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DEVELOPMENT ARTICLE

Designing a computer support system for multimedia curriculum development in Shanghai

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Abstract The CASCADE-MUCH system was designed to help teacher-designers in Shanghai, China with the development of instructional scenarios for multimedia curricula. After four rounds of prototyping, a summative evaluation was carried out to assess practicality. Results showed that the system was practical for the intended target users in Shanghai and also had potential for users in other contexts. The purpose of this article is to present the design process of the CASCADE-MUCH program and discuss how the evolutionary prototyping approach improved program quality and contributed to the designer's knowledge growth.

Keywords Development research · EPSS · Evolutionary prototyping · Teacher–designers

Introduction

With a population of 16 million, Shanghai is one of the most advanced regions in China, both in terms of economics and education. In 1988 the former State Education Committee demanded that Shanghai create a trial curriculum

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innovation and develop new curriculum materials for economically developed regions in China. By 1997, Shanghai had completed its first round of curriculum innovation. The developed curriculum standards and instructional materials for all subjects and grades have been fully implemented (Zhang, 1999).

Shanghai is currently engaged in a second round of curriculum innovation (1998–2007), which primarily aims to improve a learner's creative thinking (Wang, 2004), as well as gain experience for other regions of the country. Because of the imbalance of economic and educational development across the country, the new curriculum innovation explores applications of both emerging information and communication technology (ICT), along with more mature technologies such as multimedia in education (Sun, 2003; Zhu, Gu, & Wang, 2003). Therefore, much attention has been given to the development of new multimedia lesson materials during this new round of curriculum innovation.

The development of multimedia lesson materials is a comprehensive and complex process, which usually starts with the development of an instructional scenario, followed by program development. Such development tasks call upon several areas of expertise in subject, instructional design, multimedia design, and curriculum development. However, the designers of multimedia lesson materials in Shanghai, who are often experienced subject teachers or researchers at district educational colleges (called teacher-designers in this article), usually have insufficient experience in the design of such multimedia lesson materials.

The computer support system CASCADE-MUCH (Computer Assisted Curriculum Analysis, Design and Evaluation: Multimedia Curriculum Design in China) was intended to help teacher-designers in Shanghai design instructional scenarios for multimedia lesson materials of school subjects (called multimedia curricula in this article) and to investigate possibilities for teacher-designers in other contexts. It was initially designed to support Biology and Geography, as these subjects include a number of natural phenomena that may potentially benefit from multimedia support. As shown in Fig. 1, the process of developing a multimedia curriculum with the support system is as follows:

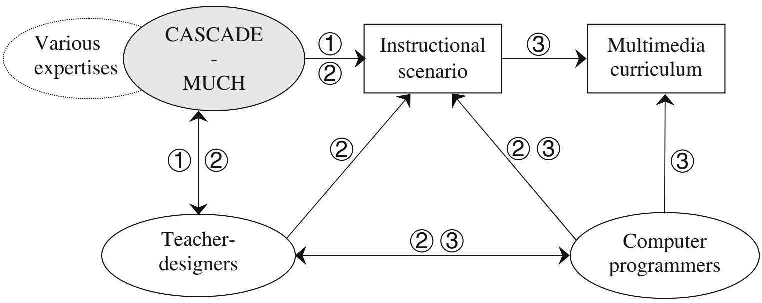

Fig. 1 Multimedia curriculum development process with CASCADE-MUCH

1. Teacher-designers can learn what content should be covered and the strategies for organizing this content in a multimedia curriculum. They can also use the support system to develop a tentative prototype of an instructional scenario. During this stage, the teacher-designers may also consult other experts to get more advice.
2. Teacher-designers will work together with computer programmers on the initial instructional scenario prototype to prepare it for programing. At this stage, several rounds of formative evaluation may be needed to improve the preliminary instructional scenario until a ready-to-use one has been produced. It is possible for teacher-designers to consult other experts at this stage as well.
3. The computer programmers will create a multimedia curriculum based on the ready-to-use instructional scenario. In addition, they may occasionally need face-to-face discussions with the teacher-designers.

