

# Teachers' Cognitive Processes from the Perspective of Distributed Cognition: An Analysis Focused on Teachers-Made Assessments

Chin-Tu Liang

Principal, Yu-Sin Elementary School, Changhua County

Adjunct Professor, Graduate Institute of Education, National Chung Cheng University

## Abstract

Few studies deal with how the gap between artifacts and task in terms of members' cognition distributed (Halverson & Clifford, 2006) in the field of teaching practice. The present study explored how the teachers' cognition evolved with a close look at the artifact, and the processes adopted by "Two-Way Specification Table" (TWST) for teachers-made assessments as an artifact designed for nine students' tests in "SiSi" Elementary School. Participatory observation, interviews, and documents were employed. The following conclusions were drawn: Firstly, after the implementation of TWST in SiSi Elementary School, teachers had produced 13 kinds of cognitive systems respectively. Secondly, during the process of implementing TWST, teachers gradually presented different stages of cognitive systems such as questioning, reflection, transformation, and creativity. Moreover, continuous discussions and sharing, the need for experts' assistance, developing the technological systems, and the positive attitude of principal were key elements in the functioning of the TWST. Lastly, after the implementation of TWST in SiSi Elementary School, it was found that teachers' cognitive systems were slightly improved.

**Keywords:** artifact, cognitive process, distributed cognition, teachers-made assessment, Two-Way Specification Table



# 分布認知觀點的教師認知歷程： 以教師自編評量為分析焦點

梁金都 彰化縣育新國小校長、國立中正大學教育學研究所兼任助理教授

## 摘要

本研究主要是採取個案研究法，並選取「西西」國小（化名）為研究個案，且以該校實施「雙向細目表」的教師自編評量為中介物，透過了觀察和訪談與文件分析等方法，蒐集 11 位研究參與者與該表持續交互影響的實地資料，以了解教師們的認知歷程。最後本研究獲致了以下結論：一、西西國小實施雙向細目表後，教師們分別產生了十三種認知系統。二、雙向細目表的歷程，教師們漸次呈現質疑、反思、轉向、創新等不同的認知階段。三、持續地討論與分享、需要專家協助、科技系統引入、校長積極推動的態度等，乃是發揮雙向細目表功能的關鍵因素。四、西西國小實施雙向細目表，教師們的認知系統大致呈現朝向上升方向發展。

關鍵詞：人造物、認知過程、分布認知、教師自編評量、雙向細目表



## Introduction

The transform and development of teachers' thinking, especially about their teaching activities, is closely related to the students' learning outcomes in the day-to-day running of school (Firestone & Riehl, 2005). Liang and Hung (2011) point out that teachers' thinking and behaviors are transformed or evolved and even make more consistent with each other by way of continuous sharing and discussing about teaching issues among them in the school. With it, when teachers converse and discuss with other colleagues about teaching practice, they can not only collaborate with each other but also achieve the teaching tasks in school (Allison, 1996; Catano & Stronge, 2006). From the perspectives of school leadership, for upgrading the qualities of students' learning, principals should understand various cognitions about teaching issues among teachers and provide more and more opportunities for their professional learning activities in teachers' professional learning communities through continuous interactive processes for teaching skills and professional knowledge (Liang & Lin, 2013).

Individuals' cognitions are distributed in situations and contexts of the organization from the perspective of distributed cognition. Such this, we are able to analyze the cognitive systems of actors (i.e., the thoughts and actions of actors) by way of the interactive processes between them and school working contexts as "artifacts" (e.g., checklists, teaching program) (Halverson & Clifford, 2006, p. 583-586). Furthermore, we have to consider the possibility that, while cognition can be distributed, they need a few "sources" for this distribution such that can operate conjointly. And we also have to consider the possibilities that each of these so-called sources, or intellectual partners (actors), can also grow such that each subsequent joining of partners will become more intelligent (Salomon, 1993, p. 111). As Perkins (1993, p. 90) also notes, the surrounding-the immediate physical and social resources outside the persons, which participates in cognition, not just act as a source of input and a receiver of output, but as a vehicle of thinking. In other words, the theory of distributed cognition maintains that teaching practices wherein communicative artifacts are put can naturally create the interaction between teachers and artifacts, and the teachers' cognition could be analyzed and

understood further. And then it even can transform teachers' cognitions and thus become more intelligent. In brief, the theory of distributed cognition can analyze teachers' cognitions and their developmental processes when principal or instructional leader adopts school working contexts as artifacts (i.e., checklist or teaching program) and interacts with teachers over and over.

Most research studies investigating distributed cognition issues focused on school and instructional leadership (e. g., Halverson & Clifford, 2006; Liang, 2011; Liang & Hung, 2011). Relatively few studies deal with how the gap between artifacts and tasks in terms of members' cognition distributed (Halverson & Clifford, 2006) in the field of teaching practice, especially the analysis of the developmental processes of teachers' cognitions through the checklist for "Two-Way Specification Table" (TWST) on teachers-made assessments as an artifact. Consequently, the findings of the present case study, which examined and analyzed teachers' cognitive systems by means of the interaction between teachers and TWST in contexts of "SiSi Elementary School", should contribute to the development of future innovative strategies for teachers' teaching and their professional knowledge.

## Literature Review

The design of the present study was based on a review of the existing literature on the analytical approach for distributed cognition, the features of "Two-Way Specification Table", and the relationship between them.

### The Analytical Approach for Distributed Cognition

The theory of distributed cognition stresses that individuals' cognitions are distributed in the social situation (Perkins, 1993). It could analyze the individuals' cognitions by way of the interactive processes between actors and the artifacts (e.g., teaching program, checklist) (Halverson & Clifford, 2006). Distributed cognition also suggests that owing to the interactive processes among members, situation, and the artifact it could bring up the transform and development on individual cognitions (Liang

& Hung, 2011). Moreover, Salomon (1993) further argues that individuals' inputs could affect the nature of the joint, distributed system through their collaborative activities (i.e., artifacts), so as to affect their cognitions, then their subsequent participation is altered, leading to subsequent altered joint performances and products. As a result, based on the perspective of such theory it could analyze the individuals' cognitions and understand how they acquire the new knowledge and abilities through collaborative activities as artifacts, which causes the interactive processes among individuals' cognitions, situation, and artifacts (Gan & Zhu, 2007; Hands, 2010; Hutchins, 1990).

