Chapter 3
The Current Status of Science Teachers' TPACK in Taiwan from Interview Data

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Teachers' knowledge about technology-infused instruction has recently attracted much research attention. This chapter focuses on science teachers' technological pedagogical and content knowledge (TPACK) in the practical context of teaching, namely, TPACK-Practical (TPACK-P). The proposed framework of TPACK-P includes three major domains—assessments, planning and designing, and teaching practice—that are theoretically transformed from the perspectives of pedagogical content knowledge (PCK). To explore science teachers' TPACK-P, 40 in-service teachers were interviewed, and a coding scheme was developed to analyze the interview responses. The findings indicated that the science teachers generally know how to adopt technologies in teaching within each domain of TPACK-P. A cluster analysis based on the participants' level of TPACK-P categorized their patterns of knowledge. Three groups of science teachers emerged from these analysis categories: infusive application, transition, and plan and design emphasis. The infusive application group represents science teachers with sophisticated levels of TPACK-P across the three domains; the transition group includes science teachers whose knowledge achieved average levels across the three dimensions. However, the plan and design emphasis group refers to the science teachers who were more knowledgeable about planning and designing technology-infused teaching than about the assessment and teaching practice domains. The overall results indicate that the knowledge of planning and designing may be a more independent part in TPACK-P that supports science teachers' implementation of technology-infused teaching. The revealed patterns of these science teachers' TPACK-P may provide the groundwork

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for developing instruments to evaluate science teachers' competence in teaching with technologies.

3.1 Introduction

In past decades, educational reforms involving information and communication technologies (ICTs) have changed the context of science classrooms worldwide (Lee et al., 2011; Linn, 2003). ICTs have modernized knowledge communication in science education and expanded learning approaches such as collaborative learning (Mäkitalo-Siegl, Kohnle, & Fischer, 2011; Suthers, 2006), inquiry-based learning (Edelson, 2001; Linn, Clark, & Slotta, 2003), project-based learning (ChanLin, 2008; Krajcik, McNeill, & Reiser, 2008), problem solving (Kim & Hannafin, 2011; Serin, 2011), and informal learning environments (Anastopoulou et al., 2012; Ebner, Lienhardt, Rohs, & Meyer, 2010). Regardless of the type or amount of technology applied in classrooms, teachers are still the key to facilitate educational reform with ICTs. Several calls about technologies in science teacher education have revealed the need for deeper investigations of teachers' competence to design and conduct effective technology-enhanced instruction (Angeli & Valanides, 2005, 2009; Lin, Tsai, Chai, & Lee, 2013). Moreover, much of effective technology-enhanced instruction involves practical knowledge regarding how a teacher makes sense or establishes application of ICTs in classrooms. This chapter focuses on the current state of Taiwanese science teachers' competence with ICT from a practical perspective.

3.1.1 The Role of TPACK

Teacher educators and policy makers have tried to establish norms for teachers' knowledge about effective teaching and classroom practices (Ball, Thames, & Phelps, 2008). In recent years, technological pedagogical and content knowledge (TPACK) has been addressed to portray teachers' competence to teach in technology-infused environments (Lin et al., 2013; Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013). For example, Mishra and Koehler (2006) used notions of pedagogical content knowledge (PCK; Shulman, 1986, 1987) to develop an integrative model illustrating the intersections of content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) to represent teachers' knowledge about discipline-specific teaching with ICTs. Researchers have also tried to identify and to measure teachers' TPACK using varied methods such as questionnaires (Archambault & Crippen, 2009; Lee & Tsai, 2010; Schmidt et al., 2009), tests (Angeli & Valanides, 2009; Kramarski & Michalsky, 2010), and interpretative interviews (Jimoyiannis, 2010; Niess, 2005). These results have established TPACK as a trustworthy construct and the basis for evaluation of teacher professional development.