The use of CASCADE-MUCH is expected to do the following:

a. help teacher-designers quickly design an initial instructional scenario prototype by providing them with in-time support;
b. facilitate discussions between teacher-designers and computer programmers after the instructional scenario prototype has been developed;
c. help teacher-designers easily revise the instructional scenario prototype based on the comments and feedback collected from the computer programmers and other experts; and
d. improve teacher-designers' professional development in multimedia curriculum design.

Conceptual framework and description of CASCADE-MUCH

A major aim of this study was to produce a practical computer support system for multimedia curriculum development by following an evolutionary prototyping approach. This section elaborates three key elements of the conceptual framework: evolutionary prototyping approach, multimedia curriculum, and electronic performance support system (EPSS). It will then briefly describe the actual CASCADE-MUCH system.

Key terms in the conceptual framework

Evolutionary prototyping approach

A development research framework was applied in this study as the research was strongly related to design and development work (cf. Richey, Klein, & Nelson, 2004; Van den Akker, 1999). In principle, development research contributes to two aspects of a research study: product improvement and knowledge growth (Van den Akker, 1999; Van den Akker & Plomp, 1993).

In this study, product improvement referred to the creation of a high quality support system that was valid, practical, and effective in helping teacher-designers create instructional scenarios for multimedia curricula (Nieveen, 1999), whereas knowledge growth referred to the designer's knowledge gain in the field of multimedia curriculum design. The knowledge growth was preferably reflected in design principles (van den Akker, 1999). In literature, other labels related to the development research approach are design research (Cobb, 2001; Collins, Joseph, & Bielaczyc, 2004; Edelson, 2002; Merrill, Drake, Lacy, Pratt, & the ID_2 research Group, 1996) and design experiments (Brown, 1992; Collins, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Winn, 2003).

In order to refine the design specifications of CASCADE- MUCH and work towards an adequate product, an evolutionary prototyping approach was followed (Smith & Brandenburg, 1991). The evolutionary prototyping approach shares similarities with rapid application development (RAD) or rapid prototyping (RP) in software engineering (Lohr, Javeri, Mahoney, Gall, Li, & Strongin, 2003; Sommerville, 1996). A notable feature of these approaches is that a prototype is created, tested, and then revised at an early stage of a project unlike traditional software models such as the waterfall model where considerable time is spent on analysis and design. Use of the RAD or RP approach has recently increased in educational fields such as course development, courseware design, and training product improvement (Lohr et al., 2003; Jones & Richey, 2000).

Multimedia curriculum

For this article, the term curriculum refers to a plan for learning as proposed by Taba (1962). The major advantage of this simple definition is that it 'allows specification for many educational levels, representations and contexts' (Van den Akker, 1998, p. 421). One challenge for curriculum development and improvement is creating balance and consistency between the various components of a curriculum. Elaborating on various typologies such as Eash (1991) and Klein (1991), this study adopted the cadre of ten components that address specific questions about the planning for student learning as a starting point: rationale, aims and objectives, content, learning activities, teacher role, materials and resources, grouping, location, time, and assessment (Van den Akker, 2003).

Multimedia often refers to a combination of various presentation forms (Verhagen, 1992) such as text, audio, and video presented in a computer. People tend to agree that a combination of proper media can make hard-to-implement instructional approaches such as simulation more feasible. Multimedia allows various levels of learner control, navigation, interactivity, and a context-rich learning environment (Hede, 2002; Wang & Cheung, 2003). An interesting and user-friendly interface and challenging activities involved in a multimedia program can motivate and engage students (Najjar, 1998; Zhu, 1997).

Multimedia curriculum is formed by a combination of both multimedia and curriculum and is defined in this study as follows:

> a plan for learning where various presentation forms (such as text, pictures, audio, video, and animation) are integrated, encoded, and presented on a computer.