With respect to analyzing the dimensions on distributed cognition theory (see Figure 1), Halverson and Clifford (2006) point out that it analyzes the development and practice of principals' leadership and distinguishes the policies from instruments (i.e., artifacts) based on the perspective of distributed cognition. Thus, the analyses on distributed cognition theory are guided by three key questions: 1) What is task? 2) What are the relevant artifacts? 3) How do tasks and artifacts link in the cognitive system? Briefly, the artifacts are adopted as analytical objects in terms of the traits of school tasks (i.e., macro tasks or micro tasks), and second, cognitive systems of members (i.e., principal's cognitive systems and teachers' cognitive systems) are understood by way of continuous interactive processes between artifact and such members (Liang & Hung, 2011). Three key questions are as follows:

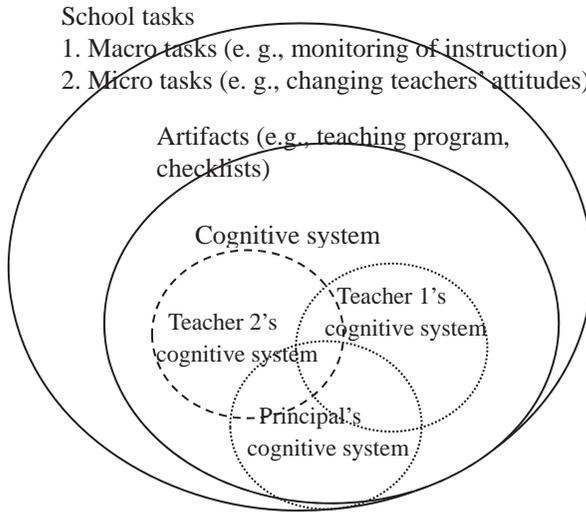


Figure 1 The Analyzing of Dimensions on Distributed Cognition Theory

Note 1. The circular dashed line means the actors' cognitive system and will change as the actors interact with the artifact continuously.

Note 2. Adapted from "Analysis of the cognitive process of a principal's instructional leadership from distributed cognition perspectives," by C. T. Liang, & C. C. Hung, 2011, *Educational Research Quarterly*, 19(2), p. 51.

### School tasks

From the perspective of distributed cognition, the traits of the actors' cognitive system are understood from what tasks (i.e., macro or micro tasks) they select in school contexts, where macro tasks involve descriptions at the more abstract tasks or the large-scale organizational level and micro tasks describe the specific behaviors derived from the macro tasks (Spillane, Halverson, & Diamond, 2001). For example, from a school leadership perspective, macro task such as "monitoring of instruction" is composed of micro task such as "changing teachers' attitudes" (Halverson & Clifford, 2006, p. 583). van der Meij and Boersma (2002: 198) also argue that the choice of tasks should be as clear as possible in order to facilitate analysis the traits of the cognitive system. Such these, from the perspective of distributed cognition, for completing the macro tasks and leadership purpose the choice of the micro tasks have to be as clear as it could be in order

to analyze the actors' cognitive systems.

### **Artifacts**

Individual cognitions as an artifact are distributed in substance and culture (Spillane et al., 2004). And an artifact is regarded as the vehicles of thinking on staff members (Perkins, 1993) and it also has social functions for communicate understanding (Hutchins, 1995). Furthermore, the artifact is penetrated within leading activities so as to complete the setting tasks (Pea, 1993). And its design includes the features that reflect the intentions of a designer (i.e., principal) on suggested uses or effects, and it is also practiced by users (i.e., teachers) (Halverson & Clifford, 2006). Namely, the actors' (i.e., principal or teachers) thoughts and actions are understood by way of the interaction between artifact and them in the leading activities or tasks. In particular, the artifact may be a language, technology, or physical space as observed cultural level on organization (Schein, 1985), formal structure and rule, as well as all kinds of agreements (Spillane et al., 2004), such as the policies or programs (Spillane et al., 2004), the checklists (Halverson & Clifford, 2006), and the logs or buildings (Gagliardi, 1990).

### **Cognitive system**

Cognitive system involves the artifacts (i.e., macro task or micro task) and actors (i.e., principal or teachers) who are needed to complete micro and macro tasks. In other words, the actors' cognitive systems are presented in "Interaction between actors and artifacts" and "The choice of actors for the features of the artifacts" for completing micro and macro tasks (Halverson & Clifford, 2006, p. 586). In particular, how actors interact with artifacts as well as what actors select the features of artifacts represent the actors' thoughts and actions (i.e., cognitive systems) (Spillane et al, 2004, p. 23). Specifically, principal's cognitive systems are appeared when they select and interact with artifacts to complete the tasks, and similarly teachers interact with such artifacts represent their cognitive systems (Halverson & Clifford, 2006, p. 585-586).

## **The Features of "Two-Way Specification Table"**

Concerning the features of TWST, we can firstly introduce the structure of Bloom's revised taxonomy, and then interpret its implementations in Taiwan.

### The structure of Bloom's revised taxonomy

Generally speaking, to complete the teaching tasks TWST as a checklist (i.e., an artifact) that include the knowledge dimension or teaching materials contents as well as cognitive process dimension, and we use it within the teachers-made assessments on students' learning tests (Lee, 2011). Concerning the TWST, the structure of Bloom's revised taxonomy (see Table 1) called "Bloom 2001" is the most representative version that is refinement and extension of original work named "Bloom 1956" which is an often utilized tool for classifying six educational objects such as knowledge, comprehension, application, analysis, synthesis, and evaluation based on what teachers expect their students to learn (Spindler & Tech, 2015). In particular, the original taxonomy consisted of only a cognitive process dimension; the revised version incorporates a knowledge dimension as well. And second change for cognitive process dimension in terminology, form in noun form (knowledge, comprehension, etc.) were written in verb form (remember, understand, etc.) that emphasizes the active cognitive behavior desired from a student (Seaman, 2011).

