Chapter 8
Designing Serious Educational Games (SEGs) for Learning Biology: Pre-service Teachers' Experiences and Reflections

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Introduction

It goes without doubt that we are living in a digital era where technology is shaping the way we live, think, and learn. Websites are becoming more popular information resources because of its convenience, and we now have online access to a multitude of learning materials and activities. Today more than half of the parents believe that videogame play provides mental simulations and that it is a positive part of child's life (Entertainment Software Association 2013). As a result, various methods have been created to harness the power of technology to support our education. The use of video games in training and learning environments, known as Serious Games (SGs) or Serious Educational Games (SEGs) (Annetta 2008), is one of the increasingly relevant trends which transforms our education because new digital innovations has significantly changed our pedagogical perspectives. Supporters of SEGs claim that video games have huge potential as a vehicle for learning and research evidence also shows its positive impact on students motivation, engagement, and learning outcomes, such as conceptual understandings and science process skills (e.g. Cheng and Annetta 2012; Clark et al. 2011; Connolly et al. 2012; Echeverría et al. 2011; Gee 2003a, b; Giannakos 2013; Lim 2008; Paraskeva et al. 2010; Prensky 2001; Sánchez and Olivares 2011). Although there remain some debates about the educational potential of video game play, the idea becomes clear that well-designed serious gaming do promote some educational goals as long as they can be done right. The type of video games and the desired ends of learning are particularly the issues that should be addressed.

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The use of SEGs is particularly important to science education, as many scientific concepts which are invisible in the real world and generally abstract and difficult to grasp can be portrayed in the virtual environment. In addition, scientific inquiry ability and problem-solving skills often require long-term cultivation and repeated practices. The complex structure of science, the trouble of reasoning about abstract concepts, and the challenges that arise in problem solving and scientific inquiry often cause students to have a sense of anxiety and difficulties in learning science compared to other subjects (Halff 2005). However, SEGs which combine game characteristics with science content not only motivate and absorb students in the embedded science learning activities, but also increase the probability of bridging virtual reality into reality in numerous dimensions. Thus they can provide students with authentic learning, an instructional approach focuses on learning through experimentation and real-world problem solving, wherein they are allowed to repeatedly experience things that are impossible in the real world without worries of real life consequences (Cheng et al. 2011).

After making a comprehensive survey of literature, we see that most of the available evidence focuses on students' science learning through SEG play; however, research that emphasizes pre- and in-service teachers' perceptions and implementations of using SEG or their professional development through designing an SEG is sparse. People, especially teachers, consider creating a game-based learning environment to be expensive and arduous. Moreover, although many governments worldwide have invested money in developing SEGs that facilitate science learning in elementary and secondary settings (e.g. http://www.fas.org/programs/ltp/games/), accessible resources of SEGs in Taiwan or projects which are funded by Taiwan's government endeavoring to create and develop SEGs are relatively deficient. For example, there are not many researchers doing the research related to serious gaming or not many SEGs or SEG-based instructions available for use in middle schools. All of these make it become more challenging and difficult for Taiwanese teachers to integrate SEGs into science classrooms.

Therefore, in fall semester 2012 a two-credit, 18-week-long course, entitled *Computers in Teaching and Learning Biology*, was delivered to 12 students who were enrolled in a teacher education program (pre-service teachers). In this course, students learned Adobe Flash™ and programming of ActionScript 3.0 and were asked to develop SEGs for biology learning by themselves. They were required to present their SEG idea and script (SEG prototype) for the midterm and demonstrate their SEG as the final exam. In-depth interviews with every pre-service teacher and instructor were conducted and recorded after the conclusion of the semester to collect data regarding feedback and comments towards this course, as well as the challenges and difficulties encountered from the perspective of students and instructor respectively.

This chapter consists of three sections. The first section discusses the theoretical framework underpinning this study. This is followed by a brief introduction of the details of the course, including how it was designed and implemented. Lastly, the major part of this chapter which focuses on the obtained results about the perceptions and challenges encountered in this course from the perspective of instructor, and pre-service teachers who completed this course and finished designing their own SEGs. Implications derived from the results, recommendations and suggestions for future implementation are also provided.

Teacher Education Courses and Technology Integration

Research indicates that teaching with technology supports student science learning in many aspects, such as the facilitation of conceptual understanding and the improvement of problem-solving abilities (Lee et al. 2010; Vogel et al. 2010). In views of the educational potential of technology use, many governments including Taiwan have developed plans to intensify their investments in constructing educational settings wherein instructors and students are encouraged and expected to teach and learn, using technology. Policy making has also responded to these acts. As a result, government institutions in charge of education worldwide have all placed a lot of effort into integrating technology (or information and communication technology; ICT) into national curriculum standards or guidelines. The newly released *Next Generation Science Standards* (NGSS), based on the *Framework for K-12 Science Education* which has its roots deeply in the most current research on science and science education, clearly identifies the importance of scientific and technological literacy for a well-educated society (http://www.nextgenscience.org/). A major commitment of the initiative is to integrate engineering/technological design into the structure of K-12 science education, in order to engage our next generations to become well-prepared citizens in the twenty-first century society who are capable of solving the major societal and environmental challenges they will face. Likewise, the *K-9* and *high school curriculum guidelines* published by Taiwan's Ministry of Education also aims to bring up K-12 students in Taiwan as individuals with knowledge and skills to deal with information and solve problems with technology. In recent years, they further encouraged the use of innovations in the teaching of all subjects to increase teaching quality by integrating technology and pedagogy (Ministry of Education 2008).

Despite the best intentions of administrators endeavor to increase technology access in educational settings, the most challenging issue remains, are teachers competent or well-prepared for teaching with technology? It is obvious that only when teachers are competent of carrying out the task of teaching with technology, do the integration of educational innovations succeed. So if the answer is that they are not capable of doing so, how can we expect students to acquire ICT knowledge and skills, and to learn with the acquired knowledge and skills, and furthermore, to design and create using those knowledge and skills? Research shows that over 90 % of teachers had access to one or more computers or other technological facilities in the classrooms every day. However, less than 50 % of teachers reported that they or their students actually use computers in the classrooms during instructional time on a regular basis (Gray et al.2010). Even if teachers do use the equipped technologies, they are likely to employ them merely for administrative support rather than instructive support, or mainly for informative or expressive purposes of supporting their existing practices instead of engaging and facilitating students in higher-order thinking activities (Wozney et al. 2006). It has been reported that teacher self-efficacy, confidence to perform specific tasks, significantly affects the extent, as well as the way, teachers use technology for everyday instructional practices in classrooms (Paraskeva et al. 2008).

