用多種科技在課堂上介紹不同的文化和傳統。 My capability of using a range of technologies to introduce different cultures and traditions in classes has been improved by participating this TPD program.	刪除。 Deleted		
13	此教師專業發展研習使我更能運用適當科技來精進學生在使用英語或數學時的邏輯思維的能力。 This TPD program improved my capability of using proper technologies to strengthen students' logical thinking when using English.		11	此教師專業發展研習使我更能運用適當科技工具來精進學生在使用英語或數學時的邏輯思維的能力。 The TPD program improved my ability to use proper technological tools to strengthen students' logical thinking when teaching English or mathematics.
14	此教師專業發展研習使我更能適合教學法、英語或數學概念和科技。 This TPD program enhance my capability of appropriately combine instructional approaches, technologies, and English or mathematics concepts.		12	此教師專業發展研習使我更能適當結合教學法、英語或數學概念和科技工具。 The TPD program enhanced my ability to appropriately combine instructional approaches, technological tools, and English or mathematics concepts.
15	此教師專業發展研習在研習中介紹了能正當的獲得數位學習工具的方法。		13	此教師專業發展研習在研習中介紹了能正當的獲得數位學習工具的方法。

	This TPD program introduces fair access to learning tools of digital learning for me to conduct in classes.			The TPD program provides fair access to learning tools associated with digital learning for me to use in class.
16	<p>此教師專業發展研習提供了我能參與的數位學習社群的資訊，該社群能啟發我找到能改進學生學習的創新科技工具。</p> <p>This TPD program provided information on digital learning communities that I can participate in to discover creative utilities of ICT to improve students' learning.</p>	<p>修正： 此教師專業發展研習啟發我找到能改進學生學習的創新科技工具。</p> <p>Amended: This TPD program inspires me to find innovative technological tools to improve students' learning</p>	14	<p>此教師專業發展研習啟發我找到能改進學生學習的創新科技工具。</p> <p>The TPD program inspires me to find innovative technological tools to improve students' learning</p>
17	<p>此教師專業發展研習使我更能運用科技來開發並呈現教科書以外的實用且獨特的教學內容。</p> <p>This TPD program enhance my skill in using technology to develop and present practical and unique content that go beyond the textbook.</p>	<p>1. “科技工具” 取代 “科技” 。 Replace “technologies” with “technological tools”</p> <p>2. “創新的” 取代 “獨特的” 。 Replace “unique content” with “innovative content”</p>	15	<p>此教師專業發展研習使我更能運用科技工具來開發並呈現教科書以外的實用且創新的教學內容。</p> <p>The TPD program enhanced my skill in using technological tools to better develop and present practical and innovative content that goes beyond the current textbook.</p>
18	<p>參與此教師專業發展研習後，我更能學生評量中運用科技來修正我的教學。</p> <p>My capability of adopting technology in student assessment to amend my teaching has been improved by participating this TPD program.</p>	<p>“科技工具” 取代 “科技” 。 Replace “technologies” with “technological tools”</p>	16	<p>參與此教師專業發展研習後，我更能學生評量中運用科技工具來修正我的教學。</p> <p>My ability to adopt technological tools for assessing students and amending my teaching has been improved by participating in the TPD program.</p>
19	<p>此教師專業發展研習提升了使我更能透過科技來預測學生對特定主題理解程度。</p>	<p>“科技工具” 取代 “科技” 。 Replace “technologies” with “technological tools”</p>	17	<p>此教師專業發展研習提升了使我更能透過科技工具來預測學生對特定主題理解程度。</p>

	This TPD program enhance my ability to predict how well students understand a specific topic via technology.			The TPD program enhanced my ability to predict how well students understood a specific topic using technological tools.
20	此教師專業發展研習幫助我達到對於教學的整體要求。 This TPD program helped me to achieve the overall requirements of teaching.	刪除。 Deleted		

## Appendix H: Questionnaire survey

### Development of Measurement Scales for Teacher Professional Development in ICT Integration: Insights into the Program Value, TPACK, and Student Learning Achievement in Primary Education



THE UNIVERSITY OF  
SYDNEY

Dear participants:

You are invited to participate in this survey regarding the value of a teacher professional development (TPD) program in the Program for Digital Teaching Enhancement in TPACK and students' learning achievement in primary schools. Please answer the questions based on your experience in the TPD Program for Digital Teaching Enhancement organised by the Ministry of Education in Taiwan within this school year. It will take about 20 minutes. Your opinions are extremely important. Before answering the questions, please ensure that you have thoroughly read the Participant Information Statement (PIS) and have signed the Participant Consent Form (PCF). The information gathered in this survey will be treated with the strictest confidentiality. No individual person can be identified from the survey. Thank you very much for your participation.

Yours faithfully,

Tzu-Ping Lu (Researcher)  
Professor Jim Tognolini (Primary Supervisor)

Faculty of Arts and Social Sciences  
The University of Sydney  
Phone: +61 2 8627 5205 | Email:  
jim.tognolini@sydney.edu.aumailto:XX@unimelb.edu.au  
Miss Tzu-Ping Lu | Email: tzlu4433@uni.sydney.edu.aumailto:XX@unimelb.edu.au

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### Section I. Demographic information

1. Gender

Male  Female  Other

2. Age

25 and under  26 to 35  36 to 45  46 to 55  56 and above years old

## 3. Subject of teaching

English Mathematics

## 4. Approximate number of hours of participation in the TPD Program for Digital Teaching Enhancement within this school year

1 to 3 4 to 6 6 and above

## 5. Teaching experience

5 years and under 6 to 10 years 11 to 15 years 16 to 20 years 21 years and above

**Section II.**

This section relates to the value of teacher professional development. Please indicate, from your point of view, the extent to which you agree each item based upon your experience in the TPD Program for Digital Teaching Enhancement (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

No.	Items	(1=strongly disagree; 5=strongly agree)				
		1	2	3	4	5
6	The TPD program focused on one or more of the following: specific content, specific knowledge, or specific skills.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	The content of the TPD program was aligned with my prior experience.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	The TPD program provided training in content based on my needs.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	The TPD program provided a variety of courses selection for me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	The TPD program provided opportunities for feedback and assessment from peers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	The TPD program provided opportunities for the educators conducting the workshops to provide feedback to the trainees.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	The TPD program provided opportunities for self-reflection.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13	The TPD program motivated me to learn actively.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14	The TPD program provided opportunities for collaborative learning with peers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15	The TPD program provided opportunities for cross-discipline collaborative learning.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

16	The TPD program provided opportunities for collaborative learning with teachers from other schools.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17	The content of the TPD program was novel and different from the previous program(s) I attended.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18	The TPD program provided an opportunity for hands-on learning.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19	The TPD program helped me to improve student learning in the area.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20	The TPD program was well aligned with my school's needs.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21	The TPD program was conducted by trainers who were considered professional educators and teachers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22	The content of this TPD program fit with my school's curriculum plan.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23	The TPD program provided practical examples of teachers applying methods taught in the program.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24	The TPD program provided recurrent training.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25	The TPD program provided follow-up advisory service to assist when implementing the ideas in the classroom.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26	The TPD program provided follow-up course design and suggestion.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27	The TPD program provided services for follow-up classroom observations and feedback.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28	I can easily apply what I have learnt from the TPD program in my class.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29	The organisers of this TPD program provided teaching materials.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30	I can easily access the teaching material introduced from the program.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31	My school provided teaching materials introduced from the program.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32	My school provided teaching equipment introduced from the program.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33	The TPD program strengthened my career as a teacher.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34	It was easy for me to rearrange my classes' timetable to attend the TPD program.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
35	The time spent on the training is efficient.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36	I can conduct the follow-up tasks from the TPD program easily.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37	The fees for participating in the TPD program were not too expensive.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38	The procedures to implement what I learnt from the TPD program were clear.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

39	I enjoy participating in the TPD program without too much stress.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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### Section III.

This section related to the improvement of TPACK-core you might have received because of the TPD program. Please indicate, from your point of view, how much you agree with each item according to your experience in the TPD program for Digital Teaching Enhancement organised by the Ministry of Education in Taiwan within this school year (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

No.		(1=strongly disagree; 5=strongly agree)				
		1	2	3	4	5
Participation in the TPD program:						
40	enhanced my capacity to use a variety of technological tools to stimulate students' motivation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
41	enhanced my capacity to use a variety of technological tools to assist students in pursuing their own interests.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
42	enhanced my capacity to use technological tools to provide information to students and peers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
43	has provided me with more choices of technological tools to improve student learning.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
44	enhanced my capacity to teach effectively by appropriately combining the technological tools and instructional content.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
45	enhanced my capacity to lead my colleagues in integrating content, pedagogical, and technological knowledge.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
46	enhanced my capacity to use technological tools to consistently improve the process of teaching English or mathematics.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
47	enhanced my capacity to use technological tools and resources when teaching.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

48	enhanced my capacity to improve my students' knowledge in English or mathematics by using a range of technological tools.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
49	enhanced my capacity to use a range of technological tools to develop an environment that is suitable for students to practice English or mathematics.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
50	enhanced my capacity to use technological tools to strengthen students' logical thinking when teaching English or mathematics.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
51	enhanced my capacity to appropriately combine instructional approaches, technological tools, and English or mathematics concepts.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
52	provided me with access to learning tools associated with digital learning in the classroom.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
53	inspired me to find innovative technological tools to improve student learning.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
54	enhanced my capacity to use technological tools to present practical and innovative content that goes beyond the current textbook.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
55	enhanced my capacity to adjust my teaching by using technological tools to assess students.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
56	enhanced my capacity to predict how well students understand a specific topic using technological tools.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
57	enhanced my capacity to increase global understanding by of students from diverse cultures through technologies.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
58	enhanced my capacity to use a range of technologies to introduce different cultures and traditions in classes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

#### Section IV. Classes' test score result

59. Please fill in the overall MEAN SCORE of your Year 5 class's test raw score results on the annual competency test for your teaching subject in 2023.