Electronic performance support system

CASCADE-MUCH is an electronic performance support system (EPSS) that supports teacher-designers in producing usable instructional scenarios for multimedia curriculum development. In this study, EPSS is broadly defined as follows: (cf. Gery, 1991; Nieveen, 1997; Stevens & Stevens, 1995):

> an integrated computerized environment where users can get immediate support to efficiently solve the problems they meet.

Compared to other ICT-based support systems, EPSS has a number of assumed advantages. It can help users perform tasks more efficiently as it can provide many kinds of immediate support (Gery, 1991). It can improve the quality of end results since users can get expert advice on how to proceed with a task, as well as how to improve the quality of the end result. Designing an EPSS also has the potential to increase domain knowledge by making implicit knowledge explicit (cf. Jonassen, Peck, & Wilson, 1999).

In the past 20 years, EPSS's have been widely used in the business world as on-the-job training methods for employees who cannot leave their job sites (Gery, 1991; Moore, Orey, & Hardy, 2000). The concept of an EPSS has been applied to the field of curriculum development since the early 1990s (cf. Nieveen & Gustafson, 1999; Van Merriënboer & Martens, 2002). A series of computer support systems for curriculum development in various contexts has been initiated and developed in the University of Twente, the Netherlands. In 1993, the first CASCADE study was initiated to guide Dutch professional curriculum developers through the often-neglected process of formative evaluation (Nieveen, 1997; Nieveen & Van den Akker, 1999). In 1996, two follow-up studies were continued to explore computer support for curriculum development in various contexts. This study, CASCADE-MUCH, was one of these two studies. The other study, CASCADE-SEA (Science Education in Africa), investigated the support of science and mathematics resource teachers in creating exemplary lesson materials for classroom use in sub-Saharan Africa (McKenney, 2001; McKenney & Van den Akker, 2005). In 1999, one more study, CASCADE-IMEI (Innovation in Mathematics Education in Indonesia) was launched to explore the development and implementation of a web-based learning environment for teachers to apply a realistic mathematics approach in their instruction (Zulkardi, 2002).

Overview of CASCADE-MUCH

The characteristics of the four main components of CASCADE-MUCH (scenario, content, support, and interface) are briefly described in this section. More detailed information of the program can be found in Wang (2001).

Scenario

An instructional scenario is the final outcome of the program. It is mainly used for: i) facilitating discussions between teacher-designers and computer programmers; and ii) guiding computer programmers through their programing processes. The instructional scenario includes information about subject, topics, learners, and designers. It can be viewed within the support program or exported to Microsoft Word.

Content

The content includes aspects of analysis and design. The analysis aspect aims at collecting information about multimedia curriculum goals (basic knowledge and skills, extended knowledge and higher-level skills, and attitudes), usage (individual learning, collaborative learning, classroom teaching); and learners (subject knowledge/skills, and computer literacy skills) to guide the design process. The design component guides teacher-designers through the multimedia curriculum design process and produces an initial instructional scenario. It provides guidance for content selection, representation, organization, and interface design.

The content selection component helps teacher-designers select proper topics for a multimedia curriculum by following a curriculum standard. The content representation component helps present the selected topics with proper presentation forms such as text, graphic, audio, animation, and video. The content organization deals with sequencing the selected topics in a linear, menu, hyperlink, or an integrated way. The interface design component attempts to help teacher-designers select a proper template for the multimedia curriculum.

Support

The support system contains four broad categories of support: information, advice, tool, and training. Information includes explanation and examples of keywords, help for the content on the current screen, and tips for navigation. Advice consists of heuristic information based on the user's profile, history, and the program's embedded expertise. The program provides two types of advice: suggestions and previews. Suggestions help users decide how to deal with the current design based on the previous settings and embedded expertise, while previews help users predict how the current settings will affect the subsequent design. Tools assist teacher-designers in carrying out tasks related to the instructional scenario development. The tools in this program include Microsoft Word, web communication facilities, and translation between Chinese and English. Finally, training intends to improve the user's task performance. Wizards and tutorial as training tools are included in this program.

