Chapter 6
Developing Preservice Teachers' Sensitivity to the Interplay Between Subject Matter, Pedagogy, and ICTs

Yu-Ta Chien and Chun-Yen Chang

Mishra and his colleagues' notion of technological pedagogical content knowledge (TPCK, renamed as TPACK in Thompson & Mishra, 2007–2008) theorizes that the required knowledge for teachers to teach with information and communication technology (ICT) involves comprehensive understanding of the transactional interplay between the subject matter being taught, the pedagogy being used, and the ICT tools being adopted in teaching practice. Aligning with the conceptualization of TPACK, developing preservice teachers' sensitivity to the interplay between subject matter, pedagogy, and ICT is a key objective for teacher preparation programs. Based on the theoretical framework of cognitive apprenticeship, we propose a 4-phase cyclic MAGDAIRE model (abbreviated from modeled analysis, guided development, articulated implementation, and reflected evaluation) to develop preservice teachers' sensitivity to the interplay between subject matter, pedagogy, and ICT. MAGDAIRE is subsequently employed to enhance the science teacher education courses of National Taiwan Normal University. The TPACK conceptual framework is adapted as an analytic tool to examine the growth in preservice science teachers' knowledge about technology integration in teaching. The results of the studies and courses indicate that, within MAGDAIRE, these preservice science teachers' reasoning on the use of ICT transited toward a more connected model in which ICT is jointly considered with subject matter and/or pedagogy. Moreover, these preservice teachers' development of TPACK stimulated them to modify their practice. In this chapter, the details of MAGDAIRE and a synthesis of the studies into MAGDAIRE are reported.

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6.1 Introduction

In reviewing the education policies issued by the Taiwan Ministry of Education (MOE), one can find that the teaching profession in contemporary Taiwanese society is expected to adopt a new element: able to teach with information and communication technology (ICT). As stated in the Information Literacy Competence Standards for Elementary and Junior High School Teachers (MOE, 2001), teachers need to know how best to make use of a range of ICT to support teaching and learning. Taking a global perspective, numerous national-level movements have been engaged to infuse ICT into classrooms in the regions of Europe (Pelgrum & Doornekamp, 2009), North America (International Society of Technology in Education [ISTE], 2008), and Asia-Pacific (Organization for Economic Cooperation and Development [OECD], 2008). In Taiwan, the MOE heavily invested resources into reducing the student-to-computer ratio with Internet access for elementary and junior high school schools; generally, the availability of ICT should no longer be a problem for teachers. According to the MOE's white paper on Information Technology Education for Elementary and Junior High Schools 2008–2011 (MOE, 2008), it is expected that more than 90 % of elementary and junior high school teachers will enrich their teaching practice with ICT. At the same time, we, as teacher educators, must reflect seriously on whether the current teacher preparation courses are able to meet this demand.

Table 6.1 provides the common structure of teacher preparation programs approved by the MOE. Clearly, the main purpose of these courses is to nourish preservice teachers' sense of what teaching is as well as how to teach. Within this program structure, the Instructional Media course is the one most related to ICT. This course focuses on basic operations of word processing, spreadsheet, and some presentation tools to patch up preservice teachers' ICT skills in a stand-alone format. Without a doubt, being able to personally use ICT is a fundamental factor contributing to teachers' use of ICT in teaching (Govender & Govender, 2009; Mahdizadeh,

Table 6.1 Common structure of teacher preparation programs in Taiwan

Field	Course
Foundations of education	Introduction to education
	Educational psychology
	Sociology of education
	Philosophy of education
Instructional methods	Principles of teaching
	Classroom management
	Educational assessment and evaluation
	Theory and practice in counseling
	Curriculum development and design
	Instructional media
Teaching practicum	Teaching materials and methods
	Practicum

Biemans, & Mulder, 2008; Sørebø, Halvari, Gulli, & Kristiansen, 2009). However, this approach has been widely criticized for its failure to correlate teachers' ICT skills with their teaching practice (Angeli, 2005; ISTE, 2008; Jang & Chen, 2010; Mishra & Koehler, 2006; Niess, 2005; OECD, 2010; Wilson, 2003). Angeli (2005) indicated that this type of ICT course often gives preservice teachers an impression that ICT is the subject matter to be learned rather than an instructional tool. It is commonly perceived by preservice teachers that the letters conventionally written in chalk are now being displayed by the latest presentation tools, but nothing else appears to have changed or needs to be changed; if so, why should teachers bother about the use of ICT in teaching? As a result, preservice teachers may lose sight of how ICT tools can be leveraged to serve educational purposes.