\_\_\_\_\_

60. Please fill in the overall MEAN SCORE of your Year 6 class's test raw score results on the annual competency test for your teaching subject in 2024. \_\_\_\_\_

## Appendix I: Project approval from the University of Sydney Human Research Ethics Committee

### 1. Approval for focus group discussions



Research Integrity & Ethics Administration  
Human Research Ethics Committee

Monday, 25 September 2023

Prof James Tognolini  
Social Work; Faculty of Arts and Social Sciences  
Email: james.tognolini@sydney.edu.au

Dear James,

The University of Sydney Human Research Ethics Committee (HREC) has considered your application.

After consideration of your response to the comments raised your project has been approved.

Approval is granted for a period of four years from 25/09/2023 to 25/09/2027

Project No.: 2023/499

Project Title: Teachers of English as a Foreign Language (EFL) Professional Development, Technological Pedagogical and Content Knowledge (TPACK) and Students' Learning Achievement

Authorised Personnel: Tognolini James; Cotton Wayne; Lu Tzu; Twing Jon S.;

First Annual Report due: 25/09/2024

#### Documents Approved:

Date Uploaded	Version number	Document Name
28/08/2023		Appendix 1 Flow chart for the recruitment procedure
28/08/2023		Appendix 2 The validation procedure of ITTE
28/08/2023		Appendix 3 The validation procedure and the construct of VT
28/08/2023		Appendix 4 PIS School administrators (custodian of the secon
28/08/2023		Appendix 5 PCF focus group interview 1
28/08/2023		Appendix 6 PIS Focus group interview 1
28/08/2023		Appendix 7 Invitation Email for school
28/08/2023		Appendix 8 PIS English Teacher 1008
28/08/2023		Appendix 9 Phone Call Script to the SA for QS
28/08/2023		Appendix 10 Phone Call Script to the SA for FG2 participants
28/08/2023		Appendix 11 Response email from RDMT
28/08/2023		Appendix 12 Focus group 1 interview protocol
28/08/2023		Appendix 13 Focus group 2 interview protocol
28/08/2023		Appendix 14 Focus group 3 interview protocol
28/08/2023		Appendix 15 PIS Focus group 2
28/08/2023		Appendix 16 PIS Focus group 3
07/07/2023		TPL Email for forwarding invitation to teachers
07/07/2023		TPL snowballing request FG2
07/07/2023		TPL snowballing request for schools
07/07/2023		TPL Focus group 2 interview protocol
07/07/2023		TPL Focus group 3 interview protocol
07/07/2023		TPL Email invitation FG1

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ABN 15 211 513 464  
CRICOS 00026A



07/07/2023		TPL Email invitation FG2
07/07/2023		TPL Email invitation FG3
07/07/2023		TPL Email invitation Survey
07/07/2023		TPL Focus group 1 interview protocol
29/05/2023		PCF for Focus Group 2 and 3
29/05/2023		PCF for School Administrator (Secondary Data)
29/05/2023		PCF for EFL Teacher (Questionnaire Survey)

#### Special Condition/s of Approval

- Focus Groups can be approved.
- It is a condition to submit a Modification for the ITTE questionnaire once developed.
- Student data will be provided as aggregate, not individual scores (described in point 4). Participants in the questionnaire survey will be requested to provide the mean score and standard deviation results for their classes in both 2023 and 2024 when completing the survey at the end of the school year in 2024. Please confirm.
- Point 7 says: The custodian of student data at each school would be the director of the academic office or the principal. It is a condition of approval to submit evidence from the data custodian before data collection.

#### Condition/s of Approval

- Research must be conducted according to the approved proposal.
- An annual progress report must be submitted to the Ethics Office on or before the anniversary of approval and on completion of the project.
- You must report as soon as practicable anything that might warrant review of ethical approval of the project including:
  - Serious or unexpected adverse events (which should be reported within 72 hours).
  - Unforeseen events that might affect continued ethical acceptability of the project.
- Any changes to the proposal must be approved prior to their implementation (except where an amendment is undertaken to eliminate *immediate* risk to participants).
- Personnel working on this project must be sufficiently qualified by education, training and experience for their role, or adequately supervised. Changes to personnel must be reported and approved.
- Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, as relevant to this project.
- Data and primary materials must be retained and stored in accordance with the relevant legislation and University guidelines.
- Ethics approval is dependent upon ongoing compliance of the research with the *National Statement on Ethical Conduct in Human Research*, the *Australian Code for the Responsible Conduct of Research*, applicable legal requirements, and with University policies, procedures and governance requirements.
- The Ethics Office may conduct audits on approved projects.



- The Chief Investigator has ultimate responsibility for the conduct of the research and is responsible for ensuring all others involved will conduct the research in accordance with the above.
- The Clinical Trials Support Office has been notified as outlined in the University's Clinical Trials Policy where a clinical trial is being undertaken.

This letter constitutes ethical approval only.

Please contact the Ethics Office should you require further information or clarification.

Sincerely,



Associate Professor Helen Mitchell  
Chair  
Human Research Ethics Committee (HREC 1)

The University of Sydney HRECs are constituted and operate in accordance with the National Health and Medical Research Council's (NHMRC) current National Statement on Ethical Conduct in Human Research (2018) and the NHMRC's current Australian Code for the Responsible Conduct of Research (2018).

## 2. Approval for questionnaire survey



### HUMAN RESEARCH ETHICS APPROVAL

The University of Sydney confirms that this project meets the requirements of the National Statement on Ethical Conduct in Human Research.

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<b>Project identifier:</b>	2023/HE000499
<b>Project title:</b>	Teachers of English as a Foreign Language (EFL) Professional Development, Technological Pedagogical and Content Knowledge (TPACK) and Students' Learning Achievement
<b>Version:</b>	1.01
<b>Chief Investigator:</b>	James Tognolini
<b>Authorised project team:</b>	Jon S. Twing Tzu Lu Wayne Cotton
<b>Approving committee:</b>	ASC 1
<b>Date of approval:</b>	Monday, 15 April, 2024
<b>Project end date:</b>	

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#### Project description

There is little evidence available on what teachers value about TPD and how TPD impacts teachers content and knowledge about technology use in the classroom. One of the reasons for this is that there are few, if any, measuring instruments that can assess the value of TPD from the perspectives of teachers. Consequently, this current research aims to first develop a scale for measuring what it is that teachers value about their TPD experience. It will then develop a further scale to measure the extent to which primary school teachers of English as a Foreign Language in Taiwan perceive their TPD impacts on their Technological Pedagogical and Content Knowledge (TPACK) profile. Finally, the study will also show the relationship between teachers TPACK and student outcomes on the National English Test for Taiwan. The results from this study will potentially inform government policies and school policies for refining the existing TPD programmes, establishing new TPD programmes to improve teachers TPACK and positively impact on students' learning.

#### Summary of changes

#### Documents approved

Date	Version	File name
15/04/2024	Version 2	03014 Clean PCF Teacher Questionnaire
15/04/2024	Version 2	0304 Clean PIS Teacher
15/04/2024	Version 2	0304 PCF Teacher Questionnaire
15/04/2024	Version 2	0204 PIS School Administrator
15/04/2024	Version 2	0204 PCF School Administrator

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**Conditions of Approval**

- Research must be conducted according to the approved proposal.
- An annual progress report must be submitted on or before the anniversary of approval and a final report on completion of the project.
- You must report as soon as practicable anything that might warrant review of ethical approval of the project including:
  - Serious or unexpected adverse events (which should be reported within 72 hours).
  - Unforeseen events that might affect continued ethical acceptability of the project.
- Any changes to the proposal must be approved prior to their implementation (except where an amendment is undertaken to eliminate *immediate* risk to participants).
- Researchers working on this project must be sufficiently qualified by education, training, and experience for their role, or adequately supervised. Changes to the project team must be reported and approved.
- Researchers must disclose any actual, potential or perceived conflicts of interest, including any financial or other interest or affiliation, as relevant to this project.
- Research data and primary materials must be retained and stored in accordance with relevant legislation and University guidelines.
- Ethics approval is dependent upon ongoing compliance of the research with the *National Statement on Ethical Conduct in Human Research*, the *Australian Code for the Responsible Conduct of Research*, applicable legal requirements, and with University policies, procedures, and governance requirements.
- If your research project is a clinical trial and is being sponsored by the University or is to be conducted on a University of Sydney site, you must comply with additional University governance requirements prior to commencing your Clinical Trial.
- The University may conduct audits on approved projects.
- The Chief Investigator has ultimate responsibility for the conduct of the research and is responsible for ensuring all others involved will conduct the research in accordance with the above.