Interface

Interface design is, of course, an important component of CASCADE-MUCH. The interface has two notable features: ease to learn and ease to use. To make the program easy to learn, consistency has been a guiding principle. The interface is consistent with other computer applications and pages are designed in a uniform format. The program itself is rather flexible in that it is split up into several parts, from which users with different backgrounds can start. Figure 2 shows a screen shot of the program.

The evolutionary prototyping approach

Overview of the design process

The design process of CASCADE-MUCH began with a preliminary research phase, where problems, conditions, and constraints were identified and target user analysis was carried out. After the preliminary research phase, the system progressed through four rounds of prototyping: design, formative evaluation, further analysis, and revision. The aim of design activity was to produce an initial prototype. The formative evaluation activities included expert appraisal, a walkthrough, and hands-on assignments. Participants varied from end

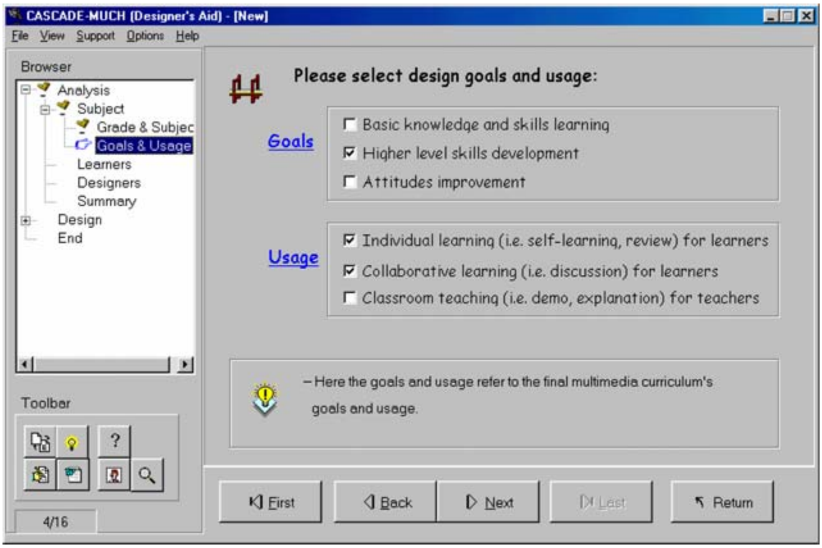

Fig. 2 A screen of the CASCADE-MUCH program

users (teacher-designers), multimedia experts, curriculum/instructional designers, computer programmers to experts in the field of computer-based learning (CBL). During the formative evaluation of each prototype, comments and suggestions were collected and further analyzed. This iterative process was repeated four times until a valid and potentially practical computer support system was developed. Here, validity meant that the prototype included 'state-of-the-art' knowledge and was internally consistent, whereas practicality meant it met the needs, expectations, and contextual constraints of the intended target group (cf. Nieveen, 1999). Table 1 lists part of the major design activities, formative evaluation activities, and revision decisions in each round of prototyping.

After four rounds of prototyping, two summative evaluation studies were conducted in Shanghai to test the practicality of the program. The first study was carried out with a group of six Biology and Geography teacher-designers, and the second study involved 13 participants including CBL designers, educational software designers, and teacher-designers of other subjects. They all walked through the program individually, filled out a questionnaire, and participated in an in-depth group discussion with the evaluator afterwards.

This section does not intend to give a detailed description of all prototyping cycles as the design process in each cycle was similar. In order to give a sound illustration of the evaluation activities in each prototyping process, an expert appraisal that took place in the third round and the hands-on workshops with the actual target group and other potential users were chosen as a sample. Detailed information with regard to each round of prototyping can be found in Wang (2001).