Mishra and his colleagues' notion of technological pedagogical content knowledge (TPCK, renamed as TPACK in Thompson & Mishra, 2007–2008) provides teacher educators with an alternative to rethink what we expect preservice teachers to do with ICT in teacher preparation courses. The conceptualization of TPACK is extended from Shulman's (1986) idea of pedagogical content knowledge (PCK), which emphasizes that the paramount element of the teaching profession is the knowledge of how to make the subject matter more comprehensible to others. TPACK further promotes the position of the knowledge of teaching tools in the original framework of PCK to a higher level and stresses its interaction with the knowledge bases of subject matter and pedagogy as well (Mishra & Koehler, 2006). It asks teachers, regarding ICT adoption in teaching practice, to deliberate on how the subject matter might be represented by the application of ICT, how the teaching/learning process might be changed by the use of ICT, and, most importantly, how to make the subject matter more comprehensible to students with the aid of ICT. Although (as detailed in previous chapters) the constructs of TPACK are still open to debate, we consider that the main idea of TPACK is useful against the tendency of viewing ICT exclusively without weighing how it may serve teaching purposes.

Koehler, Mishra, and their colleagues advocated the use of the *learning-technology-by-design* approach (Koehler & Mishra, 2005; Koehler, Mishra, Hershey, & Peruski, 2004; Koehler, Mishra, & Yahya, 2007; Mishra & Koehler, 2006) to renovate the ICT courses in conventional teacher preparation programs. It is believed that the preservice teacher will start connecting his/her knowledge bases of subject matter, pedagogy, and ICT with each other when he/she is engaged in developing ICT solutions to pedagogical problems. We recognize that the nature of the development of ICT solutions to pedagogical problems should be intertwined with the transactional interplay between subject matter, pedagogy, and ICT. However, how to manage a course driven by the learning-technology-by-design approach and how to develop preservice teachers' sensitivity to the transactional interplay between subject matter, pedagogy, and ICT in such a course still remain big challenges for teacher educators. In this chapter, we introduce a course model that has been deployed in the science teacher education courses of National Taiwan Normal University (NTNU) for taking on the aforementioned challenges. The TPACK framework is adapted as an analytic tool to examine the growth in preservice science teachers' knowledge about technology integration in teaching.

6.2 The MAGDAIRE Model

The main challenges of deploying the learning-technology-by-design approach into an ICT course are how to ensure that preservice science teachers can generate ICT solutions to pedagogical problems within a given time period and how to keep them constantly revising their solutions to fulfill their pedagogical goals. In the NTNU courses, we engage preservice science teachers in collaboratively creating prototypes of ICT-integrated instructional materials for teaching scientific topics such as wind, solar and lunar eclipses, clouds, global warming, tides, tsunamis, typhoons, and rocks. Preservice science teachers are then asked to teach with these materials in the classroom. Numerous instructional design models have been proposed in the literature for helping teachers create instructional materials such as ADDIE (Dick & Carey, 1996) and ASSURE (Heinich, Molenda, Russell, & Smaldino, 2001). The general phases of instructional design include analysis, design/development, implementation, and evaluation (Reiser, 2001). These four phases are used as the systematic structure of our ICT courses to keep preservice science teachers on the track of creating ICT-integrated instructional materials.

Given that the learning-technology-by-design approach posits that the knowledge of ICT for teaching is fundamentally situated in the development of ICT solutions to pedagogical problems (Koehler et al., 2007), the cognitive apprenticeship should be the legitimate teaching strategy to support preservice teachers' inquiry into ICT. The cognitive apprenticeship reflects the learning perspective that knowledge is in part a product of the activity in which it is used. It refers to the reciprocal teaching between the expert and the novice during an authentic problem-solving activity just beyond what the novice can accomplish alone (Collins, 1988; Collins, Brown, & Newman, 1989). Within our ICT courses, Collins et al.'s (1989) teaching strategy of cognitive apprenticeships is revised and adopted as the pedagogical framework to scale up each phase of instructional design. The preliminary model of MAGDAIRE, which is abbreviated from modeled analysis, guided development, articulated implementation, and reflected evaluation, was proposed in Chien, Chang, Yeh, and Chang (2012). Based on previous studies (Chang, Chien, Chang, & Lin, 2012; Chien et al., 2012), we revised MAGDAIRE to better develop preservice science teachers' sensitivity to the interplay between subject matter, pedagogy, and ICT. Our 4-phase cyclic model is shown in Fig. 6.1. The mentoring team leading MAGDAIRE consists of several educational researchers, in-service teachers, and ICT experts.