Table 1 *The Structure of Bloom's Revised Taxonomy*

knowledge dimension	Cognitive process dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual						
Procedural						
Meta-cognitive						

Note. Adapted from "Taxonomy for Learning, Teaching and Accessing: A Revision of Blooms' Educational Objectives (p. 29)," by W. Anderson, & D. R. Krathwohl, 2001, New York, NY: Longman; "A revision of Bloom's Taxonomy: An overview," by D. R. Krathwohl, 2002, *Theory into Practice*, 41(4), p. 216.

Regarding the "Bloom 2001", it includes two parts. On the one hand, there are four categories and eleven items in knowledge dimension. The four categories of knowledge are factual, conceptual, procedural, and meta-cognitive. Specifically, factual knowledge is considered to be knowledge of terminology and fact (i. e., knowledge of specific details,

and knowledge of terminology). Conceptual knowledge entails a deeper understanding of contents (i. e., knowledge of classifications, knowledge of principles, and knowledge of theories). Procedural knowledge maintains the knowledge of how to do something (i. e., knowledge of subject-specific skills, and knowledge of criteria for determining the timing to use appropriate procedure). Metacognitive knowledge signifies knowledge of one own cognition (i. e., strategic knowledge, knowledge about cognitive tasks, and self-knowledge) (Anderson & Krathwohl, 2001; Spindler & Tech, 2015).

On the other, six categories and nineteen items are classified in the cognitive process dimension listing additional verbs within each of six levels which more clearly delineate their nature. They are as follows: Titled remember means recalling or remembering the information (recognizing, and recalling), titled understand stresses explaining ideas (translating, interpreting, exemplifying, classifying, summarizing, comparing, and explaining), titled apply entails using the information in a new way (executing, and implementing), titled analyze maintains distinguishing between the different parts (differentiating, organizing, and attributing), titled evaluate entails justifying a stand or decision (checking, and critiquing), and titled create signifies creating a new viewpoint (generating, planning, and producing) (Anderson & Krathwohl, 2001; Spindler & Tech, 2015).

Concerning above-mentioned, TWST not only defines the categories for such two dimensions on teachers-made assessment for students' learning tests but also helps teachers know how the criteria of these categories differ. Moreover, it is important for teachers to integrate the curriculum, teaching, and assessment at such tests for promoting their teaching effectiveness (Yen & Lin, 2003).

### **The practice of "Two-Way Specification Table" in Taiwan**

Concerning TWST on teachers-made assessments for students' learning tests in Taiwan (see Table 2). It integrates the curriculum, teaching, and assessment designed by teachers, which usually uses extracting various knowledge categories (e. g., factual, conceptual, etc.) and different cognitive levels (e. g., remember, understand, etc.) from the units of teaching materials (e. g., first unit, second unit, etc.) on teachers-made assessment for students' learning tests. Due to the design of TWST, especially how one

defines cognitive levels and what extracts knowledge categories based on materials units at tests for upgrading students’ learning outcomes. They are very difficult for teachers (Wang, Wang, Wang, & Huang, 2003). Thus, they try to use an alternative method as TWST which adopts different types of questions (e.g., true or false, multiple choice items, filling in the blanks, essay, etc.) standing for different knowledge categories and various cognitive levels in the checklist for understanding their learning outcomes.

Besides, in this table “Subject” refers to mathematics, social science, etc., with “Grade” referring to grade 1, grade 2, etc.; “Teacher” referring to Teacher A, Teacher B, etc.; and with “Total” referring to total number of the questions. To summarize, after the students’ learning tests teachers can schematically understand what knowledge categories of teaching material units are needed and know which cognitive levels that the tested students have achieved.

Table 2 “Two- Way Specification Table” of Teachers-Made Assessment for Students’ Test

Subject		Grade		Teacher			Total
Knowledge dimension		Cognitive process dimension					
		Remember	Understand	Apply	Analyze	Evaluate	Create
First unit (knowledge of factual, conceptual, procedural, and meta-cognitive)	True						
	Choice						
	Filling						
	Essay						
second unit (knowledge of factual, conceptual, procedural, and meta-cognitive)	True						
	Choice						
	Filling						
	Essay						

( Continued on the next page )

Table 2 “Two- Way Specification Table” of Teachers-Made Assessment for Students’ Test (continued)

Subject	Grade	Teacher					Total
		Cognitive process dimension					
Knowledge dimension		Remember	Understand	Apply	Analyze	Evaluate	Create
Third unit (knowledge of factual, conceptual, procedural, and meta- cognitive)	True						
	Choice						
	Filling						
	Essay						
Total							

Note 1. The true refers to true and false, with choice referring to multiple choice items, and filling referring to filling in the blanks. Such true and false, etc. as questions teacher chooses standing for different knowledge categories and various cognitive levels from units of materials on teachers-made assessments.

Note 2. Adapted from “The Establishment of Chinese General Proficiency Indicator,” by Y. L. Cheng, 2006, *Journal of Liberal Arts and Social Sciences*, 2, p. 124-126; “Two-Way Specification Table as mathematics,” by I. J. Lu, & G. I. Wu, 2011, *In-service Education Bulletin*, 28(5), p. 98.

Observe that, in Table 2 regarding the students’ tests teachers usually firstly analyze and choose knowledge categories (i. e., factual or conceptual knowledge) of the units of materials (e. g., first or second unit of material of Social Science subject), and secondly edit the questions as the true or false, multiple choice items, as well as filling in the blanks, which stand for simple cognitive levels (i. e., remember, understand, and apply), respectively. In contrast, for achieving higher cognitive levels (i. e., analyze, evaluate, and create), teachers might adopt the procedural or meta-cognitive knowledge of units of materials (e. g., second or third unit of material of Social Science subject) and use as types of essay for editing questions that makes the students try to interpret and explain at tests (Chien, 2009).

Overall, it is an important process for teachers to conduct the remedial teaching plans and improve the teaching activities when they understand the knowledge categories of teaching materials’ units and the students' cognitive process during such period

(Lu & Wu, 2011). Therefore, to enhance teaching effectiveness and completing their teaching tasks, teachers should make their way to integrate the curriculum, teaching, and evaluation through designing the teachers-made assessments for students' learning test based on TWST.