Theoretically, TPACK refers to the knowledge about teaching academic contents of a specific discipline with ICTs. Therefore, science teachers' TPACK may be divergent in nature, which will be apparent, while teachers plan, enact, and evaluate lessons in different subject domains and classrooms. Previous empirical studies have found that science teachers' perceived TPACK was distinct from teachers with dissimilar academic expertise (Lin et al., 2013). Current TPACK-related research on science teacher education has mainly employed Mishra and Koehler's (2006) model of TPACK and has investigated internal components of the knowledge system (Jimoyiannis, 2010). However, it is necessary to investigate teachers' knowledge from a practical context situated in science classrooms to document how the PCK is transformed into TPACK (Angeli & Valanides, 2009; Graham, 2011). From this emerges the need to establish a comprehensive foundation for improving contemporary science teacher education based on the TPACK rationale.

3.1.2 TPACK in Science Teacher Education

Science teacher education has emphasized the need to apply general pedagogical ideas to the specific demands and contexts of learning science at different school levels. Most science teacher education programs assume that preservice teachers on one hand acquire their science content knowledge from coursework in the academic science department. On the other hand, they develop general pedagogical knowledge from education and educational psychology coursework. Such teacher education models assume that science curricula and instruction coursework as well as clinical experiences will help preservice teachers integrate their academic science and general PK into discipline-specific PK. This knowledge, called PCK, is deemed a crucial part of teachers' competence in successful science teaching. How well science teachers integrate science content and their teaching experiences into their PCK has been questioned because the theory–practice gap continues to exist. The conversion of theoretical knowledge into teaching practices appears to be a career-long process or struggle for teachers, which involves transforming as well as integrating CK and PK into PCK.

Science educators have expressed a consensus that ICTs bring great impacts to learning and teaching in science, but merely emphasizing either computer skills or pedagogy in teacher education has little benefit in preparing teachers to adequately and effectively utilize technology in their careers (Hughes, 2005; Keating & Evans, 2001; Parkinson, 1998). Like *the song remains the same* addressed by Mishra, Koehler, and Kereluik (2009), teacher educators still seek ways to enhance teachers' capability with technology. Consequently, a burgeoning consensus of teacher knowledge about teaching with technology, namely, TPACK, has more recently inspired teacher educators and researchers (Koehler & Mishra, 2005; Niederhauser & Stoddart, 2001; Web & Cox, 2004). TPACK—formerly the acronym TPCK (Thompson & Mishra, 2008)—provides a valuable framework on which to determine whether a teacher is able to effectively design and conduct technology-infused instruction (Angeli & Valanides, 2005; Mishra & Koehler, 2006). Angeli and Valanides (2009) suggested that teachers with sufficient TPACK may gradually understand the specifics of technological tools with regard to the relationships among technological tools, instructional designs, contents, student characteristics, and teaching contexts.

TPACK has attracted teacher educators' attention and focus on the issues associated with teachers' utilization of ICT in classrooms. Searching academic databases indicates that TPACK was, and still is, a hot topic in the field of educational technology and teacher education (Chai, Koh, & Tsai, 2010; Voogt et al., 2013). TPACK is deemed as having the potential to recognize and predict how teacher educators' interventions affect teachers' competence from a knowledge perspective (Graham, 2011). Moreover, a successful teacher with sufficient TPACK may be able to develop proper strategies and representations to accomplish fruitful teaching with technology.

Teachers' practical knowledge refers to how well teachers understand and apply their professional activities in the teaching context (van Driel, Beijaard, & Verloop, 2001). A similar theory–practice gap exists for TPACK: the knowledge that is directly associated with teachers' practical experience of teaching with ICTs (Graham, 2011). The integrated model of TPACK seems insufficient to explain the process of how teachers build knowledge about using ICT in science teaching contexts (Angeli & Valanides, 2009). Intrinsic influence from teaching context to TPACK is still vague in the model (Angeli & Valanides, 2009). Therefore, we adopt an extended model of TPACK-P (Yeh, Hsu, Wu, Hwang, & Lin, 2014) to unveil the struggle and status of science teachers' practical knowledge in a technology-infused teaching context and to clarify specific features of TPACK-P regarding the domains of assessment, planning and designing, and teaching practices.