6.2.1 Modeled Analysis

The main ICT tool emphasized for creating ICT-integrated instructional materials in the course is specified to the preservice teachers first. These students are explicitly informed that the main course tasks for them are, with the help of the mentoring team, to (a) create some prototypes of ICT-integrated instructional materials for their own future teaching practice and (b) teach with their prototypes before their

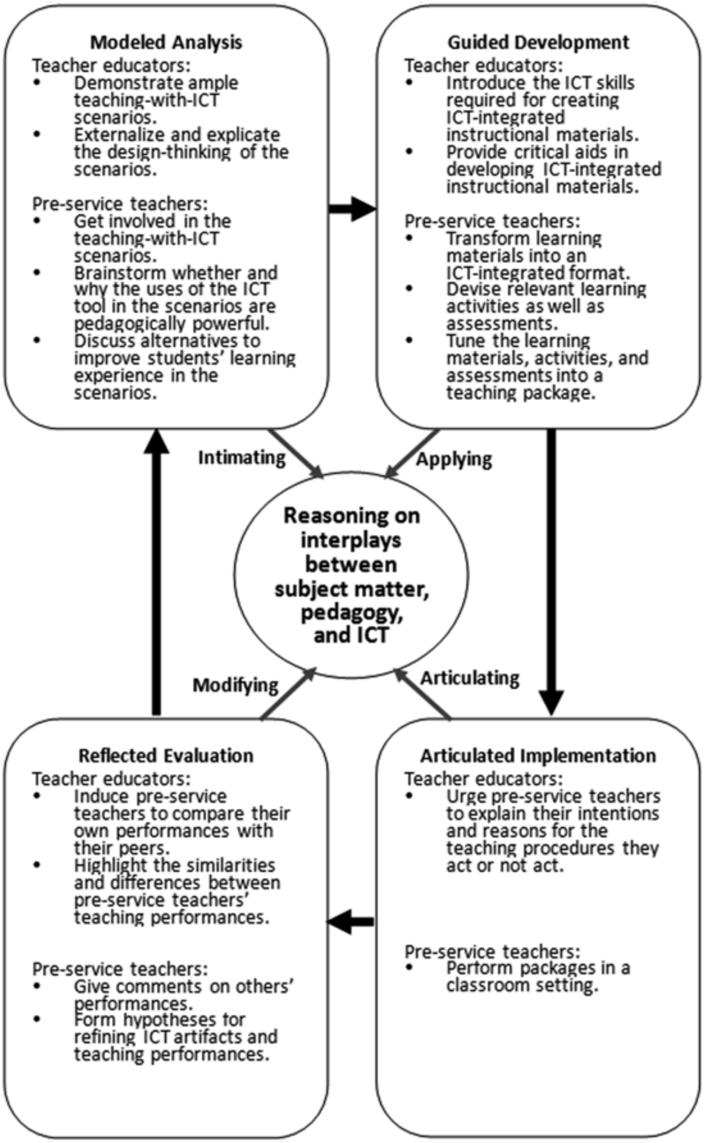

Fig. 6.1 MAGDAIRE model (Revised from Chien et al., 2012)

peers twice. They are then asked to form groups for collaboratively accomplishing the course tasks. The modeling facet of Collins' cognitive apprenticeship is applied in this phase to externalize the decision modes comprised of the interplay between subject matter, pedagogy, and ICT for the preservice teachers to imitate. To begin, the mentoring team demonstrates teaching-with-ICT scenarios of their own design for preservice teachers to experience. Within these scenarios, the preservice teachers are asked to act as students to get involved in the learning activities. At the same time, the mentoring team explicitly explains the design thinking of these scenarios; they then lead the preservice teachers to brainstorm whether and why the uses of the ICT tool in these scenarios are pedagogically powerful; and finally, they discuss alternatives to improve their students' learning experience in these scenarios. Each group of preservice teachers then selects a specific topic for teaching with the ICT tool.