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**Ethics Committee Representative**

Dr Marinda Taha  
Chair  
Modification Review Committee Chair (MRC 1)



## HUMAN RESEARCH ETHICS APPROVAL

The University of Sydney confirms that this project meets the requirements of the National Statement on Ethical Conduct in Human Research.

<b>Project identifier:</b>	2023/HE000499
<b>Project title:</b>	Teachers Professional Development, Technological Pedagogical and Content Knowledge (TPACK) and Students' Learning Achievement in Mathematics and English as a Foreign Language (EFL) in Primary Schools
<b>Version:</b>	2.02
<b>Chief Investigator:</b>	Professor James Tognolini
<b>Authorised project team:</b>	Tzu-Ping Lu Associate Professor Wayne Cotton
<b>Date of approval:</b>	Wednesday, 5 June, 2024
<b>Project end date:</b>	24 Sep 2027

### Project summary

There is little evidence available on what teachers value about TPD and how TPD impacts teachers content and knowledge about technology use in the classroom. It might due to few, if any, measuring instruments that can assess the value of TPD from the perspectives of teachers. Consequently, this current research aims to first develop a scale for measuring what it is that teachers value about their TPD experience. It will then develop a further scale to measure the extent to which primary school teachers perceive their TPD impacts on their Technological Pedagogical and Content Knowledge (TPACK) profile. Finally, the study will also show the relationship between teachers TPACK and student outcomes on a competency test from Taiwan. The results will potentially inform government and school policies for refining the existing TPD program, establishing new TPD program to improve teachers TPACK and positively impact on students' learning.

### Summary of changes

As per the approved research project by HREC on 27 July 2023 and the following approved amendment on 15 April 2024, two amendments are proposed. First, a new questionnaire generated from the previous phases of research including desk research and focus group interviews is proposed to receive permission for the application on the questionnaire survey phase. The questionnaire survey is expected to be conducted via Microsoft Form (paper questionnaire will be provided if the participants strongly require) and in-person. The online and paper format are presented in the attachment.

Second, a detailed description for pilot testing at the questionnaire survey phase is proposed to receive approval before the expected commencement date in May. The detailed recruitment process and the data collection methods are indicated in the next question. PIS and PCF of the pilot testing are attached for the review.

### Documents approved

Document type	File name	Document version	Application version
Survey or questionnaire	Online format of the questionnaire.pdf	1	2.1
Survey or questionnaire	Paper format of the questionnaire.docx	1	2.1
Participant Consent Form (PCF)	1704 PCF teacher(pilot test).docx	1	2.1



## Human Ethics Approval certificate

Participant Information Statement (PIS)	0304 PIS Teacher (pilot test).docx	1	2.1
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**Conditions of Approval**

- Research must be conducted according to the approved proposal.
- An annual progress report must be submitted on or before the anniversary of approval and a final report on completion of the project.
- You must report as soon as practicable anything that might warrant review of ethical approval of the project including:
  - Serious or unexpected adverse events (which should be reported within 72 hours).
  - Unforeseen events that might affect continued ethical acceptability of the project.
- Any changes to the proposal must be approved prior to their implementation (except where an amendment is undertaken to eliminate *immediate* risk to participants).
- Researchers working on this project must be sufficiently qualified by education, training, and experience for their role, or adequately supervised. Changes to the project team must be reported and approved.
- Researchers must disclose any actual, potential of perceived conflicts of interest, including any financial or other interest or affiliation, as relevant to this project.
- Research data and primary materials must be retained and stored in accordance with relevant legislation and University guidelines.
- Ethics approval is dependent upon ongoing compliance of the research with the *National Statement on Ethical Conduct in Human Research*, the *Australian Code for the Responsible Conduct of Research*, applicable legal requirements, and with University policies, procedures, and governance requirements.
- If your research project is a clinical trial and is being sponsored by the University or is to be conducted on a University of Sydney site, you must comply with additional University governance requirements prior to commencing your Clinical Trial.
- The University may conduct audits on approved projects.
- The Chief Investigator has ultimate responsibility for the conduct of the research and is responsible for ensuring all others involved will conduct the research in accordance with the above.

**Ethics Committee Representative**

Chair

On behalf of the University of Sydney

The University of Sydney HRECs are constituted and operate in accordance with the National Statement on Ethical Conduct in Human Research and the Australian Code for the Responsible Conduct of Research (NHMRC). All personnel named on the project should be acquainted with these documents.

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 CRICOS 00026A

**Appendix J-1: The individual teacher fit for the VT scale**

Sample No.	Total/Expected Score	Location	Standard Error (SE)	Fit Residual
1	99.00	2.64	0.27	-3.44
2	96.00	2.43	0.26	-0.06
3	97.00	2.50	0.27	-1.46
4	81.00	1.41	0.26	2.51
5	106.00	3.15	0.27	-1.05
6	113.00	3.69	0.29	-2.06
7	73.00	0.90	0.25	0.78
8	97.00	2.50	0.27	-2.58
9	92.00	2.15	0.26	-4.14
10	118.00	4.12	0.30	1.45
11	82.00	1.48	0.26	-1.86
12	82.00	1.48	0.26	0.11
13	106.00	3.15	0.27	-1.05
14	93.00	2.22	0.26	-1.01
15	76.00	1.09	0.25	1.45
16	94.00	2.29	0.26	-2.64
17	102.00	2.85	0.27	-2.92
18	107.00	3.22	0.28	5.19
19	79.00	1.28	0.26	-0.58
<b>20</b>	<b>135.81</b>	<b>7.99</b>	<b>1.19</b>	<b>...</b>
21	102.00	2.85	0.27	4.69
22	95.00	2.36	0.26	1.29
23	102.00	2.85	0.27	-8.21
24	95.00	2.36	0.26	1.22
25	113.00	3.69	0.29	3.91
26	93.00	2.22	0.26	-2.16
27	103.00	2.93	0.27	-1.58
28	96.00	2.43	0.26	-1.02
29	88.00	1.88	0.26	2.95
30	120.00	4.31	0.31	1.05
31	84.00	1.61	0.26	-1.27
32	86.00	1.74	0.26	1.67
33	107.00	3.22	0.28	-0.82
34	69.00	0.64	0.25	-1.76
35	105.00	3.07	0.27	0.75
36	90.00	2.01	0.26	2.51
37	89.00	1.94	0.26	-2.44
38	99.00	2.64	0.27	-1.40
39	105.00	3.07	0.27	-1.05
40	104.00	3.00	0.27	0.88

41	99.00	2.64	0.27	-1.05
42	88.00	1.88	0.26	1.35
43	122.00	4.51	0.32	-0.12
44	102.00	2.85	0.27	-0.49
45	99.00	2.64	0.27	0.88
<b>46</b>	<b>135.81</b>	<b>7.99</b>	<b>1.19</b>	...
47	115.00	3.86	0.29	2.79
48	83.00	1.54	0.26	1.06
49	94.00	2.29	0.26	-3.78
50	94.00	2.29	0.26	4.97
51	113.00	3.69	0.29	-1.70
52	107.00	3.22	0.28	1.27
53	72.00	0.83	0.25	0.45
54	113.00	3.69	0.29	1.60
55	83.00	1.54	0.26	-0.90
56	87.00	1.81	0.26	-3.30
57	94.00	2.29	0.26	1.66
58	93.00	2.22	0.26	-3.51
59	100.00	2.71	0.27	-0.86
60	83.00	1.54	0.26	-1.53
61	93.00	2.22	0.26	-0.33
62	69.00	0.64	0.25	-3.42
63	107.00	3.22	0.28	1.59
64	85.00	1.68	0.26	0.35
65	119.00	4.21	0.31	0.94
66	110.00	3.45	0.28	2.23
67	90.00	2.01	0.26	-2.19
68	130.00	5.57	0.43	0.02
69	102.00	2.85	0.27	-4.24
70	101.00	2.78	0.27	-0.76
71	74.00	0.96	0.25	-1.88
72	76.00	1.09	0.25	-2.49
73	90.00	2.01	0.26	-2.30
74	68.00	0.58	0.25	-4.03
75	102.00	2.85	0.27	0.98
76	91.00	2.08	0.26	-3.04
77	111.00	3.53	0.28	2.14
79	94.00	2.29	0.26	-2.38
80	108.00	3.30	0.28	0.55
81	92.00	2.15	0.26	-2.59
82	105.00	3.07	0.27	0.55
83	54.00	-0.27	0.25	0.63
84	85.00	1.68	0.26	2.48
85	109.00	3.38	0.28	1.28