Teacher education had always played a major role in preparing pre- and in-service teachers with knowledge, attitudes, and skills required to teach effectively in the classrooms, and the lack of properly integrating technology into classrooms can be seen as a reflection of the inadequacy of teacher preparation programs provided by teacher education institutes. The National Education Technology Standards for Teachers (NETS•T) require effective teachers to be capable of designing, implementing, and assessing relevant learning experiences which incorporate digital tools and resources to facilitate and inspire student learning and creativity (http://www.iste.org/standards/nets-for-teachers). However, teacher preparation courses related to effective teaching with technology offered by teacher education institutes in Taiwan are relatively few. Moreover, almost all the technology literacy-related courses are elective, hence pre-service teachers might not have to take any course empowering them to succeed in technology integration prior to graduation. Pre-service teachers even felt that many experiences and resources in teacher preparation programs are insufficient and not helpful for technology-integrated teaching (Singer and Maher 2007). Unfortunately, there remains a gap between what is taught in the teacher preparation programs and how teachers use technology effectively in the real classrooms.

Technological Pedagogical Content Knowledge (TPACK)

Obviously, successful and effective integration of technology into instructions is never as simple as merely using innovations for administrative purposes or supporting the existing practices in the classrooms, teachers are actually required to have sufficient pedagogical content knowledge (PCK) and technological knowledge. In other words, the approaches related to teaching with technology have transferred from techno-centric, which merely focuses on technology and the knowledge and skills to use various technologies, to techno-pedagogical integration, which places much more emphasis on putting both pedagogy and technology into practice in the integration process (Yurdakuli et al. 2012).

In order to prepare pre-service teachers for their future teaching career (which likely requires the integration of technology), teacher education programs have to help pre-service teachers to construct their own technology-supported pedagogical and technology-related classroom management knowledge and skills. The Technological Pedagogical Content Knowledge (TPACK) is a model that provides directions for teacher education programs to evaluate the effectiveness of their courses and prepare pre-service teachers as qualified educators with the ability to integrate technology into pedagogical strategies and content representations (Chai et al. 2011). TPACK, an expansive framework based on Shulman's (1986) concept of pedagogical content knowledge (PCK), aims to make three aspects, content, pedagogy, and technology into a whole to describe the required knowledge of using technology in a way which is contextually authentic and pedagogically appropriate in the educational settings for an effective teacher.

Representing the intersections among knowledge of pedagogy, content, and technology, the framework of TPACK includes seven dimensions of professional knowledge, namely, the Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK) and Technological Pedagogical Content Knowledge (TPACK) (Mishra and Koehler 2006). We introduce these seven dimensions as below (Abbitt 2011; Chai et al. 2011):

1. Pedagogical Knowledge (PK): Knowledge about the nature of processes and practices or methods of teaching and learning (e.g. instructional strategies, classroom management, etc.)
2. Content Knowledge (CK): Knowledge of the actual subject matter that is to be learned or taught (e.g. biology, physics, etc.)
3. Technological Knowledge (TK): Knowledge and skills required to operate particular technologies for information processing, communication, and so forth.
4. Pedagogical Content Knowledge (PCK): Knowledge of using different strategies and teaching practices to represent and formulate a given subject matter.
5. Technological Pedagogical Knowledge (TPK): Knowledge of the affordances and constraints of using technology for facilitating pedagogical approaches.
6. Technological Content Knowledge (TCK): Knowledge of using technology for representing or exploring a given subject content.
7. Technological Pedagogical Content Knowledge (TPACK): Knowledge of appropriate integration among content, pedagogy, and technology for facilitating students learning.

The TPACK framework has been widely used as a lens through which to observe and think about teacher knowledge and practice of teaching with technology in research and many evaluation studies, as most of the current research has made a lot of effort to develop valid and reliable tools and methods for assessing the obtained knowledge of teachers in terms of evaluating teacher preparation experiences. However, teachers' understandings of TPACK should also be embedded in their created learning environment. In addition to considering TPACK as a framework for evaluating teacher skills, it might be more interesting to see TPACK as a framework for teachers to design digital learning environments, such as games and simulations (Gibson 2008).

Gibson (2008) argues that in order to produce an SEG, teachers are required to improve their understandings of content, technology, and pedagogy and consequently integrate these understandings into a highly interactive innovation which the audience interacts with. Even though engaging teachers in designing an SEG is time- and effort- consuming and the process of development is complex, it is worthwhile as the whole process powerfully situates teachers in an authentic and meaningful context where personal motivation and relevance are much more increased. Also thinking of how to produce an effective SEG would require teachers to deeply consider: (a) the prior knowledge students bring to the game; (b) logical progression of the content; (c) effective scaffolding of student thinking/decision-making; and (d) ongoing formative assessment. All of this has been known for decades to be crucial for effective teaching and learning. In other words, to design and develop an SEG which provides players with a highly interactive experience not only benefits the audiences, the teachers who create the SEG do actively learn through the whole process of making SEG. Hence, the requirement of designing an SEG facilitates pre-service teachers to actively construct their own TPACK and in turn embeds their TPACK into the created SEGs. In short, the courses offered by current teacher education programs do not seem to prepare teachers with competence for teaching with technology and the process of designing an SEG might be helpful in facilitating teachers to construct their own TPACK which is required for effective integration of technology into pedagogical practices.

Project-Based Learning

Because of the aforementioned issues the course *Computers in Teaching and Learning Biology* was offered with an aim to provide pre-service teachers with an experience of project-based learning (in this case, project refers to the development of an SEG). Project-based learning has its roots in Dewey's (1938) idea of learning by doing. It is an instructional approach and offers a contextualized learning activity wherein learners are presented with problems to solve or product to develop. It is defined as "a model that organizes learning around projects" and these projects are "complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work autonomously over extended periods of time; and culminate in realistic products or presentations" (Thomas 2000, p. 1). Thomas (2000) further suggests five criteria for defining an exemplary project of project-based learning:

1. The project is the central teaching strategy, not peripheral one to the curriculum. In project-based learning, students encounter and learn the central concepts of disciplines and construct understanding via the project.
2. The project is focused on questions or problems which are so ill-defined that "drive" students to encounter (and struggle with) the central concepts and principles of a discipline.
3. The project involves and engages students in a goal-directed, constructive investigation including inquiry, knowledge building and resolution. The project is quite different from an exercise as it cannot be easily carried out by students merely with the application of already-learned information skills.