This chapter draws on the recently proposed framework of TPACK-P (Yeh et al., 2014) to document science teachers' knowledge about teaching with technologies. In order to concisely identify the patterns of such an extended form of TPACK from in-service science teachers, we reorganized the original framework into three major domains of TPACK. Hence, we endeavor in this study to clarify science teachers' TPACK-P from how they know about (a) conducting assessment with ICTs, (b) planning and designing teaching with ICTs, and (c) processing practical teaching activities with ICTs. Teachers with well-developed TPACK-P are likely to make effective use of technologies in knowing their students with assessments (Jang & Tsai, 2012), in presenting contents with pertinent planning and design (Lundeberg, Bergland, Klyczek, & Hoffman, 2003; Niess, 2005), and in dealing with classroom management (Graham, 2011; Koehler, Mishra, & Yahya, 2007). Hsu, Wu, and Huang (2007) adopted Sandholtz, Ringstaff, and Dwyer's (1997) suggestion to classify science teachers into five stages (i.e., entry, adoption, adaption, appropriation, and invention) when utilizing technological tools in instruction. Although their survey results showed a hierarchy of science teachers' professional activities with ICTs, there is still a lack of evidence to reveal the features of teachers' TPACK knowledge within these five stages. Hence, this chapter reports science teachers' TPACK-P in terms of their authentic teaching experiences based on interview data.

3.2 Revealing Science Teachers' TPACK-P

In order to reveal science teachers' TPACK-P, we adopted the rationale that science teachers' PCK is transformed during its application in a technology-infused context into TPACK-P. First, we explored science teachers' knowledge about conducting assessments with ICTs, that is, using ICTs to know more about students, identify students' learning difficulties, assist different characteristics of learners, know the types of technology-infused assessment approaches, identify the differences between technology-infused assessments and traditional assessments, and utilize e-assessments for detecting students' learning progress. Second, we identified science teachers' TPACK-P about instructional planning and designing by investigating their ICT uses to better understand subject contents, identify the topics that can be better presented with ICTs, use appropriate ICT representations to present instructional contents, and apply appropriate teaching strategies in ICT-infused instructions. Third, we investigated science teachers' TPACK-P about teaching practices with regard to their use of ICTs to indicate differences between traditional and ICT-infused instruction, indicate the influences of different ICT instructions, indicate substitute plans for technology-infused instruction, and facilitate instructional management. In summary, this chapter presents how we investigated science teachers' TPACK-P in Taiwan.

3.2.1 Methods to Reveal Science Teachers' TPACK-P

A mixed methods approach (Creswell, 2008; Creswell & Plano Clark, 2011) was applied to explore and interpret the participating science teachers' TPACK-P regarding the three domains: assessment, planning and designing, and teaching practice. Furthermore, we categorized science teachers based on their TPACK-P using a cluster analysis technique.

The current investigation recruited participants with different academic majors, teaching experience, and experience of winning educational awards for technology-infused instruction. Forty in-service science teachers in northern Taiwan were purposefully selected. The authors acquired each science teachers' permission to participate through private invitations by a telephone call or email. Although these science teachers' experiences of teaching with ICTs varied, all of them had participated in professional development programs focused on technologies in science instruction. Furthermore, we invited only those teachers who had taught science in high school for more than 5 years to ensure that they had enough experience in teaching science with ICTs.

Semistructured interviews were employed as the major approach to collect data about these science teachers' TPACK-P. A group of science educators (three professors, one postdoctoral researcher, and two doctoral students) developed the interview protocol through panel meetings and went through several roundtable discussions to ensure that the questions were appropriate to probe for science teachers'

TPACK-P. The interviews were first administered to several science teachers as pilot trials to validate the interview process (Guba & Lincoln, 1989) and to eliminate inappropriate questions. The interview questions are provided in the Appendix of this chapter.

The semistructured interviews were conducted by a postdoctoral researcher and two doctoral students; each interviewer was familiar with semistructured interview techniques. All participants agreed with audiotaping the interview. The interviews took 40–60 min. It is worth noting that the interviewers tried to avoid yes/no responses by asking follow-up elaboration and clarification questions unless the participant indeed had no idea about the question.