Formative evaluation of the third prototype

The third round of prototyping ended up with an expert appraisal workshop organized in the Netherlands, which aimed at gauging how university experts from another context would react to the validity and potential practicality of the prototype.

Table 1 Major development activities in each prototype

	1st prototype	2nd prototype	3rd prototype	4th prototype
Major design activities	• Focusing on content, support, and interface design	• Focusing on scenario, content, and support design of two subjects: Biology and Geography	• Improving scenario, content, and support design	• Improving content and support
Formative evaluation	• Expert appraisal	• Walkthrough • Expert appraisal	• Walkthrough • Expert appraisal	• Expert appraisal
Main revision decisions	• Focusing on two subjects	• Relocating supporting information to Help	• Further revising the components of content and support	• Defining the key concepts more precisely

Evaluation question, participants, instrument, and procedure

The evaluation question was as follows:

> To what extent is the prototype valid and perceived to be practical for multimedia curriculum development in other contexts?

Eight university experts were invited to the expert appraisal workshop: two were specialized in multimedia, three in instructional design, and the other three in curriculum development. They were all Ph.D. holders and had extensive experience in their research fields.

A two-part instrument was used in the formative evaluation. The first part included two different predetermined walkthroughs for multimedia experts and instruction/curriculum design experts respectively, and associated questions. The predetermined walkthroughs guided different types of expertise to specific issues or aspects of the system. The associated questions were specific and closely related to the scenario, content, support, or interface, and aimed at collecting concrete comments and suggestions. Table 2 shows part of the walkthrough and associated questions designed for the curriculum and instructional experts.

The second part of the instrument consisted of four reflective questions:

1. Is the prototype useful for intended target users to make instructional scenarios?
2. Can the prototype improve the users' professional knowledge?
3. Can the instructional scenario provide an easy way for interactive discussions between designers and computer programmers?
4. Will the instructional scenario be useful for computer programmers?

Table 2 Part of the walkthrough and associated questions used by the curriculum/instructional design experts

Screen number	Steps	Associated questions
	1. Run the main program by double clicking the "Main" icon on the desktop	
#1	2. Select English language	
#3	3. Select the first item ("I need help, please guide me through the design step-by-step"); click on the "Action" button	
1/16 (found in the left-bottom corner)	4. Click on the keyword "multimedia curriculum" ((answer question a) 5. Click on the "Next" button twice to go to the third screen	a) Do you think the definition of "multimedia curriculum" is accurate?
3/16	6. Click on the "Suggestion" button (or press F2) and "Prediction" button (or press F3) on the toolbar ((answer question b)	b) Do you think the 'suggestion' and 'prediction' tools are useful for intended target users?
	...	...

At the beginning of the workshop, the evaluator, who was the designer of the support system, gave a brief introduction. A presentation was followed to show the participants basic information about the prototype's aims, intended target users, structure, support, and interface. Curriculum development within Shanghai was also briefly introduced, and the evaluator answered questions both during and after the presentation.

Participants were also encouraged to gain hands-on experience with the prototype after the presentation. They followed the predetermined walk-throughs as shown in Table 2, and answered the associated questions. During this one hour session, the evaluator observed, facilitated, and answered questions. Following the hands-on activities, participants spent half an hour exchanging opinions about the prototype, while the evaluator took notes on all remarks and comments.

Summary of results

Associated questions. The following is a brief summary of the participants' responses to the associated questions.

a1. They all agreed with the definition of multimedia curriculum. However, some of them disagreed with the relationship between the conventional curriculum and the multimedia curriculum as described in the prototype. They commented that both should cover the same content with the same presentation forms, but from different media sources (i.e. textbooks and computers).

a2. Participants thought that the learner analysis part seemed insufficient. They felt it should include analysis of subject-related knowledge and skills, computer literacy skills, and learning styles.

a3. In each analysis and design component such as learner analysis, content selection, or content organization, some guidelines were provided to help teacher-designers carry out the tasks. A few participants challenged why those guidelines were recommended in the support system, and how they could guide teacher-designers in the design of instructional scenarios.

a4. They agreed that suggestions would be a very important type of support for users, though the suggestions in that prototype gave little useful information. Therefore, more intelligent expertise was recommended.