4. The project is student-driven to some significant degree. It allows a great deal of student autonomy and doesn't have a predetermined outcome or path.
5. The project is realistic, rather than school-like. It mainly focuses on authentic problems or questions and where solutions have the potential to be implemented.

The idea of learning by doing is consistent with the perspective of constructivist learning theory which provides a philosophical view on how people come to understand. Constructivism has influenced the practice of teaching and the design of learning environment greatly since it considers our understanding as being contextualized in our interactions with the environment, and also that learning is stimulated and results from individual's cognitive conflict or puzzlement and knowledge evolves through social negotiations (Savey and Duffy 1985). It turns out that project-based learning is a constructivist approach which creates a learning environment supporting engagement in problem-solving situations where students actively construct their own knowledge. Research has identified many positive effects of project-based learning, including the development of positive attitudes towards learning as well as the improvement of abilities on problem-solving, critical thinking, collaboration and so forth. Moreover, it results in better learning outcomes and turns students into active problem solvers rather than passive knowledge receivers (Gülbahar and Tinmaz 2006). It is a systematic teaching method concentrating both on the end-product and the experience of the process. In terms of our case, the use of project-based learning focuses on not only the SEGs created, but also the process of creating the SEGs.

However, how does one implement an effective project-based instruction? Barron et al. (1998) have identified four important design principles for reaching this tough goal. The first principle is that educators have to clearly define learning-appropriate goals that lead to deep understanding of the how and why of a project in advance. Then, suitable scaffolds of providing a series of problem-solving activities and contrasting cases need to be offered before projects are really carried out. The third design principle is the provision of frequent opportunities for formative assessment and revision, which allows both students and instructors to realize what is and isn't being learned so that the instructions can be adjusted accordingly and immediately. Finally, social organizations that promote participation and support active, collaborative learning should be encouraged.

The Course *Computers in Teaching and Learning Biology*

Computers in Teaching and Learning Biology is a two-credit, elective course of the Department of Biology at the National Changhua University, Taiwan for undergraduates who are majoring in biology and are enrolled in teacher education program. The course is of particular importance in the entire teacher education curriculum offered by the Department of Biology because it is the only course in the curriculum which aims to foster skills of pre-service teachers in designing digital learning environments and practically integrating technology with biology teaching and learning. The instructor, who is a science education researcher as well as experienced computer programmer, has many years of experience in game development. With the help of two science education experts whose research interests have focused on educational technology, the instructor designed the course to be project-oriented and design-based in such a way that students would construct their own knowledge and skills by collaborating with their group members to design and develop their own SEGs. Five learning objectives were addressed:

1. To enhance Information Communications Technology (ICT) competences and technological/engineering literacy.
2. To improve Technological Pedagogical Content Knowledge (TPACK).
3. To develop proficiency in logic/analytical thinking.
4. To cultivate abilities of creative thinking and problem solving.
5. To foster skills of communication and collaboration.

Although there are many tools which allow entry-level novices to easily create a game without programming (e.g. GameMaker http://www.yoyogames.com/gamemaker/studio), the less flexibility for expansion of those tools/engines doesn't allow game creators to take as much control as pure coding would. The benefit of making games without programming soon becomes a disadvantage because students don't really experience what real-life game programmers/engineers do. Hence, we finally decided to employ ActionScript 3.0™ as the programming language taught in this course. There are five reasons that ActionScript 3.0™ was chosen instead of other programming languages (Agarwal 2010; Brimelow 2008):

1. Adobe Flash™ is one of the widely used tools for e-learning, and ActionScipt 3.0™ is designed to be primarily used for the development of Web-based games and rich Internet applications with streaming media targeting Adobe Flash Player™ platform.
2. It is an object-oriented programming language with reusable code bases. The visual design of ActionScript 3.0™ is more accessible and comprehensive.
3. It includes strictly debugging and troubleshooting functionality allowing for easier error checks.
4. Programming structure of ActionScript 3.0™ is on the same level as writing in other higher-level languages like Java and C#, which makes it easier for students to get into more advanced programming someday.
5. Work in ActionScript 3.0™ leads directly to portability among other Adobe technologies (e.g. Adobe Integrated Runtime™ (AIR)), which allows singular experience to be delivered across multiple devices.

The course was a two-credit, 18-week-long course and the course syllabus is presented as Table 8.1. There were a total of 12 students registered in this course. They were finally divided into four groups (2–4 individuals/group) to carry the project out by group collaboration. In this course, students were taught basic principles

Table 8.1 Course syllabus of Computers in Teaching and Learning Biology

Weeks	Topics/tasks	Laboratory assignments
1	Introduction to Adobe Flash™ and ActionScript 3.0™ Object-oriented programming Introducing flowcharts of game programming	Dividing students into groups (2–4 students/group) Discussing SEG script
2	Timeline, layer and frame Event and function	Development of flowcharts
3	Variables, objects/classes, movie clip properties Path and the framework of programming	Development of storylines Finish initial idea of SEG script
4	Playing with text Loops	Assignment 1 (loops)
5	Statements	Assignment 2 (statements)
6	Keyboard event – events for keyboard	Assignment 3 (button)
7	Arrays	Assignment 4 (collision with motion tweening)
8	Add sounds and audio effects Add videos	
9	Midterm: presenting SEG prototype	
10	Presenting game sample-collision detection	Assignment 5 (collision with motion tweening)
11	Demonstrating game sample-random	
12	Demonstrating game sample: group 1	Discussion and practice of programming that group 1 needs
13	Demonstrating game sample: group 2	Discussion and practice of programming that group 2 needs
14	Demonstrating game sample: group 3	Discussion and practice of programming that group 3 needs
15	Demonstrating game sample: group 4	Discussion and practice of programming that group 4 needs
16	Demonstrating game sample	Review of ActionScript 3.0™
17	Final exam-ActionScript 3.0™ Final project Q&A	
18	Final project showcase	

of ActionScript 3.0™ programming so that they can use Adobe Flash Player™ as a platform to demonstrate their created SEGs.