3.2.2 Analysis of Science Teachers' TPACK-P

The audiotaped interviews were transcribed as verbatim texts. Transcriptions with ambiguity were returned to interviewees for verification and clarification. Thereafter, we analyzed the interview transcriptions simultaneously with thematic coding (Flick, 2002) and axial coding (Strauss & Corbin, 1990) approaches. First, all responses were aggregated to comprehensively summarize all features of science teachers' TPACK-P and then classified into thematic categories in accordance with Sandholtz et al.'s (1997) five stages of practical teaching with technologies (i.e., entry, adoption, adaption, appropriation, and invention). However, we encountered difficulty in fitting part of the TPACK-P features into the preliminary categories; for example, in the entry stage, "lack of use of technology in teaching" was not clearly differentiated from "no idea of technology application."

Therefore, we applied constant comparative methods to reinspect the levels of TPACK-P. We performed axial coding repeatedly to reveal similarities and discrepancies in interview narratives and, thus, refine the categorization. After several discussions to specify the levels, the final thematic coding categories were reformed into five categories for assessment, planning and designing, and teaching practice (Table 3.1). The categories were defined as:

- 0—No idea—represents teachers without any notion of technological application in teaching; for example, they are not conscious of using an audience response system (Kay & LeSage, 2009) to diagnose students' learning
- 1—Lack of use—represents situations that teachers simply expressed their understanding of ICTs for instruction (e.g., computer-supported, collaborative learning environment) but did not make use of it in their classes
- 2—Simple adoption—represents teachers' ICT usage in teaching without the statements related to the purpose, employment, or effect of applying ICTs
- 3—Infusive application—represents teachers' successful integration of ICTs in teaching while they clearly describe the purpose, employment, and effect of their integration

Table 3.1 Coding categories of TPACK-P and examples of category components

Domain	Assessment	Planning and designing	Teaching practice
Level 0—no idea	Never consider the possibility of using technologies in assessment	Never consider any instructional goal for technology-infused teaching	Never consider the difference between technology-infused and traditional teaching practice
	Have no idea about technological tools for assessment such as audience response system	Have no idea about proper technological representation applied in teaching	Have no idea about the effects that different technological tools can bring to teaching practice
	Not able to differentiate technology-infused and traditional assessment	Have no idea about teaching strategy for technology-infused teaching	Have no idea about applying technology to support instructional management
Level 1—lack of use	Indicate the lack of useful hardware or software to conduct assessment	Indicate that time consuming in course preparation leads to the lack of using technologies in planning and designing teaching	Indicate the avoidance of using ICTs in teaching practice based on various reasons
	Indicate that technologies are main supplement of classroom lecture rather than useful tools for assessment	Indicate that traditional lecture is much more important than technology-infused teaching	Indicate the application of technologies in instructional management gives rise to extra teaching loading
	Indicate that technology-infused assessment may be unfair	Indicate no need for making use of specific strategy for technology-infused teaching	Indicate the worry about risks that derive from practical teaching with technologies
Level 2—simple adoption	Simply mention the application of technologies to know students' comprehension of science phenomena	Simply mention why some learning units are suitable for using technology-infused teaching	Simply mention how technological tools impress students in teaching practice
	Simply mention the usage of online assessment, online questionnaire, or audience response system	Simply mention the limitation in planning and design that may be influenced by physical environment of classroom or students' responses	Simply mention the comparison of instructional aids in technology-infused and traditional teaching practice
	Simply mention the characteristics of technology-infused assessment	Simply mention useful teaching strategies (not specified) for enhancing students' motivation, engagement, and concentration	Simply mention the usage of software in instructional management

(continued)

Table 3.1 (continued)