## The Relation between Distributed Cognition and “Two- Way Specification Table”

According to the above-mentioned reasons, researcher can analyze teachers' cognitive systems through the interaction between teachers and TWST based on the theory of distributed cognition. In other words, teachers' cognitive systems and their developmental processes are understood when they extract what knowledge categories of materials' units are needed and define how various cognitive levels are reached for students by proposing the types of questions at students' tests in the light of TWST. That is, as an artifact, TWST is adopted as an analytical object in terms of micro school task of changing teachers' attitudes and macro school task of instruction monitoring. In particular, teachers can complete the teaching tasks effectively and upgrade the students' learning outcomes based on the TWST at students' tests, and further improve their professional abilities in the teaching activities or the remedial teaching strategies.

However, at the same time teachers should face the difficulties and challenges including editing the types of questions that can extract the knowledge categories of teaching materials' units and define the cognitive levels for students' learning. Therefore, it becomes a very important issue to edit teachers-made assessments at students' learning tests for upgrading the learning outcomes of students.

## Study Approach

The design of this study was based on the discussion presented in the introduction and literature review section.

### Study Framework and Methods

Case studies investigated “why” and “how” in real-life contexts (Yin, 2002). For distributed cognition theory, the present study employed the artifact as “TWST” on teachers-made assessments for students’ tests, which was chosen as a micro task for changing teachers’ attitudes derived from the macro task for monitoring of instruction in school contexts. In particular, the TWST was interacted with teachers to analyze their thoughts and actions (i.e., cognitive systems) at the “SiSi” Elementary School. The “how” was provided by identifying teachers’ cognitive systems when they interacted with TWST. And the “why” was provided by analyzing the teachers’ cognitive systems and their possible developmental processes at their school (see Figure 2).



Figure 2 Teachers' Cognitive Systems and Their Developmental Processes at SiSi Elementary School

Note 1. The light spots and their shining lights entailed the teachers' cognitive systems and their possible developmental processes, respectively, when they interacted with TWST in the school contexts over and over.

Note 2. Adapted from: Author drew

### Participants and Contexts

In present case study, the data were obtained from “Principal P” and ten teachers at “SiSi” Elementary School. In 2014, principal P selected TWST as an artifact asked policy by “W” county Government in Taiwan to interact with teachers in order to promote their teaching effectiveness. In SiSi Elementary School, ten teachers were recruited as

participants to practice TWST. In this study, they exhibited differences traits in gender, levels of seniority, and individual characteristics (see Table 3).

Table 3 *Characteristics of the Eleven Participants at “SiSi” Elementary School*

Name	Sex	Seniority	Members' characteristics and commitment to the school
Principal P	M	28	Enjoys good interpersonal relationships, exhibits concern for member needs as well as a focus on student learning, motivating teacher enthusiasm, and improving teacher professional abilities
Director A	F	20	Plans the curriculum and teaching, emphasizes the spirit of the law, and exhibits a conscientious attitude toward work
Teacher A	F	15	Team leader for teaching affairs, and responsible for TWST
Teacher B	F	24	6th grade teacher who emphasizes professional autonomy and continually expresses contrary opinions on administrative matters
Teacher C	F	15	6th grade teacher with a straightforward personality who is good at helping students visualize information in the textbook
Teacher D	F	16	5th grade teacher who has excellent teaching skills and a conscientious attitude toward teaching
Teacher E	F	7	5th grade teacher with excellent class management skills who emphasizes teachers' professional autonomy
Teacher F	M	19	4th grade teacher who exhibits proficient teaching skill but rarely interacts with colleagues
Teacher G	M	7	3th grade who exhibits few interactions with staff, unstable emotions, and mediocre teaching performance
Teacher H	F	4	2nd grade teacher who supports the school administration and enjoys good interpersonal relationships with colleagues
Teacher I	F	21	1st grade teacher who focuses on classroom teaching and values professional development and others' opinions

The recruited eleven participants were mainly considered in line with the ecological distribution of the school. We try our best to look for the members with different

backgrounds to meet their job categories (i. e., school leader, executive administrators, and teachers), gender (i. e., three male and seven female staff members V. S. twelve male staff and twenty- eight female staff members), age of service (10 years or less, 11 to 20 years, and 21 to 30 years), teaching field (from first to sixth grade teachers), and the degree (personal characteristics and commitment to the school ) so as to facilitate the collection of information on the interaction between teachers and TWST. In brief, the characteristics of the recruited eleven participants at “SiSi” Elementary School were chosen such that they could stand for the whole school.

“SiSi” Elementary School is located in the countryside of the “W” County Government, Taiwan. There are twenty classes and approximately forty teachers in this school. “Principal P” had been serving as principal for fifteen years, and had good interpersonal relationships with teachers, exhibiting concerns for teachers’ needs, setting up the professional learning communities, and constantly successful experiences at the school. In particular, he focused on creating a positive culture that had emphasized student learning, promoting teacher enthusiasm, and enhancing teacher professional expertise, etc.

Although the backgrounds of most students were from working-class families in this school, most teachers in this school possess excellent teaching skills and enthusiasm. The teachers can have sufficient support of equipment (e. g., transparency projectors and DVDs) when they need in their teaching environment. In practical, the teachers constantly discussed the teaching issues with other teachers; e.g., on how teaching strategies could be used and which kind of teaching skill should be applied. Occasionally, they also discussed about teachers-made assessments at students’ tests, which involved teachers’ cognitions and teaching technology ... etc.

### **Methods**

Participatory observations, interviews, and documents were employed in the present case study to analyze and interpret the interactions between TWST and teachers. The study was conducted within the duration of four periods (i. e., commencing stage, initial stage, medial-term stage, and final stage) from January 2014 to April 2015 (see Figure 3).