6.2.2 Guided Development

The mentoring team introduces the ICT skills required for creating ICT-integrated instructional materials; this is dependent on what kind of ICT is specified as the major tool in the course. Each group then tries to use these ICT skills to transform learning materials into an ICT-integrated format. Relevant learning activities as well as assessments should be devised at the same time; thereafter, each group tunes the learning materials, activities, and assessments into a teaching package. In this phase, the coaching and scaffolding facets of Collins' cognitive apprenticeship are applied to assist preservice teachers in applying the decision modes, which they acquired from the previous phase, to solve pedagogical problems by using the specified ICT tool. The mentoring team provides hints when the preservice teachers are struggling with the tasks in this phase; advice about the coherence of the teaching packages is also given. As the preservice teachers gain more expertise, the mentoring team gradually pushes them to think and work more independently.

6.2.3 Articulated Implementation

The preservice teachers are asked to perform their teaching packages in a classroom setting. In this phase, the articulation facet of Collins' cognitive apprenticeship is applied to facilitate preservice teachers to make their reasoning on the interplay between subject matter, pedagogy, and ICT explicitly. The mentoring team asks the preservice teachers to explain their intentions and reasons for the teaching procedures they enact or do not enact, which enables them to experience others' perspectives in the same context and across different contexts.

6.2.4 Reflected Evaluation

The preservice teachers are asked to compare their own performance with those of their peers and then to comment on others' performances. The mentoring team highlights the similarities and differences between the teaching performances.

In this phase, the reflection facet of Collins' cognitive apprenticeship is applied to facilitate preservice teachers to modify their reasoning modes of the interplay between subject matter, pedagogy, and ICT. By involving peer assessment, each preservice teacher becomes a case for others to reconsider what elements might be critical to successful and unsuccessful teaching. Moreover, the comments from peers can function as a replay for them to reanalyze their own performances. It helps preservice teachers to form hypotheses for refining their ICT artifacts and teaching performance.

It should be noted that the reflected evaluation phase takes place as the formative assessment and triggers the next cycle of MAGDAIRE. As shown in Fig. 6.1, the second round of MAGDAIRE starts at the guided development phase. The leading position in the cognitive apprenticeship should gradually shift from the mentoring team to the preservice teachers as they become more skilled team members. The main task of the mentoring team should put more emphasis on encouraging preservice teachers to iteratively test the hypotheses that they form in the reflected evaluation phase.

6.3 Studies to Evaluate the Effectiveness of MAGDAIRE

MAGDAIRE has been deployed in NTNU science teacher education courses since 2010. Each course lasts for 18 weeks. In the courses conducted in 2010 and 2011, Adobe® Flash® was chosen as the main tool to develop ICT-integrated instructional materials. The reasons behind this choice were as follows: (a) Flash can compile static images into dynamic animations through automatic procedures. It may reduce the threshold of multimedia development for preservice teachers; (b) Flash can add functions into animations to make them interactive. It may help preservice teachers to build tools to assist students in visualizing, sharing, and testing ideas; (c) Flash enables animations to record, retrieve, and exchange user information on the Internet. It may benefit preservice teachers in tracking students' learning progress; (d) Flash-made content is accessible to various computer systems and mobile devices (Adobe, 2014). The Flash-integrated instructional materials made by preservice science teachers should be usable for their future teaching. Several studies have been conducted along with the courses driven by MAGDAIRE. In the following paragraphs, we summarize the key findings of two of these studies (Chang et al., 2012; Chien et al., 2012).

Within our courses, preservice science teachers had to go through the MAGDAIRE model twice in one semester. They were asked to write down, periodically, their ideas about how to revise their ICT-integrated instructional materials and the reasons behind their decision as well. As shown in Table 6.2, Koehler et al.'s (2007) framework of TPACK was revised to analyze the preservice science teachers' reasoning patterns regarding the interplays between subject matter, pedagogy, and the use of Flash. Two main categories emerged to represent preservice teachers' modes of reasoning about revision in Flash-integrated instructional materials, including