Domain	Assessment	Planning and designing	Teaching practice
Level 3—infusive application	Describe the process of applying technological tools in conducting assessment	Describe the process of getting better understanding of academic content and teaching strategies by using technologies	Describe how technology-infused teaching especially supports learning of students who get lower achievement in traditional teaching context
	Describe in detail the process of using online assessment, online questionnaire, and audience response system to know students' ideas	Describe the integration of technologies in teaching planning and design to support students' scientific processes such as data collection, analysis, and presentation	Describe what effects that different technological tools may bring to teaching practice
	Describe the process of using technologies to know students' difficulties or alternative conceptions in learning science	Describe in detail about how to apply a specific strategy, such as computer-supported collaborative learning in planning and designing teaching	Describe in detail about the process of using technological tools to deal with instructional management
Level 4—self-evaluation	Describe how technologies can enhance traditional assessment with a more adaptive and interactive manner	Describe the reflection of successful or fruitless experience about planning and designing technology-infused teaching	Describe the reflection of advantages of technological tools that make changes in traditional teaching practice
	Describe why technology-infused assessment is better for understanding students' alternative conceptions of science	Describe the ability that a teacher shall have to efficiently integrate technologies in planning and designing technology-infused teaching	Describe multiple substitutions for possible contingency in technology-infused teaching practice
	Describe one's own experience of using technology-infused assessment and hence self-evaluate the relevant competence and possible improvement of teaching	Describe the adaptive adjustment of strategies to fit in with instructional goal of technology-infused teaching	Describe the necessity to self-evaluate application of technological tools in instructional management

- 4—Self-evaluation—represents teachers who expressed their knowledge of examining and regulating their teaching with ICTs (e.g., evaluating the design of technology-infused approaches compared to conventional teaching) to meet students' needs

The final coding themes and categorized features of TPACK-P summarized in Table 3.1 were utilized to code participants' responses to all interview questions. Since the responses might be partially categorized into different levels of TPACK-P, we deemed that the higher level might present a more sophisticated view of the teacher's TPACK-P for that question. Therefore, we assigned an achieved level to the responses for each interview question. The overall agreement of two coders achieved 0.96 and indicated a congruent coding process. Subsequently, we performed cluster analysis (Lorr, 1983) with hierarchical clustering technique on the labeled interview responses to group the participants with similar patterns of TPACK-P. In order to illustrate the pattern of these groups of science teachers' TPACK-P, both qualitative and quantitative analyses were conducted. The qualitative findings were based mainly on the interpretations of interview data; the quantitative analyses examined if the groups of teachers showed statistical difference in the three domains of TPACK-P. Due to the concerns for small sample size and the ordinal nature of the data, we applied a nonparametric statistical analysis to identify the difference, namely, a Kruskal–Wallis one-way analysis of variance (ANOVA) with a post hoc Dunn's test.

3.3 Characteristics of Science Teachers' TPACK-P

According to the analyses of descriptive statistics of the coding results on a 0–4 scale, the mean levels of participants' TPACK-P were ($n = 40$): overall, $M = 2.63$, $SD = 0.37$; assessment, $M = 2.57$, $SD = 0.60$; planning and designing, $M = 2.77$, $SD = 0.45$; and teaching practice, $M = 2.49$, $SD = 0.52$. These results implied that the Taiwanese science teachers in this investigation showed an above midrange (2.00 on a 0–4 scale) degree of competence about teaching with ICT integration. At the least, these teachers were capable of stating in general how they adopt technologies in teaching based on their experiences. Inspection of the individual response values

Table 3.2 Descriptive statistics of science teachers grouped by TPACK-P

	Group					
	1–Infusive application ($n = 18$)		2–Transition ($n = 10$)		3–Plan and design emphasis ($n = 12$)	
Domain of TPACK-P	*M*	*SD*	*M*	*SD*	*M*	*SD*
Assessment	2.94	0.48	2.58	0.50	2.00	0.40
Planning and designing	2.99	0.37	2.41	0.49	2.73	0.32
Teaching practice	2.75	0.48	2.40	0.58	2.17	0.34

indicated variation around the means and performance patterns across the three domains; therefore, further analyses were justified.