Months Periods	2014												2015			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
commencement	First and second tests															
initial stage	Third and fourth tests															
medial-term													Fifth and sixth tests			
final stage													Seventh to ninth tests			

Figure 3 The Timing of Data Collection for the Four Periods from January 2014 to April 2015

Participatory observations primarily occurred in the offices of school staff members and classrooms. The beginning of the first test of the entry, the time was about 1-2 hours; mid-term (4-12 months) observed the frequency was more frequent and longer (about 2-3 hours), and as far as possible in the distribution the different time of the week to obtain a comprehensive and diverse information; the number of the final stage gradually reduced, and slowly out of the field, the main collection of previously not received the main information (see Table 4). The data coding were identified with respect to the date of observation (“Observation Year-Date”, e.g., Ob14-1205, Ob15-0103).

Table 4 *Timing of Participatory Observations*

Month (during 2014-2015)	Times	Time (hours)	Total (hours)
01	4	1~2	6
02	6	1~2	8
03	6	1~2	10
04	9	2~3	18
05	11	2~3	20
06	10	2~3	24
07	7	2~3	15
08	9	2~3	20
09	11	2~3	22

(Continued on the next page)

Table 4 *Timing of Participatory Observations (continued)*

Month (during 2014-2015)	Times	Time (hours)	Total (hours)
10	8	2~3	11
11	8	2~3	11
12	7	2~3	10
01	7	1~2	10
02	5	1~2	8
03	4	1~2	6
04	2	1~2	5
Total			204

Moreover, interviews were primarily based on interview outlines that were reviewed from the professional opinions of three professors and two elementary school principals (see Table 5). And the coding that were identified with respect to the participant and date of the interview (“Interview participant Year-Date”, e.g., Ipp14-0103, Ita15-1212, with “pp” referring to “principal p”, “with “ta” referring to “teacher a”). The interviews took a semi-structured approach, allowing respondents to express their views more freely and to delineate the activities and their meanings in various contexts. For unclear interviews, researcher tried to seek more explicit and in-depth interviews with questioning. For example, in the interview, one of the teachers pointed out that “it was not necessary to think about these problems in the past, now I find the TWST bring a lot of teaching changes so that I would have noticed the ability of students to analyze and evaluate [higher cognitive level]” (Itb14-0410), she argued that “ compared to the TWST, although teachers’ experience will lead to changes in teaching activities, it will not pay attention to the analysis and evaluation of higher-level ability” (Itb14-0410). This means that the TWST than the teaching experience, can bring the teaching changes faster.

In addition to active data collection, the contents of document as official documents or meeting documents involved in school daily life and were identified with respect to the document and orders (“Document Order”, e.g., D-05).

Table 5 *Interview Outlines*

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1. Do you like using the TWST for teachers-made assessment at students' tests and why?
  2. What are your opinions for implementing TWST for teachers-made assessment at students' tests and why?
  3. How does TWST affect your teaching activities?
  4. Could you tell me what knowledge categories of materials' units you choose based on TWST and how use the types of questions (i. e., true or false, multiple choice items, filling in the blanks, and essay) to reach such categories?
  5. What knowledge categories of materials' units you choose based on the features of TWST with the colleagues? How do you do if you face the difficult problems?
  6. Could you tell me how you define the various cognitive levels such as titled for remember, understand, apply, analyze, and create and how use the types of questions (i. e., true or false, multiple choice items, filling in the blanks, and essay) to reach such cognitive levels?
  7. What problems of cognitive levels you define with the colleagues? How do you do if you face the difficult problems?
  8. How you or your colleagues take the right things for teachers-made assessment at students' tests and what?
  9. Could you implement TWST for teachers-made assessment at students' tests again and again after pushing forward this plan and why?
  10. Could you think the implementation of TWST is better for learning outcomes of students and improving teachers' expertise and why?
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## Research Credibility

In the field data obtained by the study, the researcher will correct the reliability of the information by participatory observations, interview and document as collection methods. Secondly, interviews with different respondents for the same theme, as well as the collection of positive and negative views on them, to benefit the authenticity of the gathering information. For example: “for teachers, it [implementing TWST] is not just an obligation for teaching, but also to pay attention to whether we care about our rights and interests, such as enriching teaching equipment, etc. (Itb14-0315)”; “Only for pushing forward the TWST for teachers-made assessment at students' tests and not to know what teachers need, this action is not fair. (Itg14-0313)” The above statements confirm that the principal push forward the practice of TWST is very difficult work due to teachers doubt it.

In addition, the original data and coding information collected by the researcher further allowed the participant to review and submit to the research peer (Teacher Z) for checking to minimize the subjectivity of the researcher and improve the reliability of data analysis.

## Findings

Based on the data for implementing TWST from four periods at “SiSi” Elementary School (e. g., commencing stage, initial stage, medial-term, and final stage), we obtained the following findings regarding the teachers’ cognitive systems and their possible development processes.

### Commencement of Implementation for TWST: First and Second Tests

The teachers-made assessments for students’ tests needed to be reviewed by TWST for ensuring their professional qualities due to the teachers in elementary schools were asked by “W” County Government in this semester (i.e., February 2014-July 2014). This requirement was to learn more teaching techniques (i. e., teachers-made assessments) for promoting teachers’ professional abilities by way of delivering and sharing with artifact (TWST) in organization (Cook & Yanow, 1993). Relatively, the teachers at SiSi Elementary School did not believe that this could promote their professional skills, because such a requirement was a top-down bureaucratic system. Namely, the communications concerning teaching techniques and activities between school administration (i.e., principal) and teachers might not happen (Lieberman & Grolnick, 1996). In other words, it was a boring policy and bought up the negative efforts in school. As were expressed by one teacher and an observed note at the first test separately: “I thought I just made such assessments based on common senses as my teaching experiences in the past, ....., so now the implementation of this plan [TWST] is boring for us”. (Itg14-0103) “For completing such requirement, some teachers casually filled the checklist [TWST] on their made assessments....., so it is a superficiality behavior”. (Ob14-0116)