The course schedule can be divided by midterm into two parts. Before midterm (week 1–8), the instructor placed much more emphasis on basic concepts and fundamentals of ActionScript 3.0™. After midterm (week 10–16), the instructor in turn introduced specific programming which each group needs according to their SEG script. Two presentations and one paper-and-pencil test were required. Each group had to present game idea and script (SEG prototype) in the midterm (week 9) and demonstrate the SEG (end-product) they created in the end of the semester (week 18).

Table 8.2 Criteria for assessing student performance

Criteria	Percentage
Participation	10
Homework assignments	30
Final exam (paper-and-pencil test)	10
Midterm presentation of SEG prototype	20
Final demonstration	30

Moreover, there was an exam assessing what they had learned about ActionScript 3.0™ in the final (week 17). In addition to in-class practices, five homework assignments were also distributed to ensure that students did learn the programming, which were taught. Although the 18-week lectures mainly emphasized the development of programming skills, each group had to regularly discuss their SEG idea and script with a science education expert at times out of classes to ensure the validity of scientific content and pedagogical methods embedded in their games.

For the midterm presentation of SEG prototype and final demonstration of the created SEG, students were required to clearly address the below questions:

- What is the main idea of creating the SEG? What is the originality of the SEG?
- What are the learning objectives?
- What are the scientific concepts embedded?
- How does the art design appear? (prototype)
- What are the programming needed? (prototype)
- Presenting the whole game script (including storylines, scenes, characters, user interface, etc.) (prototype)
- Demonstrating the created SEG (final product)

The entire course was graded according to the criteria provided by the instructor (Table 8.2).

Research Design

To explore the pre-service teachers' experiences and reflections on designing SEGs for learning biology, several tape-recorded in-depth interviews with every pre-service teacher and instructor were conducted after the semester. The pre-service teachers were asked to answer several leading questions. However, a semi-structured method was employed, which allows conversational, two-way communication between the interviewer and the person being interviewed to probe for details. These leading interview questions are presented as below:

1. What was your motivation for taking this course?
2. What have you learned from this course?
3. Are there any distinctions between your expectations and the actual practices of this course? If yes, please tell me about the distinctions?

4. What are your perceptions about the learning processes in this course?
5. Have you ever felt frustrated during this course? If yes, how did you overcome the frustration?
6. What are your suggestions for the instructor on his teaching practices in this course?
7. What are your recommendations on the arrangement of the course?
8. Do you think that this course is helpful for your instructional practices in the future?

Moreover, the instructor of the course was also interviewed in this study with the following leading questions:

1. What were the difficulties for you when teaching the pre-service teachers to make serious educational games?
2. According to your observation on the pre-service teachers' learning in making serious educational games, what was the most difficult part for them?
3. After teaching these pre-service teachers to make serious educational games, how will you modify your course design in the future?

Each interview with each interviewee lasted about 15–20 min. During the interview, each pre-service teacher or instructor was required to provide their feedback and thoughts towards this course and challenges and difficulties encountered in the course. We collected data and heard different voices from the perspective of the students and the instructor. With interviewee permissions, all the interviews were transcribed verbatim into transcriptions for data analysis. These transcriptions were first separated into narrative segments that expressed a specific idea/concept or described a particular experience, and then these narrative segments were again read repeatedly by researchers to find emerging categories. Recurring and qualitative distinct themes, conclusions, and explanations were drawn from these categories. There is one thing which should be noticed. The participants were required to provide their response which they thought was the most important for most of the questions, so most of the response categories only have 12 total responses. Although we can obtain the most important factors affecting participant learning in this course, other potential important data might likely be lost, which should be acknowledged in the future work.

Results

Pre-service Teachers' Motivation for Taking the Course

As shown in Table 8.3, about half of the pre-service teachers mentioned that they took this course because it teaches them to design and make SEGs, which they could use in their biology teaching. For example, Pre-service Teacher #12 mentioned, "I took this course because I could design and make a Serious Educational

Table 8.3 The pre-service teachers' motivation on taking the course (n = 12)

Motivation	n
1. Can design and make an educational game, and use it in biology teaching	5
2. Curious about how to use educational game in teaching	3
3. Can learn how to make animations with flash	3
4. It seems fun	1

Game by myself. It seems very interesting. I could also use it in my biology classes". Moreover, three of the pre-service teachers took this course due to curiosity about the use of SEGs in biology teaching. For instance, Pre-service Teacher #11 mentioned, "I took this course because I was curious about how to use Serious Educational Games in biology teaching." However, it should be noted that three pre-service teachers in this study mentioned that they took this course for the reason that they could learn how to make animations with Flash. For example, Pre-service Teacher #3 mentioned that "I took this course because I wanted to learn Flash in this course."

It seems that most of the pre-service teachers in this study had some basic understanding regarding SEGs. As a result, the basic understanding about SEG motivated them to take this course focusing on designing and making SEGs.

What Did the Pre-service Teachers Learn from This Course?

Learn from the Course

According to Table 8.4, only two pre-service teachers mentioned that they learned how to design SEGs. Pre-service teacher #5 mentioned that "I learned that if I wanted to design a Serious Educational Game, what I should take into account. For example, I should consider what my students could learn from playing the serious educational game. Also, I learned about how to make a simple Serious Educational Game." Moreover, a pre-service teacher (Pre-service Teacher #1) mentioned that "I learned how to transfer content knowledge of a specific topic into a Serious Educational Game in this course", and another pre-service teacher (Pre-service Teacher #2) pointed out that "In this course, I learned about how to work collaboratively with others." These descriptions stated by the aforementioned pre-service teachers are exactly in alignment with the learning outcomes expected by the instructor.

However, half of the pre-service teachers reported the skills for programming with Flash as the learning outcome derived from taking this course focusing on designing and making SEGs. The Pre-service Teacher #6 mentioned that "I learned how to program with Flash, and became familiar with using computers." Moreover, four of the teachers mentioned that they learned about designing and making games

Table 8.4 The pre-service teachers' self-reported learning outcomes derived from taking the course (n = 12)

Learning outcome	n
1. How to program with flash	6
2. Designing and making games	4
3. How to design an serious educational game	2
4. Transferring the domain knowledge into a serious educational game	1
5. How to collaboratively work with others	1

Table 8.5 The distinctions between the pre-service teachers' expectations and the actual practices of this course (n = 12)

Distinction	n
1. More efforts should be paid during taking this course	5
2. Making a game is not so easy	4
3. Programming with flash is difficult	3
4. The need for collaboration in making a serious educational game	1

throughout the course. For instance, the Pre-service teacher #3 mentioned that "I learned a lot in this course. At first, we learned how to design a game. Then, we learned how to program the modules with Flash, and made a whole game."