86	83.00	1.54	0.26	-0.27
87	113.00	3.69	0.29	1.46
88	39.00	-1.30	0.29	3.29
89	96.00	2.43	0.26	0.68
90	118.00	4.12	0.30	6.04
91	81.00	1.41	0.26	0.20
92	88.00	1.88	0.26	-2.45
93	86.00	1.74	0.26	-0.20
94	85.00	1.68	0.26	-1.77
95	86.00	1.74	0.26	-0.97
96	66.00	0.46	0.25	0.43
97	98.00	2.57	0.27	-3.31
98	88.00	1.88	0.26	0.49
99	98.00	2.57	0.27	-2.09
100	89.00	1.94	0.26	-1.58
101	117.00	4.03	0.30	2.89
102	121.00	4.40	0.32	0.88
103	83.00	1.54	0.26	-1.33
104	80.00	1.35	0.26	-0.55
105	72.00	0.83	0.25	-1.59
106	62.00	0.21	0.25	-2.96
107	58.00	-0.03	0.25	-1.42
108	80.00	1.35	0.26	-0.08
109	118.00	4.12	0.30	2.24

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*Note.* Extreme samples are presented in bold

**Appendix J-2: The individual item fit for the VT scale**

Item	C.I.	Item descriptions	Fit Residual
1	A1	"...focused on one or more of the following: specific content, specific knowledge, or specific skills."	-1.13
2	A2	"...was aligned with my prior experience. "	-1.28
3	A3	"...provided training in content based on my needs. "	1.93
4	A4	"...provided a variety of courses selection for me. "	1.15
5	A5	"...provided opportunities for feedback and assessment from peers."	0.24
6	A6	"...provided opportunities for the educators conducting the workshops to provide feedback to the trainees."	-0.83
7	A7	"...provided opportunities for self-reflection."	-0.93
8	I1	"...motivated me to learn actively. "	0.31
9	I2	"...provided opportunities for collaborative learning with peers. "	-0.30
10	I3	"...provided opportunities for cross-discipline collaborative learning. "	1.39
11	I4	"...provided opportunities for collaborative learning with teachers from other schools. "	1.47
12	I5	"...was novel and different from the previous program(s) I attended. "	0.96
13	I6	"...provided an opportunity for hands-on learning. "	-0.59
14	U1	"...helped me to improve student learning in the area. "	-0.28
15	U2	"...well aligned with my school's needs. "	-1.30
16	U3	"...conducted by trainers who were considered professional educators and teachers. "	-0.26
17	U4	"...fit with my school's curriculum plan"	-0.69
18	U5	"...provided practical examples of teachers applying methods taught in the program. "	-1.34
19	U6	"...provided recurrent training. "	-0.25
20	U7	"...provided follow-up advisory service to assist when implementing the ideas in the classroom. "	-1.06
21	U8	"...provided follow-up course design and suggestion. "	0.15
22	U9	"...provided services for follow-up classroom observations and feedback. "	1.20
23	U10	"I can easily apply what I have learnt from the TPD program in my class. "	-0.39
24	U11	"The organisers of this TPD program provided teaching materials. "	-0.65
25	U12	"I can easily access the teaching material introduced from the program. "	-0.15

26	U13	“My school provided teaching materials introduced from the program. ”	0.42
27	U14	“My school provided teaching equipment introduced from the program. ”	1.14
28	U15	“...strengthened my career as a teacher. ”	-1.10
29	C1	“It was easy for me to rearrange my classes’ timetable to attend the TPD program. ”	<b>6.80</b>
30	C2	“The time spent on the training is efficient.”	-0.25
31	C3	“I can conduct the follow-up tasks from the TPD program easily. ”	-0.63
32	C4	“The fees for participating in the TPD program were not too expensive. ”	<b>3.27</b>
33	C5	“The procedures to implement what I learnt from the TPD program were clear. ”	-0.33
34	C6	“I enjoy participating in the TPD program without too much stress. ”	<b>3.25</b>

*Note.* “C.I.” refers to items’ corresponding indicators. Fit residuals above 2.50 are presented in bold.

**Appendix J-3: The individual item fit for the VT scale after eliminate misfit Items 29, 34, 32**

Item	C.I.	Item descriptions	Fit Residual
1	A1	“...focused on one or more of the following: specific content, specific knowledge, or specific skills.”	-0.93
2	A2	“...was aligned with my prior experience. ”	-1.28
3	A3	“...provided training in content based on my needs. ”	2.58
4	A4	“...provided a variety of courses selection for me. ”	1.58
5	A5	“...provided opportunities for feedback and assessment from peers.”	0.50
6	A6	“...provided opportunities for the educators conducting the workshops to provide feedback to the trainees.”	-0.73
7	A7	“...provided opportunities for self-reflection.”	-0.80
8	I1	“...motivated me to learn actively. ”	0.47
9	I2	“...provided opportunities for collaborative learning with peers. ”	-0.20
10	I3	“...provided opportunities for cross-discipline collaborative learning. ”	1.83
11	I4	“...provided opportunities for collaborative learning with teachers from other schools. ”	1.78
12	I5	“...was novel and different from the previous program(s) I attended. ”	1.30
13	I6	“...provided an opportunity for hands-on learning. ”	-0.52
14	U1	“...helped me to improve student learning in the area. ”	0.03
15	U2	“...well aligned with my school’s needs. ”	-1.38
16	U3	“...conducted by trainers who were considered professional educators and teachers. ”	-0.01
17	U4	“...fit with my school’s curriculum plan”	-0.82
18	U5	“...provided practical examples of teachers applying methods taught in the program. ”	-1.27
19	U6	“...provided recurrent training. ”	0.24
20	U7	“...provided follow-up advisory service to assist when implementing the ideas in the classroom. ”	-0.97
21	U8	“...provided follow-up course design and suggestion. ”	0.04
22	U9	“...provided services for follow-up classroom observations and feedback. ”	1.56
23	U10	“I can easily apply what I have learnt from the TPD program in my class. ”	-0.33
24	U11	“The organisers of this TPD program provided teaching materials. ”	-0.83
25	U12	“I can easily access the teaching material introduced from the program. ”	-0.08

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26	U13	“My school provided teaching materials introduced from the program. ”	0.78
27	U14	“My school provided teaching equipment introduced from the program. ”	1.61
28	U15	“...strengthened my career as a teacher. ”	-0.98
30	C2	“The time spent on the training is efficient.”	0.44
31	C3	“I can conduct the follow-up tasks from the TPD program easily. ”	0.17
33	C5	“The procedures to implement what I learnt from the TPD program were clear. ”	0.22

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**Appendix J-4: The individual teacher fit for the VT scale after eliminating extreme samples and misfit items 29, 34, 32**

Sample No.	Total/Expected Score	Location	Standard Error (SE)	Fit Residual
1	93	3.09	0.29	<b>-3.90</b>
2	87	2.58	0.29	0.25
3	91	2.92	0.29	-1.27
4	77	1.73	0.29	<b>2.57</b>
5	98	3.53	0.30	-1.14
6	103	3.98	0.31	-1.74
7	66	0.86	0.27	0.74
8	89	2.75	0.29	<b>-2.94</b>
9	85	2.40	0.29	<b>-4.02</b>
10	108	4.46	0.32	1.33
11	75	1.57	0.28	-2.03
12	78	1.82	0.29	-0.95
13	98	3.53	0.30	-1.14
14	87	2.58	0.29	-0.63
15	70	1.17	0.28	1.73
16	86	2.49	0.29	-2.31
17	94	3.18	0.29	<b>-2.63</b>
18	104	4.07	0.31	<b>4.37</b>
19	74	1.49	0.28	-0.04
21	95	3.26	0.30	<b>4.68</b>
22	90	2.83	0.29	1.26
23	93	3.09	0.29	<b>-7.86</b>
24	86	2.49	0.29	1.46
25	105	4.16	0.31	<b>3.83</b>
26	86	2.49	0.29	-2.02
27	94	3.18	0.29	-1.57
28	90	2.83	0.29	-0.77
29	78	1.82	0.29	<b>2.75</b>
30	110	4.67	0.33	1.48
31	76	1.65	0.29	-1.48
32	78	1.82	0.29	1.71
33	98	3.53	0.30	-0.34
34	64	0.71	0.27	-1.77
35	99	3.61	0.30	-0.10
36	85	2.40	0.29	<b>2.67</b>
37	82	2.15	0.29	-2.16
38	93	3.09	0.29	-1.35
39	97	3.44	0.30	-0.64
40	99	3.61	0.30	0.09

41	93	3.09	0.29	-1.00
42	79	1.90	0.29	1.46
43	111	4.78	0.34	-0.01
44	95	3.26	0.30	-0.44
45	95	3.26	0.30	0.32
47	110	4.67	0.33	0.98
48	79	1.90	0.29	1.12
49	86	2.49	0.29	<b>-3.28</b>
50	83	2.24	0.29	<b>4.83</b>
51	103	3.98	0.31	-2.47
52	99	3.61	0.30	0.93
53	66	0.86	0.27	0.16
54	105	4.16	0.31	1.99
55	75	1.57	0.28	-1.00
56	82	2.15	0.29	<b>-2.78</b>
57	86	2.49	0.29	1.51
58	86	2.49	0.29	<b>-2.84</b>
59	93	3.09	0.29	-0.70
60	75	1.57	0.28	-1.59
61	85	2.40	0.29	0.10
62	63	0.64	0.27	<b>-3.95</b>
63	102	3.88	0.30	0.43
64	78	1.82	0.29	0.75
65	113	5.02	0.36	-0.75
66	102	3.88	0.30	<b>2.60</b>
67	81	2.07	0.29	-2.27
68	120	6.20	0.51	-0.25
69	94	3.18	0.29	<b>-5.63</b>
70	95	3.26	0.30	-0.78
71	66	0.86	0.27	<b>-3.34</b>
72	69	1.09	0.28	<b>-3.13</b>
73	82	2.15	0.29	-1.95
74	62	0.57	0.27	<b>-6.09</b>
75	97	3.44	0.30	0.46
76	84	2.32	0.29	-2.39
77	107	4.36	0.32	-0.32
79	87	2.58	0.29	-1.80
80	100	3.70	0.30	0.62
81	85	2.40	0.29	-2.31
82	94	3.18	0.29	0.51
83	50	-0.28	0.27	0.61
84	76	1.65	0.29	2.45
85	104	4.07	0.31	0.38
86	77	1.73	0.29	0.20