These negative voices were spread everywhere in the school at the commencement of implementation for TWST. However, the actors' (teachers') various cognitive systems were understood when they constantly interacted with artifact (TWST) which was derived from the macro-tasks (i.e., monitoring of instruction) and micro-tasks (i.e., changing teachers' attitudes) (Liang & Hung, 2011). For example, relative to such negative voices one teacher had been identified as a professional teacher vocalized a positive view: "The tests [TWST] for improving teachers' teaching planning can help teachers to understand the actual situations of students' learning outcomes (Itd14-0212)". Moreover, other teachers, after the first test, started to review the problems and find the reminder function by TWST for their made assessments, although they endured the pressure from authority asking such policy. It also created a more impartial opinion to them, as views were explained by two teachers: "We could easily hold the focal point about the teaching materials through TWST checking to promote the effectiveness of teaching activities". (Ida14-0305) "Principal always checks it [TWST] again and again so that I should make it carefully on such assessments . . . .; it is a reminder which is important thing for me, especially for a novice". (Ith14-0313)

Furthermore, at second test the participative teachers shared and discussed with each other about their made assessments which were reviewed by TWST once again. It could gradually adjust the cognitive systems of actors (participative teachers) when they continually interacted with artifact (TWST) (Halverson & Clifford, 2006). Meanwhile, some teachers, professional attitudes, appeared different thoughts and behaviors. For examples: "For teachers teachers-made assessment based on TWST is a professional affair, but it, asking by school administration, is not a proper thing". (Itb14-0331) "These [teachers-made assessments in the past] are unfair for students and need to be corrected by way of reviewing with TWST....., so such policy is needed". (Iti14-0408)

Some [teachers] proposition teachers-made assessments directly take sampling questions from DVD [question bank for students' tests] on computer. It is unfair to low social status students because they have few chances to practice such questions [relative to some students who high social status have many

times to practice such questions over and over due to their parents may print them from DVD]. (Itf14-0402)

Consequently, it [TWST] contributed the sharing and exchange among members [teachers] (Salomon, 1993). The negative opinions of some teachers appeared on campus when TWST prior to the implementation, and other teachers turned around gradually to the fair and positive opinions after the first test. Moreover, after the second test teachers started thinking about their professional attitudes which created the different thoughts and behaviors. That is to say, during the commencement of implementation for TWST, teachers presented cognitive systems such as negative opinions, fair and positive opinions, and thinking about their professional attitudes.

### Initial Stage for TWST: Third and Fourth Tests

Although the foregoing self-professional issues most of the teachers faced, a few teachers adopted the perfunctory attitudes that written assignments they casually filled the checklist [TWST] in reaction to this policy in school. At the same situation, a few teachers thought such reviewing TWST for teachers-made assessments as a bad thing which violated the professional autonomy of teachers. And they insisted they had rich professional competences for completing the teaching tasks and thus didn't like to be suspected and challenged about their professional abilities (Hargreaves, 2001), as expressed by one teacher at third test: "I believe I have excellent teaching abilities, but for me such requirement [filled checklist of TWST] from school is a suspect behavior....., for us the perfunctory filling checklist means a resistant attitude to such school policy". (Itg14-0515)

In this stage a resistant attitude the teachers showed and their professional abilities were questioned. However, after reviewing the made TWST, some teachers found the situations that students' performances in tests centered on the lower cognitive level as remembering level and understanding level and only even in the single level (e.g., in remembering or understanding level). These highlighted the problems and myths about teachers' teaching strategies and processes. By such doing, teachers examined and

reflected such problems by employing the opportunities of sharing and discussing with others, and gradually found the more available teaching activities or strategies to resolve them. Namely, members (teachers) were able to create more intelligent, reflective, and applicative actions and outcomes when they deeply understood the related issues and contents (teachers-made assessments) (Meyer, 2007), as was explained by two teachers: “We find out our problems [teaching activities and focuses] in favor in level of remembering and understanding or only in remembering level after checking the checklist [TWST] .....” (Itc14-0513)

If we are able to discuss the details and content of TWST more often, we trust we could design more flexible cooperative learning activities for students and more suitable teaching materials for upgrading the students' learning outcomes, such as upgrading the cognitive level from remembering to the analysis by the strategies of cooperating learning. (Itd14-0603)

Since practicing TWST at SiSi Elementary School many times, some teachers were gradually familiar with its connotations and significances. For example, several teachers could make distinctions for their assessments with each other on the basis of TWST and thus attract interesting and discussing in it for other teachers. Such artifact (i.e., TWST) as a vehicle for communicating understanding could advance the opinions for sharing and exchange among the members (i.e., teachers) so that they grew more intelligent (Hutchins, 1995; Salomon, 1993). As were explained by one teacher and the principal: “The all-inclusive contents of teachers- made assessments are showed according to the checklist (TWST), which include the all teaching units, all knowledge categories, and multiple cognitive levels”. (Ipp14-0626) “The opinions of sharing and discussing on TWST among teachers can distinguish the outcomes among students and provide a little strategies of remedial teaching for them”. (Ite14-0630)

Based on such situations, some teachers still adopted the attitudes of resistance and doubt in initial stage for TWST. And then some started to reflect the teaching questions at the same time after constant interacting and contacting with it, and even rose up the

more teachers to make differentiated for assessments. In other words, they could create more new knowledge due to the facilitation of the reciprocities and cooperation among teachers when the artifacts intervened (Liang, 2011). In sum, the attitudes of resistance and doubt, reflecting their teaching problems, and make differentiated for assessments teachers presented such cognitive systems in initial stage for TWST.