Reflective questions.

Q1: Is the prototype useful for intended target users to make instructional scenarios?

The answers to this question were rather positive. They believed that the prototype had the potential to be useful in developing instructional scenarios. However, three participants commented that an obvious limitation of the prototype was that it did not provide direct help or advice for making design decisions in a format like 'based on ..., you are advised to ...'. One participant suggested improving: i) consistency of terms and lists; and ii) specification of theoretical models and examples.

Q2: Can the prototype improve users' professional knowledge?

A majority thought the prototype had the potential to increase users' professional knowledge, though several improvements were needed to do so. One participant argued that more information should be given on why the practical guidelines were important and how they affected the design. Another participant suggested adding further elaboration on taxonomies and arguments to the prototype.

Q3: Can the instructional scenario provide an easy way for interactive discussions between designers and computer programmers?

Answers to this question were very positive. They agreed that the prototype's scenarios could form a good platform for discussions between teacher-designers and computer programmers. One participant mentioned that more 'intelligence' was needed in the instructional scenario, while another participant suggested adding more space for designers and computer programmers to negotiate their ideas.

Q4: Will the instructional scenario be useful for computer programmers?

Answers to this question varied. Three participants agreed that it would be helpful, while four were unsure. One participant disagreed because he thought the scenario was not described in sufficient detail.

In conclusion, the answers to the reflective questions indicated that although the first three design goals in this prototype were generally well achieved, the goal of improving designers' professional knowledge for multimedia curriculum design was not. The workshop showed that opinions of the multimedia experts were more positive than those of the curriculum or instructional design experts. This was probably because the multimedia experts found the prototype more productive since they could make instructional scenarios, while the curriculum or instructional experts walked through the prototype without producing any artifact.

Revision decisions. After analyzing the comments and suggestions, the designer came up with the following revision decisions:

r1. The relationship between a conventional curriculum and a multimedia curriculum needed to be adjusted [a1]. It would be more accurate to say that a multimedia curriculum and a conventional curriculum usually cover the same content with the same presentation forms, but from different media sources.

r2. The analysis of learning styles would not be included in the prototype [a2] since a multimedia curriculum would meet the various needs of learners with different learning styles rather than serve a group of students with particular learning styles. Also, little research evidence has indicated that learners with special learning styles may favor particular learning strategies and perform better than others without such learning styles. Nevertheless, two models for analyzing learning styles proposed by Dunn and Dunn (1992) and Kolb (1981) were added to the help file for those who might be interested in applying this concept.

r3. More intelligent expertise would be added to the prototype [a3, a4]. The intelligent expertise referred mostly to the interrelationships between the analysis and design parts of the program. The way in which the analysis part supports the design part should be stated explicitly.

Assessment of the final prototype practicality

The CASCADE-MUCH support system had become acceptable through four iterative cycles of prototyping. In order to verify to what extent it would be practical for intended target users, it was further assessed through two summative evaluation studies in Shanghai.

Evaluation question, participants, instrument, and procedures

The overall evaluation question for the two assessment studies was:

> To what extent is the CASCADE-MUCH program practical for both primary target users and other users in the context of Shanghai?

The first study was conducted with the primary target group users. Six teacher-designers including four Biology and two Geography teachers, were invited to take part in a micro-evaluation workshop. Two of them had experience in multimedia curriculum design while the rest had little experience. In the second study, 13 participants took part in a micro-evaluation workshop. Participants included seven subject teachers, three CBL designers from secondary schools, and three software developers from education-related computer companies.

The main instrument used for data collection was a two-part questionnaire. The first part consisted of thirty four-point Likert scale questions as shown in Table 3. A four-point scale without a mid-point was used to force participants to take a position, even if it did push them towards the positive end of the scale (cf. Garland, 1991). The second part listed three open-ended questions:

1. What is the perceived usefulness of the support program?
2. To what extent do you think the program is practical?
3. How can the program be further improved?