It is surprising that most of the pre-service teachers may have placed their focus on learning to program with Flash or making games, rather than designing and making "Serious Educational" games. This may be due to the fact that the pre-service teachers in this study lacked relevant knowledge or ability in programming with Flash, hence their insufficient prior knowledge in programming may have distracted their attention during their learning processes. Consequently, they paid most of their attention on programming rather than integrating educational purposes into the games they designed and made.

The Distinctions between the Pre-service Teachers' Expectations and the Actual Practices of This Course?

Only 2 of the 12 pre-service teachers expressed that the actual practices of the course were almost the same as what they expected before taking the course. However, the other teachers mentioned various distinctions between what they expected and the actual practices of the course. Table 8.5 summarizes the distinctions that the pre-service teachers mentioned. Most of the pre-service teachers, such as Pre-service teacher #7, mentioned that "The teacher told us that lots of efforts would be needed in developing a game. However, the efforts I put in during this course were much more than I expected." Besides, some pre-service teachers also

Table 8.6 Pre-service teachers' perceptions of their learning processes (n = 12)

Perception	n
1. Experiencing interesting and meaningful learning	5
2. I spent a lots of time in coding	2
3. Experiencing student-centered instruction	1
4. The loading increased; however, there was insufficient time	1
5. More detailed explanations from the instructor will be helpful	1
6. I could not follow the teacher's instruction	1
7. Lots of homework to be done after school	1

mentioned that making a game was not so easy. Pre-service Teacher #6 expressed that "At beginning, I felt that it would not be too difficult to design and make a Serious Educational Game. However, I was able to design a game but was not able to finish making it." Other pre-service teachers, such as Pre-service Teacher #10 mentioned, "I spent lots of time in programming with Flash. However, it was still very difficult for me."

It seems that the workload of this course was too heavy for the pre-service teachers. In particular, for the pre-service teachers without prior knowledge in programming with Flash, as it took them substantially longer periods of time to complete their game design.

Pre-service Teachers' Perceptions of Their Learning Processes

As revealed in Table 8.6, five of the pre-service teachers perceived their learning processes as "interesting and meaningful." For example, Pre-service Teacher #3 mentioned, "I felt that this course is interesting." Another one, pre-service Teacher #4, mentioned, "In traditional classes, it is always teacher-centered; however, in this course, we experienced learner-centered instruction in class."

Yet, it is worthy to note that six course participants did not report the learning process was either interesting or student-centered. In fact, they expressed less positive perceptions regarding this course and perceived the course as very effort- and time- consuming because they had to spend much time in coding and homework assignments. For example, Pre-service Teacher #1 expressed that "The loading of the course gradually increased; however, there was insufficient time for me to study it." Pre-service Teacher #8 mentioned, "I felt lots of homework to be done after school. However, I did not have sufficient time."

The explanations offered by the instructor might be another important issue as one participant needed more detailed explanations from the instructor and one felt the instruction offered by the teacher is hard to be followed. Pre-service Teacher #2 mentioned, "I was not so good in programming. Therefore, I always felt that more detailed explanations from the instructor would be needed and helpful." Pre-service Teacher #8 mentioned, "I felt lots of homework to be done after school. However, I

Table 8.7 Pre-service teachers' frustrations during taking this course (n = 12)

Frustration	n
1. Programming and coding	8
2. Completing the homework	1
3. How to integrate what I have learnt into the game	1
4. How to implement our design	1
5. Low quality of the game	1

did not have sufficient time." It turns out that the major challenge for these pre-service teaches probably lies on their lack of prior knowledge of programming, suggesting the very need for modifying the design and arrangement of this course in the future.

Pre-service Teachers' Frustrations During Taking This Course

The tape-recorded interviews in this study also explored what the pre-service teachers felt frustrated during taking this course. Only Pre-service Teacher #12 did not feel frustrated during taking this course, while the others mentioned various frustrations. However, it is interesting to find Pre-service Teacher #12 got the lowest score on this course, although he said that he did not encountered any frustration in this course.

As shown in Table 8.7, most of the teachers mentioned that they felt frustrated in programming and coding, and one of them (Preservice Teacher #1) also mentioned that she felt frustrated because she was always not be able to complete the homework on time. Compared with aforementioned frustrations, some teachers expressed their frustrations were caused by further personal commitments. For example, Pre-service Teacher #5 expressed that "I felt frustrated when I tried to integrate what I have learnt into the Serious Educational Game we designed and developed." Pre-service Teacher #10 said, "I felt frustrated. When we had finished the game design (prototype), we could not implement our game design (end-product)." Also, Pre-service Teacher #6 mentioned that "I felt so frustrated because the quality of the Serious Educational Game we made is low." It seems that the more efforts were made by these pre-service teachers in this course, the more frustrated they might be oriented to feel. These frustrations might be a result from the pre-service teachers' insufficient experiences of mastering in designing and making SEGs.

The Ways that the Pre-service Teachers Overcome Their Frustrations

Table 8.8 shows that discussing with peers or teachers in classes is the most common way for these pre-service teachers to overcome the frustrations they had. Besides, some pre-service teachers tried to overcome their frustrations by using

Table 8.8 The ways that the pre-service teachers overcome their frustrations (n = 12)

Way of overcoming frustration	n
1. Discussing with team members and then discuss with the teacher in classes	12
2. Making use of other resources, such as Google, YouTube, other books	4
3. Practicing with the instructional materials provided by the instructor	1
4. Asking the instructor after school	1

other online resources, such as the tutorials provided on Google™ or YouTube™, to find out how to do programming with Flash™. Also, they might read books about programming. Pre-service Teacher #3 also stated, "when I felt frustrated, I would practice again with the instructional materials provided by the instructor."

It is admirable that most of the pre-service teachers spent much time discussing with peers or teachers in classes, yet only one tried to seek assistance from the instructor after classes. Pre-service Teacher #4 mentioned, "I always discussed with the instructor on Facebook after school when I did not know how to solve the problems." The reason might be due to the issue that these pre-service teachers didn't know the instructor none the less provides assistance anytime even after classes, so they felt hesitated to ask. It suggests that it would be much more helpful if more scaffolds, such as available resources or synchronous and /or asynchronous interactions after school, were provided in the future.