Table 6.2 Coding protocol of preservice teachers' reasoning patterns

Main category	Subcategory (code)	Exemplar
Isolated Content (C) Pedagogy (P) Flash (F)	Content (C): reasoning on the actual science subject matter that is to be taught such as clarifying the facts, concepts, and theories of the chosen subject matter	We have to clarify the explanation for the greenhouse effect. When solar radiation passes through the earth's atmosphere, it warms the planetary surface. The greenhouse gases in the atmosphere absorb the infrared thermal radiation emitted from the planetary surface. Furthermore, the greenhouse effect already exists before the occurrence of the so-called global warming
	Pedagogy (P): reasoning on the processes and methods of teaching and learning; furthermore, how it encompasses overall educational purposes, values, and aims such as arranging students' learning steps	We should administer a test to students by the end of the course. It can help us to understand students' learning progress and offer us information to give students appropriate feedback
	Flash (F): reasoning on the use of Flash but not specifically related to the chosen subject matter or teaching strategies such as the operation of one particular function of Flash	The animation may suddenly break off while playing. Maybe we should use the frame-by-frame approach to compile the animation
Joint Content pedagogy (CP) Flash content (FC) Flash pedagogy (FP) Flash content pedagogy (FCP)	Content pedagogy (CP): reasoning on how particular aspects of a science subject matter are organized, adapted, and represented for instruction such as specifying one teaching strategy to complement one particular concept of the chosen subject matter but not related to the use of Flash	By comparing with other subjects in the domain of Earth Science, the learning unit of rocks puts more emphasis on students memorizing the facts. In addition to introducing the characteristics of varied kinds of rocks and the Mohs hardness scale, we should encourage students to compare the differences in the hardness, crystal system, crystal class, and streak between minerals to enhance their learning motivation
	Flash content (FC): reasoning on how the chosen science subject matter might be shaped by the application of Flash such as leveraging one particular function of Flash to present the chosen subject matter	Pictures of clouds can be embedded with more detailed information by utilizing ActionScript. We attempt to revise the scripts to make the clouds' characteristics such as cloud classification and cloud height appear when the cursor is moved onto the cloud pictures

(continued)

Table 6.2 (continued)

Main category	Subcategory (code)	Exemplar
	Flash pedagogy (FP): reasoning on how teaching as well as learning might be changed by the use of Flash such as leveraging one particular function of Flash to support one particular teaching strategy	The online testing system should be added, with ActionScript, to count students' scores. If a student enters wrong answers to a question too many times, the system will automatically force him/her to view the animation that explains the concept of the question
	Flash content pedagogy (FCP): reasoning on how the chosen science subject matter might be shaped by the application of Flash and the impact of such applications on teaching methods such as leveraging one particular function of Flash to present the chosen subject matter and support one particular teaching strategy	We plan to add interactive functions into the animation depicting sea waves to allow students to manipulate the variations in water depth along the coastline. Then, students can test their hypotheses of the relation between water depth and wave speed and then discuss the data they obtain from the animation with peers. It will facilitate students in exploring the relationship between water depth and wave speed. It also helps to explain the differences between deep and shallow waves

Adapted from Chang et al. (2012)

(a) isolated modes, indicating that content, pedagogy, or Flash were addressed in isolation, and (b) joint modes, indicating that content, pedagogy, and Flash were treated as intertwined elements. It was found that, as shown in Fig. 6.2, preservice teachers' reasoning patterns showed profound changes toward a more joint mode across time; they became aware that teaching with Flash should be a work blending subject matter, pedagogy, and Flash. As shown in Fig. 6.3, when compared to the first round of MAGDAIRE, the percentage of the summation of joint patterns at the second round of MAGDAIRE significantly increased from 50 to 80 % ($p < .05$).

Semistructured interviews were conducted to retrospectively infer possible mechanisms that facilitated the changes in preservice science teachers' reasoning patterns regarding the interplays between subject matter, pedagogy, and the use of Flash. The main themes of the interviews that relate to this chapter were (a) the contradictions in the preservice teachers' instructional planning processes within the context of MAGDAIRE and the solution to the said problems (e.g., what difficulty did you encounter in this course and how did you resolve it?) and (b) the preservice teachers' perceptions of the usefulness of the ICT-integrated materials they produced within the context of MAGDAIRE (e.g., will you implement your ICT-integrated materials in your future teaching practice? Why or why not?). An inductive analysis was conducted on the interview data. The documents of the preservice teachers' practice, including weekly coursework, videotaping for group presentations, discussion in an online forum, and comments on peers' work, were used to examine and refine the interpretation of the interview data.