### The Medial Stage for TWST: Fifth and Sixth Tests

Teachers had been regarded TWST as a part of teachers-made assessments after practicing the fourth tests, and they started to mind its connotations such as how material contents or units distributed, what types of questions adopted, and even how cognitive levels defined or distinguished. In fact, such difficulties of skills on TWST got more passive for some teachers, as was expressed by one teacher:

We [same grade teachers] have to discuss and compare the connotations and the types of questions about teachers-made assessments so that can understand the differences about cognitive levels on them.....; this is a routine in every student tests, but it is difficult for us. For other teachers the proportion of each material unit on the teachers-made assessments is emphasized than the cognitive levels. (Itc14-0919)

However, most teachers gradually considered and discussed the cognitive levels and the teaching materials on TWST. Namely, artifacts could promote their influence due to the functions of sharing and discussing about them among members (Louis & Marks, 1998). More specially, evaluating how cognitive levels of questions were diagnosed functions and adjusting how teaching activities practiced were needed when some teachers designed the teachers-made assessments for students' tests at school. And even a few teachers as same grade or same subject teachers got together to complete on each teachers-made assessment and shared and discussed the qualities of such assessments. As was said by one teacher:

I think I have been considered the various types and contents of questions on teachers-made assessments, for example, after filling repeat the table [TWST] type of essay as evaluation cognitive level and conceptual knowledge of third unit of mathematics material we show many times on assessments, especially through talking and discussing with other teachers..... (Ite14-1112)

Such this, the practice of TWST embodied the traits of “teachers as professional leaders” (Lima, 2008) over time, as was explained one meeting. “At a faculty meeting, Teacher F expresses he is gradually able to take into account the teaching actions to reach various cognitive levels (e.g., understanding and analysis) on teachers-made assessments” (D-04). In other words, it naturally stimulated the several teaching strategies for teachers. For example:

Some teachers feel more related to the understanding level from the perspectives of teaching subjects (e.g., calculation questions in mathematics), and relatively few stress the higher cognitive levels such as evaluation and creation deriving from adopting the posted teaching method....., we decide to change the flexible teaching strategies” .(Iti14-1219)

Thus, teachers started to adjust their teaching strategies and available tried to fill the gaps between their teaching and students’ learning due to TWST facilitating practice attitudes. Based on above-mentioned points, in the medial phase of implementation for TWST, the teachers of SiSi Elementary School firstly encountered the skills difficulties that they couldn’t define the cognitive levels about teachers-made assessments. Moreover, for promoting students’ learning outcomes the teachers shared and discussed with each other about the teachers-made assessments in order to start up the opportunities for facilitating the teaching strategies. In other words, teachers showed their agencies in the routine activities [TWST] by making relevant work programs and injecting new ideas (Chen, 2007). In brief, encountering skills difficulties, sharing and discussing with each other about assessments, and facilitating their teaching strategies were three cognitive

systems in this stage.

## Final Stage for TWST: Seventh, Eighth, and Ninth Tests

For teachers TWST launched a chance for facilitating their teaching strategies due to gradually understanding the traits about various cognitive levels in terms of teachers-made assessments. Furthermore, in this case, it was necessary for expert teachers to help other teachers to get more external resources, during the transformational processes of their teaching strategies in order to understand how cognitive levels on such assessments were identified. And the teachers' teaching experiences also was the key factors for promoting such skills. Namely, the interaction among individual cognitions, individual abilities, collective culture, and collective resources in organization were also able to upgrade the organizational competitiveness (Küpers, 2007). As was explained by one observation note:

In a discussing meeting, Teacher E expresses the action on TWST to discuss with other teachers that can review the students' outcomes and understand the students' learning problems after the tests.....; she also suggests teachers adopt it [TWST] and further use the remedial teaching system [collective resources] in school to supplement the relevant knowledge categories or materials units for students..... (Ob15-0106)

In addition, during the implementation of TWST, experts' participating and giving professional opinions could contribute and refine the teachers' professional abilities and further promote the collective effectiveness in the organization (Kolikant, McKenna, & Yalvac, 2006). And constant discussing and sharing in teachers' professional learning communities also were to bring up their mutual understanding and develop the common knowledge (Cook & Yanow, 1993), as was expressed by one teacher and one document:

I use the TWST on assessments by way of discussing with other teachers, especially expert teacher [Teacher D] concerning the 'reading comprehension',

in ‘Curriculum Learning Community’ formed from the professors’ opinions, expert teachers’ views, and actual situations....., for me, the use of TWST is a professional development processes” (It15-0312).

Hiring professors to explain the importance of the TWST on the assessment for teachers, including the content and types of the questions, not only explain the meaning of each level, but also take one by one for example....., especially teachers how to edit the various types of questions. (D-7)

General speaking, most of the teachers had invested time in the investigation and development about their teaching practice with TWST; Relatively other teachers who had no more time to interact with it were also influenced. Especially, the pushing teachers’ professional development attitudes principals intended actively, which could further strengthen the function of artifact in order to contribute teachers’ actual teaching outcomes (Liang & Hung, 2011). Two teachers pinpointed his opinions: “Most of the teachers always discuss with same grade teachers about the problems on teachers-made assessments regarding TWST that can strengthen the [professional] abilities.....; in other words, this will put a lot of pressure on me”. (Itc15-0325) “The principal actively push TWST and continue discusses with teachers over and over....., that should help us have a clearer concept on it” (Iti15-0326).

Namely, organizational learning could deliver the artifact to staff members so as to they obtained collectively the technologies and abilities about it (Cook & Yanow, 1993). That is, in the past teachers only discussed the contents of TWST during the tests period, and recently they continually triangulated their teaching thoughts and actions with teaching practice and assessments of TWST as an artifact and kept on discussing and sharing with their team or communities members so that they promoted their teaching outcomes after the year and a half after implementation of TWST.

Surprisingly, the school had been researched and developed the information system to TWST that could give teaching reminder messages when the user [teachers] signed students’ scores of tests in this system, and even suggested the effective teaching topics

and strategies to teachers such as what the proportions of teaching material were provided and how cognitive levels were needed. Scilicet, the use of information technology could avoid the abuse of human and material resources, and made teachers-made assessments based on standard process improved their teaching and students' learning outcomes (Wang et al., 2003), as was explained by two teacher. "From system-reminder messages in this test I know the several problems on understanding [cognitive] level, so I decide to adopt the multiple instructional media to improve the students' understanding abilities". (It15-0410)

I found that the questions on assessments I edited that inclined to analyze level, but the students seem to be unable to get high scores. Therefore, I will especially emphasize adopting the teaching strategy for actual comparison, such as the use of experimental way to understand the different factors, there will be different effects, and let the students themselves to see. This may enhance the ability of students to analyze. (Iti15-0407)

For these reasons, the school integrated the human and material resources and adopted the expert opinions to break through the existing boundaries and limitations during the final stage of implementation of TWST. And the principal's pushing attitudes and teachers' triangulation used on their thoughts with teaching practice and assessments of TWST could help the teachers adopt more effective teaching activities. In sum, the integration of human and material resources, the needs of experts' opinions, principal's positive attitudes, and the triangulation used on teachers' thoughts with teaching practice and assessments of TWST were four cognitive systems in this stage.