Pre-service Teachers' Suggestions on Instruction

The pre-service teachers in this study provided three major suggestions for the instructor:

1. More basic instruction in programming and coding would be helpful: For instance, Pre-service teacher #2, #3, and #6 mentioned that "If the instructor could provide more basic instruction on programming and coding, we might be able to progress in programming and coding step by step."
2. More instructional time would be needed: Five pre-service teachers (#4, #5, #9, #10, and #12) stated that more instructional time would be needed because both designing and making Serious Educational Games were required in this course.
3. Classroom videos and more detailed handouts for students would be helpful: Pre-service Teacher #7 and #11 advocated for classroom videos and more detailed handouts for students. Then, the students could practice and rehearse by themselves after school.

Pre-service Teachers' Recommendations on the Arrangement of the Course

The pre-service teachers in this study also provided three major recommendations on the arrangement of the course:

1. The instructional time of the course should be extended: Half of the pre-service teachers suggested that the course should be extended to a two-semester course.
2. The loading of homework should be reduced: Five pre-service teachers mentioned that if the loading of homework is too heavy, the students may feel frustrated.
3. The participants of the course should be limited: a pre-service teacher also advocated that the class should be a small-sized one. Then, every student will have more time discussing with the instructor in classes.

Pre-service Teachers' Attitudes towards the Usefulness of the Course for Their Instruction in the Future

Except for Pre-service Teacher #12, all pre-service teachers expressed positive attitudes towards the usefulness of the course for their biology teaching in the future. Through the process of creating their own SEGs, they got a better understanding about how to visualize the scientific concepts which are abstract into concrete representations. They also gained a clearer idea about what it is meant by authentic, meaningful learning and how to implement it in their biology classes to provide their students a context wherein they can apply the learned knowledge to solve problems in novel situations. These are perceived helpful for their biology teaching in the future.

However, it is interesting to find that two felt positive toward the course, yet low desire to further develop another SEG in the future was found. Pre-service teacher #6 mentioned that "I think taking this course is helpful for my instruction in the future. However, I will not develop a Serious Educational Game by myself in the future. I would like the Serious Educational Game developed by others, and I could use it in my classes." Pre-service Teacher #10 also expressed a similar perspective. Some teachers also mentioned that they obtained basic experiences in designing and making a Serious Educational Game, and these experiences would help them to use a Serious Educational Game in the classrooms more effectively (the Pre-service Teacher #3, 4, 11). Again, the programming issue seems a major challenge and stress for these pre-service teachers, which decreases their inclination to create new SEGs in the future.

We thought the most encouraging result is the inspiration of their conceptual ideas about creating an SEG. These participants did learn about how to situate their scientific knowledge into a game format and also knew how to write a creative game script. We believe that they are still willing to create their own SEGs as long as appropriate assistance can be provided, such as cooperation with game designers and programmers who can help them transfer their conceptual ideas into end-products.

The Instructor's Reflection

In this study, the instructor was also interviewed to provide directions for the improvement of the course. The instructor was asked to reflect on the difficulties he encountered when teaching pre-service teachers on SEG design and development. He mentioned that "As beginners in programming and coding, these pre-service teachers faced huge challenges in programming and coding with their insufficient ability. They also faced the challenges in integrating their professional knowledge into the Serious Educational Games." In other words, the major challenge that the instructor encountered while teaching these pre-service teachers to design and make SEGs was about how to help these pre-service teachers obtain basic ability in programming and coding, and guide them to integrate their professional knowledge in biology and biology teaching into the games.

During the interview, the instructor also stated the difficulties for the pre-service teachers in making SEGs. He mentioned that "Basically, the pre-service teachers did not have any problem in programming or coding in classes. However, they often lacked sufficient practices after school. Without continuous practices, these pre-service teachers shortly forgot what they have learned in classes and accordingly, they felt more difficult in programming and coding as an increasing content should be mastered. When I divided the instruction of programming into several parts, students were not able to make connections among these parts by themselves. That is, it is not easy for them to construct an integrated understanding regarding the computer program for an SEG. However, the most difficult thing for students was to have the insights on the logic of how a computer program is executed." The above-mentioned results indicated that for those who are with only professional knowledge in biology and biology teaching, programming and coding will be the major obstruction for their success in developing SEGs. Finally, the instructor also proposed possible ways in helping pre-service teachers design and make SEGs. He advocated that if the instructional time can be extended, the students could have more time practicing in classes. Also, it will allow students to complete their homework in classes. Then, instructors could provide immediate feedbacks to students, and students' frustrations could be reduced and the quality of the created SEGs as well as students' learning outcomes could be improved.

Discussion

Researchers argue that teacher education has a primary, inherent goal, which is to enable pre-service teachers to effectively transfer what they learn in teacher preparation courses to their future teaching (Howard 2002). Especially since we are now living in a digital era where technology is closely and inseparably connected to our daily lives, today's educators have to put all of their effort to not only reach these two goals, but also achieve the two goals through the integration with technology. Since the use of SEGs in science education has gradually grabbed much attention and its positive impact (e.g. improving knowledge acquisition, increasing learning motivation, enabling problem solving, encouraging collaboration, and so forth) on science education now has been widely evidenced, we thought it might be feasible to reach the two primary goals by engaging pre-service teachers in the activity of developing SEGs. We believe the act of creating SEGs, which provides players with an authentic context and a highly interactive experience, not only benefits the audiences but also allow the pre-service teachers to actively learn through the whole process of designing and creating SEGs. Therefore, the course *Computers in Teaching and Learning Biology* was offered as a project-based, design-oriented, and student-centered course with the expectation that pre-service teachers can construct their own knowledge and skills of TPACK through the processes of designing and making SEGs and embed the TPACK into the created SEGs.

However, the course *Computers in Teaching and Learning Biology* had been suspended for several semesters and was only re-offered since the fall of 2012. As it was the first time the course was delivered as a project-based experience which requires pre-service teachers to create their own SEGs, it was a wholly new and unfamiliar experience for both the students and the instructor alike. Hence, many challenges and difficulties were encountered while implementing this course as was expected. We interviewed both pre-service teachers and the instructor in-depth with a main focus on investigating the challenges and difficulties in carrying out this course. In so doing, we hope to provide a wide-ranging set of contextualized findings to support further research and it is also expected that the conditions associated with successful implementation of such a project-based learning (learning by designing SEGs) for pre-service teacher education can be somewhat delineated. By further examining the above-mentioned results derived from this study, we found these pre-service teachers basically had a positive attitude towards this course. They generally agreed that the whole learning experience of taking this course is interesting, student-centered, and meaningful, and they also thought this course is helpful in their future biology teaching as long as they are not required to do programming by their own. They also did learn some basic ideas about the integration of technology into pedagogy that they don't see elsewhere in their curriculum. However, four major issues: time, programming, course loading, and transfer/integration, were also revealed regarding challenges and difficulties of the implementation of this course, from both the perspective of the pre-service teachers and the viewpoint of the instructor. The descriptions of the four issues are provided as below.