The cluster analysis successfully categorized the teachers into three groups in terms of their pattern of coded response levels for all interview questions (Table 3.2). We then interpreted the patterns and described these three groups based on the three domains of science teachers' TPACK-P as follows. First, a group of 18 teachers demonstrated higher and balanced levels in each domain of TPACK-P that approximated level 3—infusive application; we identified this group as "infusive application, IA," for further discussion. Second, the mean level of a group of 10 teachers demonstrated lower levels but balanced performance across the domains of TPACK-P compared to the IA group; their response levels were near to the overall mean value. We identified this group as "transition, TR." Last, a group of 12 teachers showed a thoroughly different pattern of TPACK-P levels: a fairly high mean level in the planning and designing domain and noticeably lower levels in the other two domains than the IA and TR groups. We identified this group as "plan and design emphasis, PD."

The results of Kruskal–Wallis one-way ANOVA indicated that the PD group had a significant ($p < 0.001$) main effect across the three TPACK-P domains, but there were no significant main effects for the IA ($p = .18$) and TR ($p = .88$) groups. Based on the results for the PD group, a series of pairwise comparisons were used on the domains using the Dunn's test. The post hoc Dunn's tests revealed that the PD group achieved significantly higher levels in planning and designing than the other two domains (plan and design vs. assessment, $p < .01$; plan and design vs. teaching practice, $p < .05$). These results suggest that these teachers' knowledge about assessment and teaching practice were more similar domains within their TPACK-P and that these two domains are directly related with actual implication of technologies in instruction. Furthermore, the planning and designing competence of these teachers may be a more independent domain and, therefore, have less influence on predicting their teaching implementation. However, such an assertion may need further support and exploration.

Generally, the IA group achieved higher levels because these teachers tended to think about teaching practice with technologies with greater consideration of students' needs. For example, one might consider the possibility to overcome the limits of traditional assessments (i.e., tests with paper and pencil) by applying technologies. Exemplar responses from the interviewees follow:

> T23: Tests with paper and pencil can also estimate [students'] affections or something, right? But in fact, this part will be exhausting [on paper and pencil tests]. With technology, not only for [more learning] time, it can present [the assessment] in more [and] different manners. In that way, [students] can [have] his/her own way to answer. For example, someone likes a movie clip, someone likes an animation or something. The animation may replace a large number of words in the test, especially when the wording [in the tests] was [difficult]. In that way, we may make students realize the assessment [can measure] their achievement more precisely.

Some other teachers criticized the overemphasis on rehearsing factual knowledge in traditional assessments. Instead, they highlighted the possibility that technologies can contribute to alternative ways of assessment:

> T15: If you really focus on students' development of science literacy, you can never simply aim at their ability to solving questions in an examination. Moreover, students need to develop some practical competence, such as observation of natural phenomena, operating scientific equipment, and so forth. It is not possible to use paper and pencil tests to probe these competencies [of students]. But technological tools such as manipulative simulations in earth science can help you observe the students' operational skills. You can even track their process of thinking by examining the log file recorded in the software.

The student-centered idea was also reflected in how these science teachers designed the technology-embedded teaching. The availability for learning with technology may be first emphasized when planning and designing teaching. The teachers who achieved the highest level (coded as 4—self-evaluation) in the assessment domain also responded with student-centered ideas about designing software that focused on learning:

> T23: [In designing teaching,] I will first consider whether this tool is proper or not, as well as if students have corresponding equipment to use in learning, like e-schoolbag [mobile learning equipment] or something. As a result, when the teacher designs some learning software [that is] only available or executable on some platform or browser, this may detract from students' participation. We should consider other tools or interface [to avoid] falling into such situations.
>
> T12: [In designing teaching] what I really care about is the diversity of students, especially from the perspective of motivation and engagement. Designing and integrating a technology-embedded curriculum can help me attract students with lower motivation that possibly resulted from lower cognitive ability. As to students with high academic achievement, the technological tools about science learning, such as some apps for the iPad that they seldom make use of in daily life, may trigger their curiosity and enthusiasm to explore the relevant scientific knowledge.

The IA group teachers clearly defined the manner to manage the interactions with students, such as online communications. The following quotes provide a glimpse of a teacher's idea that related to his knowledge about implementation as well as planning and designing teaching:

> T23: We may not apply this [online communication] in normal class. To me, if you want to establish a blog or forum, you must spend time to maintain it. Yes, I am sure such kind of communication is the teachers' responsibility. Furthermore, the administrator [the teacher] must be good at organizing students' statements, discussion and reveal the answers from different viewpoints. For now, I don't think there is a good platform for doing this. Facebook may be a possibility, but for most situations students may just chat, [using a] kind of instant communication [that is] hard to use for learning purposes.