87	103	3.98	0.31	1.36
88	36	-1.37	0.31	1.03
89	90	2.83	0.29	0.61
90	111	4.78	0.34	<b>5.57</b>
91	74	1.49	0.28	0.36
92	82	2.15	0.29	-2.23
93	78	1.82	0.29	-0.06
94	76	1.65	0.29	-2.33
95	78	1.82	0.29	-1.12
96	57	0.21	0.27	<b>-3.73</b>
97	92	3.00	0.29	<b>-3.48</b>
98	83	2.24	0.29	0.13
99	91	2.92	0.29	<b>-2.73</b>
100	82	2.15	0.29	-1.30
101	106	4.26	0.31	<b>3.09</b>
102	109	4.56	0.33	0.74
103	77	1.73	0.29	-1.05
104	73	1.41	0.28	-0.67
105	68	1.01	0.28	-1.17
106	59	0.35	0.27	<b>-2.71</b>
107	54	0.00	0.26	-1.54
108	74	1.49	0.28	-0.10
109	106	4.26	0.31	2.12

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Fit residuals beyond  $\pm 2.50$  are presented in bold.



**Appendix J-5: Residual correlation matrix of the refined VT scale**

	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Item	C.I.	A1	A2	A3	A4	A5	A6	A7	I1	I2	I3	I4	I5	I6	U1	U2	U3
1	A1	x	0.34	-0.05	-0.04	-0.05	0.02	0.00	0.04	-0.25	-0.16	-0.19	0.15	0.01	0.17	-0.03	0.04
2	A2		x	-0.12	-0.15	-0.04	0.09	0.12	0.02	-0.11	0.02	-0.19	0.03	0.13	0.15	0.24	0.08
3	A3			x	0.35	-0.05	-0.08	-0.22	-0.05	0.04	0.16	0.02	0.01	-0.20	-0.15	-0.01	-0.17
4	A4				x	0.00	0.16	-0.07	-0.14	-0.04	0.06	-0.07	0.06	0.02	-0.11	-0.19	-0.16
5	A5					x	0.27	0.10	-0.11	0.14	0.04	0.07	-0.02	-0.13	-0.24	0.06	-0.03
6	A6						x	0.31	-0.12	0.12	-0.03	-0.15	-0.14	0.00	0.02	0.05	-0.07
7	A7							x	0.12	0.15	-0.10	-0.06	-0.02	0.11	0.01	-0.01	-0.07
8	I1								x	0.10	0.14	0.21	-0.03	0.00	0.03	-0.05	-0.10
9	I2									x	0.10	0.10	-0.26	-0.21	-0.17	-0.02	-0.13
10	I3										x	0.13	0.14	-0.01	-0.10	-0.15	-0.07
11	I4											x	0.02	-0.02	-0.09	-0.04	-0.14
12	I5												x	0.18	0.17	0.01	0.01
13	I6													x	0.31	-0.16	0.11
14	U1														x	0.05	0.11
15	U2															x	0.14
16	U3																x

Note. "C.I." refers to items' corresponding indicators.

(Continued) Item 17 to 33

	Item*	17	18	19	20	21	22	23	24	25	26	27	28	30	31	33
Item*	C.I.	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14	U15	C2	C3	C5
1	A1	-0.09	0.00	-0.07	-0.08	-0.13	-0.18	-0.04	-0.02	0.09	0.04	-0.08	0.11	-0.08	-0.07	-0.06
2	A2	0.03	0.09	-0.21	-0.24	-0.20	-0.30	-0.07	0.09	0.13	-0.07	-0.04	0.10	-0.09	-0.20	-0.04
3	A3	0.08	-0.21	0.11	0.05	0.06	0.19	-0.01	-0.20	-0.15	-0.14	-0.31	-0.22	-0.14	-0.18	-0.12
4	A4	-0.07	-0.14	0.04	0.01	0.07	0.12	-0.11	-0.13	-0.34	-0.26	-0.22	-0.13	-0.11	0.03	0.09

5	A5	0.02	-0.05	0.08	0.00	-0.03	-0.11	-0.34	-0.09	-0.09	-0.03	0.03	-0.10	-0.13	-0.12	-0.08
6	A6	0.12	0.06	-0.28	-0.05	-0.09	-0.12	-0.21	-0.14	-0.20	0.01	0.03	0.02	-0.22	-0.01	-0.07
7	A7	0.00	0.15	-0.20	-0.10	-0.08	0.09	-0.21	-0.16	-0.06	-0.02	-0.14	0.25	-0.32	-0.10	-0.12
8	I1	-0.19	-0.04	0.03	-0.16	-0.17	-0.18	0.08	-0.12	0.10	0.00	0.03	0.10	-0.11	-0.15	-0.23
9	I2	0.12	-0.07	-0.05	-0.06	-0.01	-0.02	-0.11	-0.13	-0.06	-0.11	-0.04	0.04	-0.05	0.00	-0.02
10	I3	-0.30	-0.19	-0.08	-0.25	-0.30	-0.26	0.11	-0.08	0.06	-0.15	0.09	-0.10	0.10	-0.02	-0.11
11	I4	-0.01	-0.20	0.16	0.02	0.03	-0.02	-0.15	-0.26	-0.15	-0.10	-0.24	-0.09	0.17	0.07	-0.18
12	I5	-0.07	-0.01	-0.03	-0.03	-0.17	-0.15	-0.12	0.08	-0.05	-0.05	-0.19	-0.07	-0.09	-0.23	-0.17
13	I6	-0.24	0.06	0.03	-0.11	-0.13	-0.10	0.02	0.03	-0.08	-0.21	-0.05	0.09	0.05	-0.15	-0.08
14	U1	-0.12	0.14	-0.03	-0.17	-0.21	-0.24	0.09	-0.02	-0.01	-0.16	-0.15	-0.03	0.09	0.06	-0.02
15	U2	0.53	0.15	-0.18	-0.26	-0.37	-0.27	-0.05	0.10	0.00	0.21	-0.07	0.22	-0.07	-0.17	-0.22
16	U3	0.05	0.30	-0.09	-0.08	-0.16	-0.18	-0.01	0.10	0.12	-0.10	0.03	0.15	0.00	-0.24	-0.02
17	U4	x	0.21	-0.27	-0.10	-0.13	-0.07	-0.02	0.11	-0.05	0.23	-0.16	0.02	-0.12	-0.15	-0.05
18	U5		x	-0.25	0.05	-0.16	-0.18	-0.16	0.20	0.08	-0.12	-0.04	0.19	-0.07	-0.10	-0.09
19	U6			x	0.29	0.30	0.25	0.04	-0.15	-0.26	-0.27	-0.21	-0.31	0.03	0.06	0.09
20	U7				x	0.71	0.47	-0.18	-0.10	-0.25	-0.16	-0.16	-0.21	-0.07	0.01	-0.06
21	U8					x	0.68	-0.11	-0.02	-0.13	-0.17	-0.16	-0.29	-0.09	0.03	0.04
22	U9						x	-0.05	-0.05	-0.18	-0.06	-0.13	-0.16	-0.20	-0.02	-0.12
23	U10							x	0.20	0.07	0.00	0.18	-0.09	0.18	0.10	0.01
24	U11								x	0.35	0.02	0.05	0.03	-0.11	-0.22	0.03
25	U12									x	0.21	0.24	0.05	-0.07	-0.05	-0.06
26	U13										x	0.47	0.15	-0.08	-0.08	-0.04
27	U14											x	0.07	-0.05	0.09	0.12
28	U15												x	-0.03	-0.13	-0.13
30	C2													x	0.40	0.26
31	C3														x	0.40
33	C5															x

Note. "C.I." refers to items' corresponding indicators.