Time Issue

The insufficiency of instructional time seems the major deficit of this course as mentioned by both students and the instructor. In fact, the curriculum of teacher preparation programs in Taiwan (unlike most countries) has a rather tight schedule, so that teacher preparation courses related to effective teaching with technology offered by teacher education institutes are relatively few. Moreover, even when the courses are offered, almost all of them are elective and two-credit only. Hence, the time issue becomes a dilemma for teacher educators in Taiwan. On the one hand, if the course is offered as a three- or four- credit course, the redundant credit(s) might be not able to be counted into the required credits for graduation. On the other hand, if the course remains two-credit, students might think the difficulty is too great for a two-credit course. Both of these situations will significantly decrease students' motivations of taking this course, which clearly reflects the inadequate arrangement of the current teacher preparation courses for improving the technological literacy of pre-service teachers.

Programming Issue

Almost all of these pre-service teachers mentioned that they felt frustrated in programming and coding. However, according to the instructor's reflections, these pre-service teachers appeared to not have any problem in programming and coding in classes. The major problem was they usually lacked sufficient practices after school and didn't effectively construct an integrated understanding. This is actually a serious problem which has to be overcome if the course still has to be offered in the future. A very important reason why ActionScript 3.0™ was used as the programming language to be taught in this course instead of using other existing tools which allow novices to easily create a game without programming was that, we hoped the analytical and logical thinking of these pre-service teachers could also be improved by learning how to program, a worthy byproduct perhaps. It was believed that while it might be difficult for these pre-service teachers to learn programming, once they are familiar with programming and learn the logical thinking process behind it, it would be very helpful for them in solving real-life problems and for making decisions in the future. Also, being familiar with the programming structure of ActionScript 3.0™ will make it much easier for them to get into more advanced programming someday (if they need). But indeed, it is impossible for pre-service teachers or others to gain mastery within a short time period, particularly when the skill in question is complex programming. Substantially more time is required to allow repetitive practice in order to construct an integrated understanding of the execution of computer programs, so that mastery of programming can be gained. Some pre-service teachers expressed that they felt their ability of analytical and logical thinking had improved after receiving the training of programming in this course.

Course Loading Issue

Another issue regarding challenges and difficulties is course loading. The criteria for assessing student performance in this course include participation (10 %), homework assignments (30 %), final paper-and-pencil exam (10 %), midterm presentation of prototype (20 %), and final demonstration (30 %) (as shown in Table 8.2). Despite the midterm presentation of prototype and final demonstration of SEGs that were group work, the five homework assignments and final paper-and-pencil exam required pre-service teachers to finish individually. The assignments and exam were basically designed with an aim to forcing pre-service teachers to practice the taught programming during the time outside of classes and to ensure that they learned to program. Although these pre-service teachers were required to hand in these assignments individually, they could discuss with their group members, peers, and the instructor, as well as work together to figure out how to finish the assignments. However, as mentioned earlier that these pre-service teachers are undergraduates who are majoring in biology and are enrolled in teacher education program, meaning that they have to take responsibilities for not only the assignments in this course, but also the other requirements of the department of biology. Needless to say, the students with biology major would have the tightest course schedule compared to students with other majors since they need to carry out many laboratory experiments. Their feeling that the course workload was too heavy was therefore understandable. Not enough instructional time to allow these pre-service teachers to have sufficient practice in classes again becomes the major issue. Later, we will propose some solutions and suggestions that might be helpful.

Transfer/Integration Issue

The transfer/integration issue is difficult, to unravel but also important to consider. However, It was frustrating, but not surprising to us, to find that some pre-service teachers still have difficulties in transferring what they have learned into games or completing their games, so they felt the quality of their games was quite low. According to the results, we can see that there might be two transfers/integrations that needed to be taken into account. First is the "transferring/integrating" of their professional knowledge in biology and biology teaching into the game format (integrating scientific concepts, educational objectives, and instructional strategies with game features), and the other is "transferring/integrating" the design of prototype into a real game product. These pre-service teachers showed fewer difficulties in the first transfer/integration after regularly discussing with the science education expert and their group members, which ensures the content validity of their game scripts. However, they were not able to properly transfer the design of prototype into a real game product, even though they might be able to write a very good game script which appropriately integrates scientific concepts with game features and develop a sound prototype. This might be because these pre-service teachers were not familiar with the design process and had insufficient design thinking skills. According to Razzouk and Shute (2012), the design process is iterative, exploratory, and sometimes chaotic. Besides, to properly transfer the design of prototype into a real game product, these pre-service teachers should have design-thinker characteristics as revealed in the study by Razzouk and Shute (2012). These design-thinker characteristics include having learner-centered concern, ability to visualize, predisposition toward multifunctionality, systemic vision, ability to use language as a tool, affinity for teamwork, and avoiding the necessity of choice. These pre-service teachers likely did not experience the design process before taking the course, and they might lack of training in design thinking and skills. Moreover, as mentioned earlier in this chapter that one of the learning objectives of this course was to improve students' TPACK. However, in reviewing the framework of TPACK, we found that it represents the intersections among knowledge of pedagogy, content, and technology, so that seven dimensions are included. For these pre-service teachers, they might have sufficient knowledge in pedagogy and content because the course was offered for juniors who have had took many related courses to obtain a certain extent of content and pedagogical knowledge, yet they still have not gained mastery of technology (programming). The lack of programming skills sooner becomes the major obstacle for their success in developing SEGs. Besides, these teachers might not have sufficient experiences in playing digital games or not familiar with instructional design. Their lack of understanding of game and/or instructional design also hindered their success in developing SEGs. In other words, the insufficient knowledge of technology, lack of understanding of game, or instructional design resulted in immature construction of TPACK, and this immature TPACK is eventually revealed in the final game product. That is the major reason that the pre-service teachers felt frustrated in implementing their game design (prototype) and integrating what they have learned about the programming into the game construction.

What Has Been Learned?