The procedures of both studies were similar. Both workshops started with an introduction to the aims of the system, procedure, and time schedule of the workshop. After the introduction, each participant made an instructional scenario for any topic in their subject textbooks. Participants worked individually and were encouraged to raise any questions, while the evaluator

Table 3 Perceived practicality of the four components

		Primary users (n = 6)			Other users (n = 13)		
		Mean*	Max	Min	Mean	Max	Min
Scenario	1. The scenario includes what I intended to include	3.3	4	2	3.1	4	2
	2. The scenario is well structured	3.5	4	2	3.3	4	2
	3. I can easily modify the scenario within Microsoft Word	3.7	4	3	3.4	4	3
	4. I am satisfied with the produced scenario	3.8	4	3	3.3	4	2
	5. The meanings of the elements in the scenario are clear.	3.3	4	2	3.4	4	3
	6. The produced scenario can help me easily discuss my wishes with computer programmers	3.5	4	3	3.2	4	3
	7. I believe that the scenario would be easy to understand for computer programers	3.7	4	3	3.0	4	2
Content	8. I could easily understand the content on each screen	3.3	4	2	3.6	4	3
	9. The content fits my practical needs for multimedia curriculum (or learning materials) design	3.0	4	2	3.2	4	1
	10. I could easily understand the explanations of keywords/models	3.5	4	3	3.3	4	2
	11. I learned some useful information from the support system	3.3	4	2	3.3	4	1
Support	12. The help function provided me with useful models	3.3	4	2	3.1	4	1
	13. The suggestions gave me valuable expert advice	3.4	4	3	3.2	4	2
	14. The previews indicated to me what would be affected by the current settings	3.4	4	2	3.2	4	2
	15. The additional explanations of the suggestions/previews helped me understand why the suggestions/previews were given	3.0	4	1	3.2	4	2
	16. The tips provided me with useful information	3.8	4	3	3.5	4	3
	17. The Edit Panel support tool could help me easily make instructional scenarios	4.0	4	4	3.5	4	2
	18. I could easily export scenarios into Microsoft Word	3.7	4	2	3.5	4	2
	19. I think the explanations/examples of keywords are practical	3.3	4	2	3.4	4	1
	20. The concept-mapping tool is useful in making content selection	3.4	4	3	3.5	4	2
Interface	21. User tasks on each screen are clear	3.7	4	3	3.2	4	2
	22. The meanings of buttons on each screen are clear	3.5	4	3	3.3	4	2
	23. I like the fonts and colors on each screen	3.2	4	1	2.7	4	1

Table 3 continued

	Primary users (n = 6)			Other users (n = 13)		
	Mean*	Max	Min	Mean	Max	Min
24. The navigation tools (linear and browser) are easy to use	3.8	4	3	3.3	4	3
25. I think the amount of information on each screen is adequate	3.7	4	3	3.1	4	1
26. I think each screen has a consistent design	3.8	4	3	3.1	4	1
27. I believe that the interface is consistent with other computer programs	3.7	4	3	2.8	4	2
28. The interface is easy to learn	3.5	4	3	3.5	4	3
29. The interface is easy to use	3.7	4	3	3.5	4	3
30. I feel the program is error-free	3.2	4	2	2.5	4	1

*4 = agree; 3 = slightly agree; 2 = slightly disagree; 1 = disagree observed and took notes. This hands-on phase lasted for about one and a half hours. After the participants finished their assignments, the evaluator helped them check whether completed instructional scenarios had been successfully exported to Microsoft Word so they could fill out the questionnaire.

A further in-depth discussion focused mainly on the perceptions of the system, and how to improve the program further followed the questionnaires.