**Appendix J-6: Frequencies of item responses to the VT questionnaire**

Item No.	Corresponding Indicators	1. Strongly disagree		2. Disagree		3. Neutral		4. Agree		5. Strongly agree	
		n	%	n	%	n	%	n	%	n	%
1	A1	0	0%	3	3%	20	19%	57	53%	27	25%
2	A2	0	0%	2	2%	19	18%	53	50%	33	31%
3	A3	2	2%	12	11%	50	47%	32	30%	11	10%
4	A4	1	1%	6	6%	41	38%	42	39%	17	16%
5	A5	0	0%	6	6%	29	27%	54	50%	18	17%
6	A6	0	0%	2	2%	26	24%	58	54%	21	20%
7	A7	0	0%	3	3%	19	18%	59	55%	26	24%
8	I1	1	1%	3	3%	27	25%	50	47%	26	24%
9	I2	0	0%	3	3%	24	22%	54	50%	26	24%
10	I3	1	1%	2	2%	25	23%	62	58%	17	16%
11	I4	1	1%	5	5%	48	45%	38	36%	15	14%
12	I5	0	0%	3	3%	41	39%	46	43%	16	15%
13	I6	0	0%	3	3%	18	17%	63	59%	23	22%
14	U1	0	0%	2	2%	15	14%	63	59%	27	25%
15	U2	0	0%	4	4%	28	26%	56	52%	19	18%
16	U3	0	0%	1	1%	15	14%	54	50%	37	35%
17	U4	0	0%	3	3%	27	25%	57	53%	20	19%
18	U5	0	0%	3	3%	22	21%	57	53%	25	23%
19	U6	0	0%	15	14%	43	40%	38	36%	11	10%
20	U7	0	0%	12	11%	37	35%	45	42%	13	12%
21	U8	1	1%	8	7%	33	31%	51	48%	14	13%
22	U9	2	2%	11	10%	42	39%	38	36%	14	13%
23	U10	0	0%	4	4%	22	21%	65	61%	16	15%
24	U11	0	0%	3	3%	32	30%	57	53%	15	14%
25	U12	0	0%	4	4%	32	30%	56	52%	15	14%
26	U13	1	1%	3	3%	46	43%	43	40%	14	13%
27	U14	1	1%	2	2%	35	33%	46	43%	23	22%
28	U15	0	0%	3	3%	13	12%	68	64%	23	22%
30	C2	0	0%	4	4%	39	36%	53	50%	11	10%
31	C3	0	0%	11	10%	52	49%	35	33%	9	8%
33	C5	0	0%	6	6%	27	25%	58	54%	16	15%
<b>Average</b>		<b>0</b>	<b>0%</b>	<b>5</b>	<b>5%</b>	<b>31</b>	<b>29%</b>	<b>52</b>	<b>48%</b>	<b>19</b>	<b>18%</b>

**Appendix J-7: Raw-score-to-ability translation for VT scale**

<b>Raw score</b>	<b>Logit score</b>	<b>(continue)</b>	
		<b>Raw score</b>	<b>Logit score</b>
0	-10.68	63	0.64
1	-9.86	64	0.71
2	-9.29	65	0.79
3	-8.89	66	0.86
4	-8.58	67	0.94
5	-8.31	68	1.01
6	-8.07	69	1.09
7	-7.86	70	1.17
8	-7.66	71	1.25
9	-7.47	72	1.33
10	-7.29	73	1.41
11	-7.11	74	1.49
12	-6.94	75	1.57
13	-6.76	76	1.65
14	-6.58	77	1.73
15	-6.40	78	1.82
16	-6.20	79	1.90
17	-6.00	80	1.98
18	-5.78	81	2.07
19	-5.54	82	2.15
20	-5.26	83	2.24
21	-4.93	84	2.32
22	-4.52	85	2.41
23	-4.04	86	2.49
24	-3.56	87	2.58
25	-3.18	88	2.66
26	-2.88	89	2.75
27	-2.63	90	2.83
28	-2.43	91	2.92
29	-2.25	92	3.01
30	-2.09	93	3.09
31	-1.94	94	3.18
32	-1.81	95	3.26
33	-1.69	96	3.35
34	-1.58	97	3.44
35	-1.47	98	3.53
36	-1.37	99	3.62
37	-1.28	100	3.70
38	-1.19	101	3.79
39	-1.10		

40	-1.02	102	3.88
41	-0.94	103	3.98
42	-0.86	104	4.07
43	-0.78	105	4.16
44	-0.71	106	4.26
45	-0.63	107	4.36
46	-0.56	108	4.46
47	-0.49	109	4.56
48	-0.42	110	4.67
49	-0.35	111	4.78
50	-0.28	112	4.90
51	-0.21	113	5.02
52	-0.14	114	5.15
53	-0.07	115	5.28
54	0.00	116	5.43
55	0.07	117	5.59
56	0.14	118	5.77
57	0.21	119	5.97
58	0.28	120	6.21
59	0.35	121	6.49
60	0.42	122	6.86
61	0.49	123	7.40
62	0.57	124	8.20

**Appendix K-1: The individual teacher fit for the ITTE scale**

Sample No.	Total/Expected Score	Location	SE	Fit Residual
1	56	3.170931	0.435	
2	68	5.480786	0.4617	
3	53	2.613779	0.4184	
4	50	2.111004	0.3985	
5	73	6.788522	0.6205	
6	60	3.950652	0.4384	
7	50	2.111004	0.3985	
8	58	3.5611	0.4393	
9	52	2.440038	0.4117	
10	70	5.921132	0.4965	
11	48	1.803665	0.3865	
12	55	2.97999	0.4307	
13	73	6.788522	0.6205	
14	54	2.793969	0.4251	
15	53	2.613779	0.4184	
16	64	4.706299	0.437	
17	58	3.5611	0.4393	
<b>18</b>	<b>75.81033</b>	<b>8.662369</b>	<b>1.2459</b>	<b>extm</b>
19	40	0.723198	0.3514	
<b>20</b>	<b>75.81033</b>	<b>8.662369</b>	<b>1.2459</b>	<b>extm</b>
21	46	1.51388	0.3762	
22	62	4.331784	0.4361	
23	57	3.365253	0.4379	
24	46	1.51388	0.3762	
25	66	5.084049	0.4444	
26	57	3.365253	0.4379	
27	58	3.5611	0.4393	
28	53	2.613779	0.4184	
29	47	1.656816	0.3812	
30	70	5.921132	0.4965	
31	50	2.111004	0.3985	
32	52	2.440038	0.4117	
33	56	3.170931	0.435	
34	51	2.272558	0.405	
35	62	4.331784	0.4361	

36	60	3.950652	0.4384	
37	57	3.365253	0.4379	
38	57	3.365253	0.4379	
39	64	4.706299	0.437	
40	72	6.454406	0.5629	
41	60	3.950652	0.4384	
43	72	6.454406	0.5629	
44	53	2.613779	0.4184	
45	57	3.365253	0.4379	
<b>46</b>	<b>75.81033</b>	<b>8.662369</b>	<b>1.2459</b>	<b>extm</b>
47	71	6.17134	0.524	
48	44	1.238322	0.3671	
49	56	3.170931	0.435	
50	63	4.519395	0.4359	
51	62	4.331784	0.4361	
52	69	5.693478	0.4758	
53	68	5.480786	0.4617	
54	66	5.084049	0.4444	
55	57	3.365253	0.4379	
56	37	0.364843	0.3431	
57	63	4.519395	0.4359	
58	49	1.954887	0.3923	
59	62	4.331784	0.4361	
60	47	1.656816	0.3812	
61	64	4.706299	0.437	
62	43	1.105218	0.363	
63	71	6.17134	0.524	
64	54	2.793969	0.4251	
65	70	5.921132	0.4965	
66	67	5.278786	0.4515	
67	55	2.97999	0.4307	
<b>68</b>	<b>75.81033</b>	<b>8.662369</b>	<b>1.2459</b>	<b>extm</b>
69	57	3.365253	0.4379	
70	57	3.365253	0.4379	
71	44	1.238322	0.3671	
72	42	0.97504	0.359	
73	53	2.613779	0.4184	

74	38	0.481953	0.3455
75	55	2.97999	0.4307
76	56	3.170931	0.435
77	64	4.706299	0.437
78	56	3.170931	0.435
79	50	2.111004	0.3985
80	64	4.706299	0.437
81	52	2.440038	0.4117
82	58	3.5611	0.4393
83	28	-0.67974	0.3616
84	75	7.809162	0.8948
85	56	3.170931	0.435
86	58	3.5611	0.4393
87	59	3.75669	0.4392
88	24	-1.25295	0.4063
89	74	7.209702	0.7138
90	73	6.788522	0.6205
91	54	2.793969	0.4251
92	47	1.656816	0.3812
93	44	1.238322	0.3671
94	49	1.954887	0.3923
95	49	1.954887	0.3923
96	38	0.481953	0.3455
97	57	3.365253	0.4379
98	57	3.365253	0.4379
99	58	3.5611	0.4393
100	53	2.613779	0.4184
101	71	6.17134	0.524
102	74	7.209702	0.7138
103	55	2.97999	0.4307
104	57	3.365253	0.4379
105	57	3.365253	0.4379
106	43	1.105218	0.363
107	31	-0.31721	0.345
108	52	2.440038	0.4117
109	68	5.480786	0.4617

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*Note.* Extreme samples are presented in bold