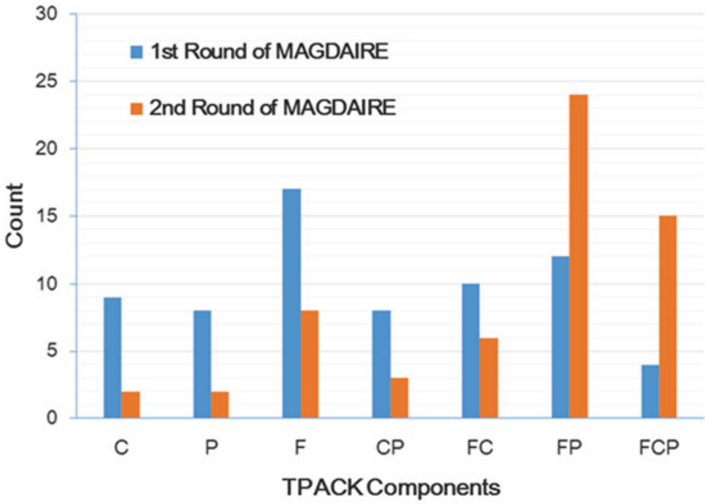

Fig. 6.2 Distribution of preservice teachers' reasoning patterns over phases (Data source of this figure: Chang et al., 2012). *C* content, *P* pedagogy, *F* flash, *CP* content pedagogy, *FC* flash content, *FP* flash pedagogy, *FCP* flash content pedagogy

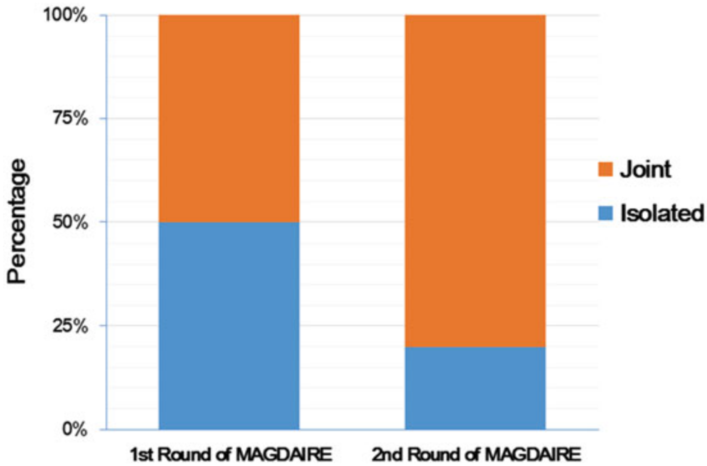

Fig. 6.3 Percentages of the isolated and joint patterns over phases (Data source of this figure: Chang et al., 2012)

The case of John's group from Chien et al. (2012) illustrates the changes in these preservice science teachers' reasoning and its relation to their practice. John's group chose the topic "typhoon" from the Taiwanese high school Earth Science textbook as the subject matter to be taught. Within the modeled analysis phase, they decomposed the teaching-with-ICT scenarios, which were demonstrated by the mentoring team, to justify why and how Flash should be used in teaching. John's group thought that Flash would be powerful to compile the textbook's static diagrams with explanatory text into animations. They believed that animations would attract students' attention and make the topic more comprehensible. Such simple means–end connections between the use of Flash and possible consequences became their major principle of ICT development; they tried to transform the content of the textbook into animations whenever possible in the guided development phase. However, John's group felt pretty depressed in the articulated implementation phase because the reactions of peers were far from what they expected. John's group had the impression that other preservice science teachers were indeed attracted by the transition effects of animations during the microteaching session, but they did not pay much attention to the scientific explanations embedded in the animations. Furthermore, John's group recognized that, while using Flash to compile animations was not difficult, it was a time-consuming process. They were afraid that, within the limited course time, their final ICT-integrated instructional materials would become fancy but superficial if they just kept focusing on transforming the entire textbook material into animations.

In the reflected evaluation phase, John's group came up with another approach to keep students' attention: constantly posing questions to students. This decision fundamentally changed the structure of their ICT-integrated instructional materials. They started reconsidering what concepts could be intertwined to form a series of interrelated questions and then decided to put more emphasis on the complex interaction between typhoon, topography, wind direction, and rainfall. The question *Why can a typhoon bring about various rainfalls over different locations?* was set as the main question driving the whole teaching procedure. In the second round of the guided development phase, John's group shifted their efforts to create an animation that depicted various typhoon pathways on a Taiwan map. As shown in Fig. 6.4, some interactive functions were added to the animation, enabling students to manipulate typhoon pathways. The data about rainfall and wind direction of typhoons Matsa, Haytang, and Dujuan (which struck Taiwan in 2003 and 2005) in different areas were also embedded in the animation. It was found that John's group's use of Flash became more content specific. In the second round of the articulated implementation phase, the main theme of John's group was to engage students in forming hypotheses about relations between rainfall, wind direction, and landforms. The role of animations was repositioned as the tool for students to generate answers rather than reading materials only. The interactive models of typhoons Matsa, Haytang, and Dujuan embedded in the animation were used to test students' hypotheses. The form of classroom activities became more interactive; it shifted from lecturing with Flash to interacting with Flash. As for the perspective of motivation empowerment, the value toward the use of Flash changed from "just for fun" to helping students to think harder.