In contrast, the TR group teachers reflected more of a teacher-centered perspective about TPACK-P:

> T17: Utilizing technologies in assessment is simply making the test like a game.
>
> T33: Students still need to experience the calculation in tests, somehow just with a more funny way.

T6: I will not imagine that technology is able to provide significant assistance for summative evaluation because this involves the problematic equity of testing with technologies.

These opinions might inhibit them from knowing more about what technology can do when evaluating both students' achievement and their own instruction. Moreover, these teachers presented some arbitrary ideas about adopting technologies in instructional planning and designing. Their responses to the interview questions were, therefore, coded at a lower level (2—simple adoption) of TPACK-P. For example, one teacher appeared to be subjective about indicating the factors that might influence technology-embedded instruction:

T17: [The critical factor will] be hardware. This is a quite common problem among us [science teachers].

I: Yes, hardware, then what are the other factors?

T17: We must rely on chalk and talk for most situations. Because the planning of such kind of teaching is more flexible. Even though we know how to use PowerPoint to teach, but I am just not getting used to [it]. I have no flexibility of control when I am inspired by something about expanding my teaching designs.

The PD group of teachers presented a different pattern of responses. These teachers tended to be knowledgeable about planning and designing teaching with technology. However, they hold less sophisticated knowledge about applying technologies in assessment and teaching practice:

T4: I am traditional about assessment because paper and pencil test is the most efficient way of testing in my [learning] experience.… I am not familiar with the computer classroom in school, and I am not using any special technological tools in my teaching, even for making use of the Internet.

On the contrary, she could address why technology was important to satisfy instructional goals and needs in planning and designing:

T4: When you cannot situate your students in the real-world context, technology can be a good alternative. For example, you can never have your students experience all kinds of ecosystems or see all kinds of animals live when you introduce taxonomy. It is also difficult to help your students understand a complex physiological process such as blood circulation with verbal explanations. These are the most important reasons that we need computers in instruction.

These findings indicate that the participating science teachers indeed hold varied TPACK-P, even though they may be capable of adopting technology in teaching. The qualities and patterns of TPACK-P can be used to characterize science teachers' TPACK. These findings provided insights into the development of research tools for probing teachers' TPACK, while the estimations of TPACK in recent research were based mostly on self-reported perceptions of such knowledge (Archambault & Barnett, 2010; Schmidt et al., 2009; Yurdakul et al., 2011). Objective evaluations of teachers' professional development and knowledge, such as TPACK, may be an immediate indicator of success or failure of policies administered in teacher education. The findings in this research may inform both teacher educators and stakeholders with a practical direction of developing objective evaluation of science teachers' TPACK.

Still, it is worth noting that many of these teachers met difficulty in responding to some interview questions of the planning and designing domain, even though they presented the highest mean level (2.77) in this part. Almost a quarter (9 of 40) of the participants had no idea about naming and describing a proper strategy to apply technology in planning and designing their teaching. Teacher T25, for example, when asked about describing the strategies she used in instructional design, could only reply that she used technology throughout the teaching process but was unable to indicate the specific strategies applied. She could, however, clearly describe both the topics and technological tools that are suitable for technology-embedded instruction based on her successful classroom experiences. The unfamiliarity with instructional strategies of these participants may imply that science teachers seldom emphasize the educational theories and evidence-based practices applied in their teaching. Instead, their ideas about planning and designing may rely heavily on their teaching or learning experiences.

Previous psychological research has addressed the influence of successful mastery experience over psychometric features about teaching, such as science teaching self-efficacy (Klassen, Tze, Betts, & Gordon, 2010; Lumpe, Czerniak, Haney, & Svetlana, 2012) as well as attitudes and epistemic beliefs (Hofer, 2000; Palmer, 2002). Successful teaching experience is deemed as the most important source contributing to teachers' confidence in accomplishing a specific instructional task, such as teaching with technologies. Furthermore, such experience may affect teachers' beliefs that shape their TPACK-P. These findings suggest that teacher educators should pay more attention to how science teachers acquire mastery experience in future professional development programs regarding their individual characteristics and needs.