**Appendix K-2: The individual item fit for the ITTE scale**

Item	C.I.	Item descriptions	Fit Residual
1	T1	"...to use a variety of technological tools to stimulate students' motivation. "	0.508
2	T2	"...to use a variety of technological tools to assist students in pursuing their own interests. "	-2.043
3	T3	"...to use technological tools to provide information to students and peers. "	-2.128
4	T4	"...has provided me with more choices of technological tools to improve student learning. "	-1.812
5	T5	"...to teach effectively by appropriately combining the technological tools and instructional content. "	-1.345
6	T6	"...to lead my colleagues in integrating content, pedagogical, and technological knowledge. "	1.313
7	T7	"...to use technological tools to consistently improve the process of teaching English or mathematics. "	-3.267
8	T8	"...to use technological tools and resources when teaching. "	-2.577
9	T9	"...to improve my students' knowledge in English or mathematics by using a range of technological tools"	-1.716
10	T10	"...to use a range of technological tools to develop an environment that is suitable for students to practice English or mathematics. "	-1.479
11	T11	"...to use technological tools to strengthen students' logical thinking when teaching English or mathematics. "	0.662
12	T12	"...to appropriately combine instructional approaches, technological tools, and English or mathematics concepts. "	2.441
13	T13	"...to learning tools associated with digital learning in the classroom. "	-1.249
14	T14	"...inspired me to find innovative technological tools to improve student learning.	0.35
15	T15	"...to use technological tools to present practical and innovative content that goes beyond the current textbook. "	1.434
16	T16	"...to adjust my teaching by using technological tools to assess students. "	-1.239
17	T17	"...to predict how well students understand a specific topic using technological tools. "	0.273
18	T18	"...to increase global understanding by of students from diverse cultures through technologies. "	<b>4.067***</b>
19	T19	"...to use a range of technologies to introduce different cultures and traditions in classes. "	<b>2.907</b>

*Note.* "C.I." refers to items' corresponding indicators. Fit residuals above 2.50 are presented in bold. \*\*\* represents *p* values smaller than 0.001.

**Appendix K-3: The individual item fit for the ITTE scale after eliminating Item 18**

Item	C.I.	Item descriptions	Fit Residual
1	T1	“...to use a variety of technological tools to stimulate students’ motivation. ”	0.202
2	T2	“...to use a variety of technological tools to assist students in pursuing their own interests. ”	-2.056
3	T3	“...to use technological tools to provide information to students and peers. ”	-1.937
4	T4	“...has provided me with more choices of technological tools to improve student learning. ”	-1.729
5	T5	“...to teach effectively by appropriately combining the technological tools and instructional content. ”	-1.156
6	T6	“...to lead my colleagues in integrating content, pedagogical, and technological knowledge. ”	1.560
7	T7	“...to use technological tools to consistently improve the process of teaching English or mathematics. ”	-3.176
8	T8	“...to use technological tools and resources when teaching. ”	-2.434
9	T9	“...to improve my students’ knowledge in English or mathematics by using a range of technological tools”	-1.782
10	T10	“...to use a range of technological tools to develop an environment that is suitable for students to practice English or mathematics. ”	-1.397
11	T11	“...to use technological tools to strengthen students’ logical thinking when teaching English or mathematics. ”	0.876
12	T12	“...to appropriately combine instructional approaches, technological tools, and English or mathematics concepts. ”	2.560
13	T13	“...to learning tools associated with digital learning in the classroom. ”	-0.832
14	T14	“...inspired me to find innovative technological tools to improve student learning.	0.328
15	T15	“...to use technological tools to present practical and innovative content that goes beyond the current textbook. ”	1.616
16	T16	“...to adjust my teaching by using technological tools to assess students. ”	-0.868
17	T17	“...to predict how well students understand a specific topic using technological tools. ”	0.764
19	T19	“...to use a range of technologies to introduce different cultures and traditions in classes. ”	<b>4.158</b>

*Note.* “C.I.” refers to items’ corresponding indicators. Fit residuals above 2.50 are presented in bold.

**Appendix K-4: The individual item fit for the ITTE scale after eliminating Items 18 and 19**

Item	C.I.	Item descriptions	Fit Residual
1	T1	“...to use a variety of technological tools to stimulate students’ motivation. ”	0.27
2	T2	“...to use a variety of technological tools to assist students in pursuing their own interests. ”	-1.72
3	T3	“...to use technological tools to provide information to students and peers. ”	-1.61
4	T4	“...has provided me with more choices of technological tools to improve student learning. ”	-1.52
5	T5	“...to teach effectively by appropriately combining the technological tools and instructional content. ”	-0.84
6	T6	“...to lead my colleagues in integrating content, pedagogical, and technological knowledge. ”	1.82
7	T7	“...to use technological tools to consistently improve the process of teaching English or mathematics. ”	-3.26
8	T8	“...to use technological tools and resources when teaching. ”	-2.06
9	T9	“...to improve my students’ knowledge in English or mathematics by using a range of technological tools”	-1.68
10	T10	“...to use a range of technological tools to develop an environment that is suitable for students to practice English or mathematics. ”	-1.38
11	T11	“...to use technological tools to strengthen students’ logical thinking when teaching English or mathematics. ”	1.07
12	T12	“...to appropriately combine instructional approaches, technological tools, and English or mathematics concepts. ”	2.50
13	T13	“...to learning tools associated with digital learning in the classroom. ”	-0.53
14	T14	“...inspired me to find innovative technological tools to improve student learning.	0.48
15	T15	“...to use technological tools to present practical and innovative content that goes beyond the current textbook. ”	1.84
16	T16	“...to adjust my teaching by using technological tools to assess students. ”	-0.22
17	T17	“...to predict how well students understand a specific topic using technological tools. ”	1.40

*Note.* ““C.I.” refers to items’ corresponding indicators. Fit residuals above 2.50 are presented in bold.

**Appendix K-5: The individual teacher fit for the ITTE scale after eliminating extreme samples and misfit Items 18 and 19**

Sample No.	Total/Expected Score	Location	SE	Fit Residual
1	50	3.35	0.50	<b>-4.77</b>
2	61	5.98	0.50	0.17
3	48	2.85	0.48	-1.43
4	44	2.00	0.44	<b>3.42</b>
5	65	7.15	0.63	-0.52
6	54	4.38	0.49	-1.71
7	47	2.62	0.47	-0.30
8	52	3.88	0.50	<b>-3.11</b>
9	46	2.40	0.46	-0.81
10	66	7.59	0.73	-0.19
11	44	2.00	0.44	-1.37
12	48	2.85	0.48	-1.16
13	65	7.15	0.63	-0.52
14	50	3.35	0.50	-0.48
15	45	2.20	0.45	0.52
16	57	5.08	0.48	-0.10
17	53	4.13	0.50	-0.58
19	35	0.51	0.38	<b>-3.40</b>
21	38	0.96	0.40	<b>3.42</b>
22	56	4.85	0.48	0.93
23	51	3.61	0.51	<b>-5.28</b>
24	41	1.46	0.42	-0.40
25	63	6.50	0.54	1.21
26	51	3.61	0.51	<b>-5.28</b>
27	52	3.88	0.50	1.38
28	49	3.09	0.49	-0.21
29	43	1.81	0.43	<b>2.83</b>
30	62	6.23	0.52	0.93
31	47	2.62	0.47	-1.15
32	47	2.62	0.47	-0.27
33	51	3.61	0.51	<b>-5.28</b>
34	45	2.20	0.45	-0.99
35	55	4.62	0.49	-1.04
36	54	4.38	0.49	-1.18

37	51	3.61	0.51	-0.47
38	50	3.35	0.50	0.14
39	59	5.52	0.48	-0.30
40	66	7.59	0.73	-0.86
41	55	4.62	0.49	0.75
43	66	7.59	0.73	-0.48
44	49	3.09	0.49	-1.26
45	50	3.35	0.50	0.78
47	63	6.50	0.54	-0.02
48	40	1.29	0.41	-1.53
49	50	3.35	0.50	-2.01
50	55	4.62	0.49	<b>4.18</b>
51	56	4.85	0.48	-0.90
52	61	5.98	0.50	0.25
53	61	5.98	0.50	1.42
54	62	6.23	0.52	1.52
55	51	3.61	0.51	<b>-5.28</b>
56	32	0.09	0.37	-0.70
57	57	5.08	0.48	1.49
58	44	2.00	0.44	0.20
59	54	4.38	0.49	<b>3.07</b>
60	41	1.46	0.42	-0.51
61	58	5.30	0.48	1.41
62	37	0.81	0.39	0.83
63	63	6.50	0.54	-0.99
64	50	3.35	0.50	1.40
65	62	6.23	0.52	<b>5.11</b>
66	59	5.52	0.48	0.78
67	51	3.61	0.51	<b>-5.28</b>
69	51	3.61	0.51	<b>-5.28</b>
70	50	3.35	0.50	-1.96
71	38	0.96	0.40	<b>-2.51</b>
72	38	0.96	0.40	-1.62
73	46	2.40	0.46	-0.83
74	34	0.37	0.38	<b>-5.54</b>
75	51	3.61	0.51	-0.63
76	50	3.35	0.50	<b>-4.77</b>

77	58	5.30	0.48	-1.04
78	50	3.35	0.50	<b>-4.77</b>
79	44	2.00	0.44	-1.20
80	60	5.75	0.49	1.37
81	47	2.62	0.47	-0.95
82	51	3.61	0.51	1.10
83	25	-0.85	0.39	-0.20
84	67	8.20	0.91	0.03
85	50	3.35	0.50	<b>-2.51</b>
86	51	3.61	0.51	<b>-5.28</b>
87	53	4.13	0.50	1.35
88	20	-1.71	0.46	1.56
89	66	7.59	0.73	-0.86
90	67	8.20	0.91	-0.12
91	48	2.85	0.48	-1.87
92	42	1.63	0.42	0.08
93	38	0.96	0.40	-1.08
94	43	1.81	0.43	-0.44
95	44	2.00	0.44	0.20
96	36	0.66	0.39	<b>-2.54</b>
97	51	3.61	0.51	<b>-5.28</b>
98	51	3.61	0.51	<b>-5.28</b>
99	52	3.88	0.50	-0.23
100	47	2.62	0.47	-0.99
101	64	6.80	0.58	0.64
102	66	7.59	0.73	-0.07
103	49	3.09	0.49	-0.33
104	51	3.61	0.51	0.23
105	51	3.61	0.51	0.28
106	37	0.81	0.39	-2.10
107	28	-0.43	0.37	-0.66
108	46	2.40	0.46	-1.15
109	60	5.75	0.49	0.75

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*Note.* Fit residuals beyond  $\pm 2.50$  are presented in bold.