Briefly, teachers' cognitive systems slightly inclined toward the rising trend in the year and a half after implementation of TWST (see Figure 4).

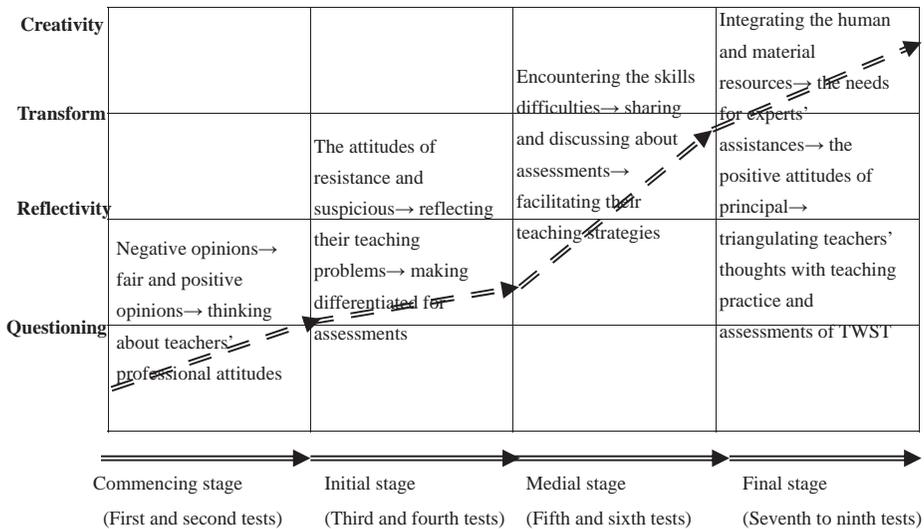


Figure 4. The Processes of Teachers' Cognitive Systems for Implementation of TWST at SiSi Elementary School

Note. The arrows indicate the development direction of teachers' cognitive systems at four stages.

## Conclusions and Suggestions

The present study explored how the teachers' cognition evolved with a close look at the artifact, the processes adopted by TWST on teachers-made assessments as an artifact at nine students' tests in SiSi Elementary School. The following conclusions and suggestions were drawn:

### After the Implementation of TWST in SiSi Elementary School, at Least Thirteen Types of Teachers' Cognitive Systems were Identified

Based on the data at nine tests, after the implementation of TWST in SiSi Elementary School, thirteen types of teachers' cognitive systems were found. Firstly, during the commencement of implementation for TWST, teachers presented cognitive systems such as negative opinions, fair and positive opinions, and thinking about their

professional attitudes. Secondly, the attitudes of resistance and suspicious, reflecting their teaching problems, and making differentiated for assessments teachers presented such cognitive systems in the initial stage on TWST. Thirdly, we analyzed the encountering the skills difficulties, sharing and discussing about assessments, and facilitating teachers' teaching strategies, which were three cognitive systems in the medial stage. Lastly, integrating the human and material resources, the needs for experts' assistances, developing the technological systems, and the positive attitudes of principals, and triangulating teachers' thoughts with teaching practice and assessments of TWST teachers presented in the final stage.

### **During the Process of Implementing TWST, Teachers Gradually Presented Different Stages of Cognitive Systems Such As Questioning, Reflection, Transforming, and Creativities**

After the implementation of TWST, negative opinions, fair and positive opinions, and thinking about teachers' professional attitudes leaned slightly a stage of questioning. In the initial stage, the reflective significance was created from the attitudes of resistance and suspicion, reflecting their teaching problems, and making differentiated for assessments. Moreover, the transformational period in the medial stage represented teachers appeared encountering the skills difficulties, sharing and discussing about assessments, and facilitating their teaching strategies. Lastly, the creativity period was found at the final stage, which appeared from the integrating the human and material resources into triangulating teachers' thoughts with teaching practice and assessments of TWST.

### **Continuous Discussions and Sharing, the Needs for Experts' Assistances, Developing the Technological Systems, and the Positive Attitudes of Principal Were Key Elements in the Functioning of the TWST**

In the light of the findings, teachers presented negative opinions or attitudes of resistance and suspicion in commencement and initial stages, and thus facilitating

teachers' teaching strategies or triangulating teachers' thoughts with teaching practice and assessments of TWST by way of the actions of continuous discussing and sharing when they contacted and encountered the skills difficulties concerning proportion of materials contents and topics of cognitive levels. Moreover, teachers understood the features about TWST, how the cognitive levels were discriminated and how students' outcomes were defined, due to experts' assistances. In addition, the technological systems, remedial teaching system and reminder- messages, were pulled into TWST for students' tests identified the various cognitive levels and knowledge categories of materials' units to stir up teachers adopting the available teaching strategies. Finally, principal's positive attitudes strengthened the functions of TWST and teachers' professional abilities in order to promote the teachers' teaching outcomes. In sum, the four factors were the critical factors for exerting the functions of TWST.

### After the Implementation of TWST in SiSi Elementary School, Teachers' Cognitive Systems Were Slightly Moving Toward the Rising Trend

After implementation of TWST, owing to constantly interaction with TWST teachers gradually developed the thirteen cognitive systems and experienced the periods of questioning, reflectivity, transformation, and creativity, especially the critical factors of continuous discussions and sharing, experts' assistances, developing the technological systems, and principal's positive attitudes. In brief, such these cognitive systems were slightly moving toward the rising trend after implementation of TWST.

In result, we could point out the following suggestions: 1) The schools could use the existing artifacts such as checklists, teaching plans, remedial teaching system to facilitate the discussing and sharing among teachers in order to create more and more cognitive systems development for them. 2) Principals can promote the teachers' professional development by way of encouraging the discussing and sharing among teachers, grasping the experts' assistances, pulling into technological systems, and actively pushing attitudes. 3) Continuously pushing relevant artifacts based on the educational values are required that could extend and promote the educational or teaching outcomes.

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