Through reviewing peer performance, John's group noticed that the one-way linear connection between the three typhoon models would have difficulty in accommodating each student's learning pace as well as the teacher's teaching pace. They then increased referential links and nodes among each section of their ICT-integrated instructional materials to form various operating pathways. The method of

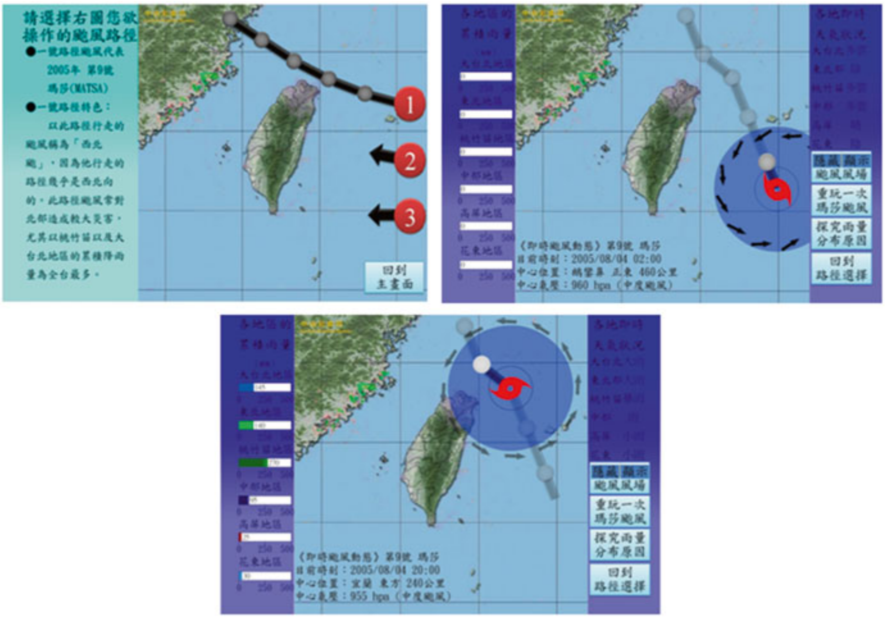

Fig. 6.4 Screenshots of John's group's ICT-integrated instructional materials

information presentation transformed from linear to nested formats. However, they were still concerned about whether students could be well prepared for future Earth Science tests from their teaching. After the second round of the reflected evaluation phase, John's group tried to add more systematic guidance and drill-and-practice exercises into the animations to help students prepare for tests. Their perceptions of teaching with ICT seemed to be in the transition between instructivist orientation and constructivist orientation. In sum, John's group reexamined the connections between the use of Flash and their practice from the views of subject matter selection, motivation empowerment, information presentation, activity design, and pedagogy transition. This case suggested that MAGDAIRE could evolve preservice science teachers' TPACK. Moreover, it stimulated these preservice science teachers to modify their reasoning modes and, consequently, revise their practice. Other cases delineating the changes in preservice science teachers' reasoning and practice within MAGDARE can be found in Chien et al. (2012).

6.4 Concluding Remarks

In this chapter, we introduced the MAGDAIRE model for renovating ICT courses in conventional teacher preparation programs. The TPACK framework was adapted as an analytic tool to examine the growth in preservice science teachers' knowledge about technology integration in teaching. The key findings indicated that MAGDAIRE facilitated preservice science teachers to reexamine the connections between the use of ICT and their teaching practice. Moreover, MAGDAIRE significantly enhanced preservice teachers' sensitivity to the transactional interplay between subject matter, pedagogy, and ICT. It is worthy to note that several of the preservice science teachers who participated in MAGDAIRE voluntarily entered the 2012 ICT-integrated microteaching competition that was held by the NTNU Office of Teacher Education and Career Service. Their teaching performances were appreciated by in-service teachers as well as teacher educators and won first and second prizes in the competition. This encouraging news makes us confident that MAGDAIRE has a positive and practical impact on preservice science teachers.