**Appendix K-6 Residual correlation matrix of the ITTE scale**

ITTE	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Item	C.C.	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17
1	T1	x	0.23	0.04	0.20	0.07	-0.06	0.15	-0.15	-0.27	-0.14	-0.20	-0.22	-0.33	0.00	-0.09	0.00	-0.17
2	T2		x	0.25	0.07	0.06	-0.14	0.26	0.00	-0.09	-0.24	-0.23	-0.29	-0.12	-0.04	-0.16	-0.07	-0.09
3	T3			x	0.22	0.08	-0.05	0.22	0.05	-0.10	-0.13	-0.06	-0.18	0.01	-0.18	-0.10	-0.21	-0.31
4	T4				x	0.16	-0.23	0.18	0.07	-0.17	0.00	-0.25	-0.30	-0.05	0.10	-0.13	-0.07	-0.22
5	T5					x	-0.14	0.10	0.10	0.19	-0.06	-0.26	-0.12	-0.04	-0.19	-0.26	-0.19	-0.11
6	T6						x	-0.28	-0.18	-0.07	-0.12	0.25	0.03	-0.33	-0.07	0.00	0.05	-0.08
7	T7							x	0.10	0.05	-0.08	-0.18	-0.22	0.05	-0.10	-0.28	-0.33	0.01
8	T8								x	0.26	-0.12	-0.08	-0.20	0.14	-0.07	-0.18	-0.19	-0.02
9	T9									x	0.06	-0.07	-0.10	0.11	-0.22	-0.01	-0.21	-0.04
10	T10										x	0.30	0.15	-0.16	-0.08	-0.13	-0.02	-0.15
11	T11											x	0.24	-0.25	-0.19	-0.31	0.04	-0.10
12	T12												x	-0.04	-0.21	-0.13	0.04	0.02
13	T13													x	0.07	0.16	-0.06	0.02
14	T14														x	0.31	-0.16	-0.11
15	T15															x	0.00	-0.07
16	T16																x	0.09
17	T17																	x

**Appendix K-7: Analysis of variance of residuals for the test of DIF between subjects in ITTE scale**

Item	Class interval (CI)		Gender (PF)		Subjects by CI	
	F (df=2)	p <	F (df=1)	p <	F (df=2)	p <
1	0.921	0.402	0.254	0.616	2.535	0.084
2	2.499	0.087	0.054	0.816	0.235	0.791
3	0.031	0.970	1.267	0.263	6.052	0.003
4	0.656	0.521	4.388	0.039	1.139	0.324
5	0.149	0.861	0.079	0.780	0.861	0.426
6	1.804	0.170	2.966	0.088	-0.382	1.000
7	3.528	0.033	0.656	0.420	1.823	0.167
8	7.284	0.001	1.394	0.241	3.281	0.042
9	0.359	0.699	0.110	0.741	0.748	0.476
10	1.445	0.241	0.114	0.736	0.701	0.499
11	1.316	0.273	5.448	0.022	3.987	0.022
12	1.360	0.261	0.546	0.462	-0.056	1.000
13	1.659	0.196	5.076	0.026	-0.476	1.000
14	0.336	0.715	0.281	0.597	1.042	0.357
15	0.894	0.412	5.685	0.019	2.001	0.141
16	0.310	0.734	0.393	0.532	-0.021	1.000
17	2.293	0.106	2.692	0.104	2.787	0.066

*Note.* number of class intervals = 3; Bonferroni adjusted  $p$  value = 0.0005; \*\*\* represents significant  $p$  value

**Appendix K-8: Analysis of variance of residuals for the test of DIF between years of teaching experience in ITTE scale**

Item	Class interval (CI)		Years of teaching experience (PF)		Years of teaching experience by CI	
	F (df=2)	$p <$	F (df=4)	$p <$	F (df=8)	$p <$
1	0.986	0.377	2.133	0.083	1.642	0.124
2	2.415	0.095	0.166	0.955	0.693	0.696
3	0.028	0.972	1.795	0.137	0.705	0.687
4	0.587	0.558	0.838	0.505	0.149	0.996
5	0.147	0.863	1.791	0.138	0.281	0.971
6	1.824	0.167	0.805	0.525	1.137	0.347
7	3.494	0.035	2.457	0.051	0.312	0.960
8	7.216	0.001	3.074	0.020	0.459	0.882
9	0.353	0.704	0.337	0.852	0.947	0.482
10	1.443	0.242	0.973	0.427	0.815	0.591
11	1.191	0.309	0.763	0.552	1.091	0.377
12	1.555	0.217	0.402	0.806	2.737	0.010
13	1.630	0.202	1.513	0.205	0.657	0.727
14	0.342	0.711	0.688	0.602	1.305	0.252
15	0.797	0.454	0.674	0.612	0.531	0.830
16	0.311	0.733	0.936	0.447	0.751	0.646
17	2.179	0.119	1.592	0.183	0.704	0.688

*Note.* number of class intervals = 3; Bonferroni adjusted  $p$  value = 0.0005; \*\*\* represents significant  $p$  value

**Appendix K-9: Frequencies of the ITEM response to the ITTE questionnaire**

Item No.	Corresponded Indicators	Strongly disagree		2. Disagree		3. Neutral		4. Agree		5. Strongly agree	
		n	%	n	%	n	%	n	%	n	%
1	T1	2	2%	2	2%	19	18%	56	54%	25	24%
2	T2	0	0%	2	2%	18	17%	64	62%	20	19%
3	T3	0	0%	2	2%	13	13%	62	60%	27	26%
4	T4	0	0%	2	2%	16	15%	56	54%	30	29%
5	T5	0	0%	3	3%	20	19%	55	53%	26	25%
6	T6	0	0%	6	6%	39	38%	51	49%	8	8%
7	T7	0	0%	3	3%	20	19%	57	55%	24	23%
8	T8	0	0%	1	1%	13	13%	57	55%	33	32%
9	T9	0	0%	2	2%	22	21%	59	57%	21	20%
10	T10	0	0%	2	2%	26	25%	58	56%	18	17%
11	T11	0	0%	4	4%	24	23%	57	55%	19	18%
12	T12	0	0%	4	4%	23	22%	52	50%	24	23%
13	T13	0	0%	2	2%	17	16%	57	55%	28	27%
14	T14	0	0%	1	1%	17	16%	62	60%	24	23%
15	T15	0	0%	2	2%	17	17%	53	51%	31	30%
16	T16	0	0%	4	4%	17	16%	59	57%	24	23%
17	T17	0	0%	4	4%	20	19%	58	56%	21	20%
<b>Average</b>		0	0%	3	3%	20	19%	57	55%	24	23%

**Appendix K-10: Raw-score-to-ability translation for ITTE scale**

<b>Raw score</b>	<b>Logit score</b>	<b>(continue)</b>	
		<b>Raw score</b>	<b>Logit score</b>
0	-10.83		
1	-10.00	35	0.51
2	-9.39	36	0.66
3	-8.96	37	0.81
4	-8.59	38	0.97
5	-8.27	39	1.13
6	-7.96	40	1.29
7	-7.66	41	1.46
8	-7.35	42	1.63
9	-7.02	43	1.81
10	-6.64	44	2.00
11	-6.18	45	2.20
12	-5.56	46	2.40
13	-4.60	47	2.62
14	-3.72	48	2.85
15	-3.17	49	3.09
16	-2.77	50	3.35
17	-2.45	51	3.61
18	-2.17	52	3.88
19	-1.93	53	4.14
20	-1.71	54	4.38
21	-1.51	55	4.62
22	-1.33	56	4.85
23	-1.16	57	5.08
24	-1.00	58	5.30
25	-0.85	59	5.52
26	-0.71	60	5.75
27	-0.57	61	5.98
28	-0.44	62	6.23
29	-0.30	63	6.50
30	-0.17	64	6.80
31	-0.04	65	7.15
32	0.09	66	7.59
33	0.23	67	8.20
34	0.37	68	9.07