3.4 Concluding Remarks

This chapter examined science teachers' practical knowledge about teaching with technology through interviewing different science-subject teachers. Based mainly on their responses, we concluded the construct of TPACK-P acts as a serviceable framework that recognizes science teachers' knowledge about applying technologies in respect of assessment, planning and designing, and teaching practices. The current status of these Taiwanese science teachers' TPACK-P revealed a triad that indicated they presented an unbalanced combination of the three domains of TPACK.

Moreover, the findings provide preliminary value for future development of assessment tools that are reliable for evaluating science teachers' TPACK-P. This may also provide insights for estimating the effect of professional learning on both in-service and preservice science teacher education. In order to establish the standard to assess science teachers' TPACK-P, there is still a need for more comprehensive evidence sources. Research findings from different social or cultural contexts, approaches other than qualitative settings, as well as participants with diverse teaching experience (e.g., preservice teachers) may contribute to understanding teachers' overall TPACK and the patterns of their TPACK-P.

Knowledge of instructional planning and designing may be partly independent of knowledge about implementation of instruction with regard to assessment and teaching practices. This implies a direction for future investigations to reveal science teachers' other characteristics that may affect their TPACK-P, such as beliefs about science teaching (Lumpe et al., 2012) and conceptions of science teaching (Yung, Zhu, Wong, Cheng, & Lo, 2013). The findings provided in this chapter suggest that science teacher educators and policy makers should conduct programs of improving science teachers' TPACK-P based on technology affordance that address the needs of teaching and learning within the current educational milieu.

Appendix: Interview Questions

Assessment Domain

1. How does technology help you realize students' individual differences?
2. How does technology help you realize students' characteristics of learning?
3. How does technology help you recognize students' difficulties about learning?
4. Can you provide some examples of using proper technological tools to afford different students' learning?
5. Is there any other way that can help you make use of adaptive technologies to assist students' learning?
6. Do you know technology-infused assessment?
7. Have you ever used technological tools to conduct assessment?
8. Can you design technological tools (including hardware and software) for assessment?
9. Can you recognize the difference between technology-infused assessment and traditional assessment?
10. How do technologies help you in formative assessment? How do technologies help you in summative assessment?

Planning and Designing Domain

1. How do you apply technologies to improve your understanding about academic content in teaching?
2. Is technology-infused teaching especially suitable for some academic content in teaching? Why?

3. What factors will affect your technology-infused teaching when you try to conduct planning and designing such teaching? How do you deal with these possible factors?
4. What goal do you have when you conduct planning and designing technology-infused teaching? How do you follow the goal?
5. Have you ever collected teaching materials by using ICTs? Can you provide some examples?
6. Will you prepare any substitutes when you conduct planning and designing technology-infused teaching? Can you provide some examples?
7. In planning and designing technology-infused teaching, how do you choose suitable technological tools to present your teaching? What about this in varied learning context such as normal classroom and laboratory? Can you provide some examples?
8. In planning and designing technology-infused teaching, is there any suitable teaching method or teaching strategy? Why?
9. What will you expect about your students' responses while you apply suitable teaching method or teaching strategy in technology-infused teaching?

Teaching Practice Domain

1. In your teaching experience, how does technology affect your course proceeding? Is there any difference when there is no technology infused?
2. In your teaching experience, how does technology affect your students' learning performance? Is there any difference when there is no technology infused?
3. In your teaching experience, how does technology affect your students' motivation? Is there any difference when there is no technology infused?
4. In your teaching experience, have you ever applied technological tools with varied characteristics to support course proceeding? How do these tools affect your teaching?
5. In technology-infused teaching, how do you deal with the contingency of hardware and software? What will you do if the contingency delays your teaching schedule?
6. Do you know any technological tools for instructional management? Can you provide some examples based on your teaching experience?
7. What is the advantage of applying technologies in instructional management? What about disadvantages?

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