From this experience, a model representing students' learning from the processes of designing and making SEGs (Fig. 8.1) has emerged. Transforming an original/conceptual idea into an end-product (in this case, SEG) requires iterations of design/redesign cycle (unfortunately, the course as taught did not provide enough time to do). The design/redesign cycle describing the prototype of design has to be iteratively modified based on feedback from continuous tests. Only by taking great pains to perform the design/redesign iterations, can a valuable end-product finally being created. The iterations of design/redesign cycle have a reciprocal interaction with students' design thinking/skills, TPCK, communication, and collaboration. Namely, students have to properly employ their design thinking/skills, TPCK, as well as communication and collaboration in order to run the cycle well, and reciprocally,

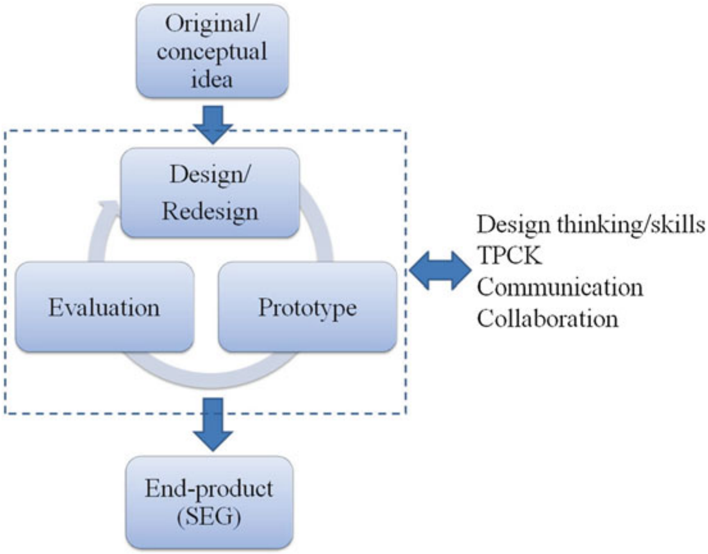

Fig. 8.1 The proposed model showing students' learning from designing SEGs

their design thinking, TPCK, communicative and collaborative skills are further improved through several design/redesign iterations.

In addition to the improvement of TPCK, one of the most valuable parts of the research is the enhancement of students' design thinking. Design thinking is a mindset about our faith of being able to creatively, independently, and resourcefully design meaningful and innovative solutions for making positive impact on the world. It can be characterized as empathy-driven, human-centered, collaborative, optimistic, and experimental (IDEO 2012). Because design thinking needs the full integration of empathy into solutions, students finally realize there is no a perfect answer and a single problem can be addressed in different ways. The importance of design thinking in education has nowadays attracted much attention, as design thinking requires students to actively find effective solutions by looking at a problem from different perspectives and supports the use of outside resources for learning and problem solving. Design thinking inspires changes and is highly relevant to today's workplace; therefore, many studies have now much encouraged researchers and educators to embed design thinking throughout the curriculum (Beckman and Barry 2007).

Future Work

Several suggestions for the successful implementation of learning by designing SEGs have emerged from the current work.

Cooperating with Other Professional Departments

One suggestion is to offer the course in cooperation with other professional departments, such as the department of computer science and information engineering or management. In fact, in the real world most of the games that are currently available also result from teamwork among experts with specialty in different fields. If there can be collaborations between different departments to offer this course, there would be students with different majors taking it. Consequently, the student groups in this course can be heterogeneous as suggested by much of the literature. For example, a group might consist of different students with major in biology, education, science computer, and/or information engineering. It turns out that students with biology majors can contribute content knowledge of science and pedagogical knowledge of biology teaching, and students from the department computer science or information engineering/management give ideas regarding programming and technological issue. This kind of heterogeneous grouping is an enhancer of group work because within the group, everyone learns from everyone else, and students are given more opportunities to participate in classes, just as Vygotsky's advocacy that students' zone of proximal development (ZPD) can be significantly improved through the teamwork within heterogeneous groups.

Providing More Scaffolds and Social Organizations for Helping Student Learning in This Course

The provision of more scaffolds is absolutely necessary. As students had mentioned in the interviews, more detailed handouts and useful resources, such as books and websites related to the tutorials or teaching of ActionScript 3.0 programming, should be provided as appropriate scaffolds. The use of exemplary cases is also highly encouraged. For an act or an event, there should be many different methods of programming. If the exemplary cases of programming for the same act/event can be provided, then the pre-service teachers or students can analyze and compare the differences and similarities between two or more examples. Moreover, a large number of websites that provide resources with open codes should be suggested. In so doing, it might be much more helpful for pre-service teachers and students in coming up with their own logic and method of programming. In addition, with today's technological advances, digital facilities must be utilized in a more proper way. Some pre-service teachers stated that the in-class instructions should be recorded and saved as tutorial videos. These videos then can be uploaded onto the web so that students could practice and rehearse repeatedly after school. Furthermore, educators and instructors should facilitate interactions between group members or students and instructors after school and assist them to build on-line social organizations wherein synchronous and asynchronous discussions between or within groups can be easily carried out.

Administrating Appropriate Number of Formative Assessments for Self-Diagnosis and Instruction Adjustment

When teaching design, formative assessment provides students feedback for their design work, and is critical for the success in design work. To evaluate student learning process and outcomes, it is important to assess the levels and various iterations in design. Although some participants argued the course workload was too heavy, we still recommend appropriate number of formative assessment should be administrated during the implementation of the course. However, the way it is administrated could be slightly modified. For example, it could be conducted as a format of self-assessment on-line that students decide when and how many times they would like to carry out these assessments. Or the assessments and assignments can be worked on through teamwork instead of being finished individually. Although it is up to the instructors or educators to determine if the performance of these assessments/assignments should or should not be counted into the criteria of final scores, the most important thing is that the results of these formative assessments and homework assignments benefit both students and instructors by allowing them to realize what is and what is not being learned. The instructions can then be adjusted accordingly and immediately. Moreover, it will also help students develop metacognition which includes the ability to plan their learning, monitor their own understanding, and to find resources and create solutions when necessary.

Whether having teachers learn to create SEGs by their own is feasible or desirable becomes a critical question raised from the current study. From the experience we have learned, we still admire and encourage the efforts of offering the courses in the future. We think the challenges can be overcome with appropriate strategies as previously suggested, and what can be learned for the pre-service teachers through the whole process of learning by creating an SEG is more than the investment required.

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