References

Adobe. (2014). *Adobe Flash runtimes statistics.* Retrieved March 25, 2015, from http://www.adobe.com/tw/products/flashruntimes/statistics.html

Angeli, C. (2005). Transforming a teacher education method course through technology: Effects on preservice teachers' technology competency. *Computers & Education, 45*(4), 383–398.

Chang, C.-Y., Chien, Y.-T., Chang, Y.-H., & Lin, C.-Y. (2012). MAGDAIRE: A model to foster pre-service teachers' ability in integrating ICT and teaching in Taiwan. *Australasian Journal of Educational Technology, 28*(6), 983–999.

Chien, Y.-T., Chang, C.-Y., Yeh, T. K., & Chang, K.-E. (2012). Engaging pre-service science teachers to act as active designers of technology integration: A MAGDAIRE framework. *Teaching and Teacher Education, 28*(4), 578–588.

Collins, A. (1988). *Cognitive apprenticeship and instructional technology*. (Report No. BBN-R-6899). Cambridge, MA: BBN Laboratories. Retrieved from ERIC Database. (ED 331 465).

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Hillsdale, NJ: Lawrence Erlbaum.

Dick, W., & Carey, L. (1996). *The systematic design of instruction* (4th ed.). New York: HarperCollins.

Govender, D., & Govender, I. (2009). The relationship between information and communications technology (ICT) integration and teachers' self-efficacy beliefs about ICT. *Education as Change, 13*(1), 153–165.

Heinich, R., Molenda, M., Russell, J. D., & Smaldino, S. E. (2001). *Instructional media and technologies for learning* (7th ed.). Englewood Cliffs, NJ: Prentice Hall.

International Society of Technology in Education. (2008). *National educational technology standards for teachers*. Eugene, OR: Author.

Jang, S.-J., & Chen, K.-C. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. *Journal of Science Education and Technology, 19*(6), 553–564.

Koehler, M. J., & Mishra, P. (2005). Teachers learning technology by design. *Journal of Computing in Teacher Education, 21*(3), 94–102.

Koehler, M. J., Mishra, P., Hershey, K., & Peruski, L. (2004). With a little help from your students: A new model for faculty development and online course design. *Journal of Technology and Teacher Education, 12*(1), 25–55.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education, 49*(3), 740–762.

Mahdizadeh, H., Biemans, H., & Mulder, M. (2008). Determining factors of the use of e-learning environments by university teachers. *Computers & Education, 51*(1), 142–154.
Ministry of Education. (2001). Information education report [in Chinese]. Taipei, Taiwan: Author. Retrieved from http://content.edu.tw/primary/info_edu/tp_tt/content/nerc-1/law/teacher_point.htm
Ministry of Education. (2008). *White paper on information technology education for elementary and junior high schools 2008–2011*. Taipei, Taiwan: Author.
Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.
Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*(5), 509–553.
Organization for Economic Cooperation and Development. (2008, May). *New millennium learners: Initial findings on the effects of digital technologies on school-age learners*. Paper presented at the OECD/CERI International Conference on Learning in the 21st Century: Research, Innovation and Policy, Paris, France. Retrieved from http://www.oecd.org/site/educeri21st/40554230.pdf
Organization for Economic Cooperation and Development. (2010). *Inspired by technology, driven by pedagogy: A systemic approach to technology-based school innovations*. Paris: Author. doi:10.1787/9789264094437-en
Pelgrum, W. J., & Doornekamp, B. G. (2009). *Indicators on ICT in primary and secondary education* (Report No. EACEA-2007-3278/001-001). Retrieved from Education, Audiovisual & Culture Executive Agency website: http://eacea.ec.europa.eu/llp/studies/documents/study_on_indicators_on_ict_education/final_report_eacea_2007_17.pdf
Reiser, R. A. (2001). A history of instructional design and technology – Part II: A history of instructional design. *Educational Technology Research and Development, 49*(2), 57–67.
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–31.
Sørebø, Ø., Halvari, H., Gulli, V. F., & Kristiansen, R. (2009). The role of self-determination theory in explaining teachers' motivation to continue to use e-learning technology. *Computers & Education, 53*(4), 1177–1187.
Thompson, A. D., & Mishra, P. (2007–2008). Breaking news: TPCK becomes TPACK! [Editorial]. *Journal of Computing in Teacher Education*, *24*(2), 38 & 64.
Wilson, E. K. (2003). Preservice secondary social studies teachers and technology integration: What do they think and do in their field experiences. *Journal of Computing in Teacher Education, 20*(1), 29–39.