Summary of results

Results of the primary target group users. As displayed in Table 3, the four components of the system were perceived to be rather practical as the mean scores of the four components were 3.3 and higher. Nevertheless, a small number of users disagreed with some specific statements such as Q15 and Q23, which got the minimal scale (Min = 1).

Based on the evaluator's observations and discussions, it could be concluded that the participants were satisfied with the practicality of the system. They could use it to make initial instructional scenarios with few difficulties. Two participants suggested that the program should have a simplified version to support new users or novice designers.

Results with users from other contexts. Table 3 also includes results of the second study. The results indicate that the four components of the system were also perceived to be practical by the other users. Participants generally agreed with each statement related to the four components: scenario, content, support, and interface. However, some specific questions had rather low means. Three means in the 'interface' part were below 3.0 and Q30 got the lowest score (2.5), which implied that some debugging was needed to remove errors. Overall, the interface needed more improvement.

During the group discussion, many teacher-designers recommended that the support system should be extended to support other subjects as well. All seven teacher-designers in the second study clearly expressed that they would be willing to use the support system in the future when they were developing instructional scenarios. Two CBL designers and one software developer also mentioned that they would be glad to use it.

Moreover, some participants stated that one of the most encouraging advantages of the support system was that it could help teacher-designers become acquainted with a systematic approach to multimedia instructional design. One constructive suggestion noted that the system should support collaborative work to aid long-distance communication between teacher-designers and computer programmers.

Discussion

By following an evolutionary prototyping approach, this study aimed at designing a valid and practical computer support system for multimedia curriculum design in Shanghai. In this concluding section, issues regarding the prototyping approach, formative evaluation, and design principles are discussed, and suggestions for further research are offered.

Evolutionary prototyping approach

The evolutionary prototyping approach has been widely adopted in software engineering and an increasing number of educational designers have devised ways to apply it to instructional design and curriculum development (Jones & Richey, 2000). They argue that instructional design processes are nonlinear (cf. Gustafson, 2002) and so complex that 'the simple, linear version of the ADDIE model is not useful to conduct complex design enterprises' (Van Merriënboer & Martens, 2002, p. 6). The design process of this study has confirmed that the evolutionary prototyping approach is appropriate for complicated instructional systems since it supports the following (cf. Nieveen, 1999; Nieveen & Van den Akker, 1999):

- gradual clarification of design specifications and approximation to an optimal solution;
- easy communication between the designer and the users based on actual prototypes instead of abstract specifications; and
- involvement of end users during the development processes, raising the chances for commitment.

Moreover, this study revealed that the designer gained much knowledge while engaged in the design activities and processes. This supports the notion that the design process creates good opportunities for designers to further understand the complexity of educational systems in an evolutional prototyping approach (cf. Edelson, 2002).

There were, however, some limitations to this approach. For example, conducting a prototyping process within the development research framework can be quite time consuming. Each round of prototyping in this study took about 6 months to a year, which was difficult to reduce as the activities were performed within the framework of development research. Development research requires considerable time devoted to analysis and design activities, planning and performing formative evaluation studies, and reporting formative evaluation results.

Using an evolutionary prototyping approach to conduct development research appears to be rather complex (Edelson, 2002), particularly when done in different contexts. Because the researcher was usually situated in the Netherlands and the support system was designed for a Shanghai, China context, communication between the program designer and the target groups became a challenge. The formative evaluation activities require much synchronous and asynchronous communication between the designer and the target groups. However, because of the distance and time zones between them, the synchronous communication was often hard to implement. This limitation also affected this study's completion of the design and formative evaluation activities to a certain extent.

The results of this study offer some general suggestions for applying the evolutionary prototyping approach in a development research framework. First, end users' involvement in the prototyping process from the very beginning of a project is crucial because it can ensure that the final product meets their needs, hence shortening the development time of the whole project (Jones & Richey, 2000). Second, a comprehensive record of each prototype and of the ongoing design process is important (cf. Cobb et al., 2003) because each version of the prototype reflects the designers' thinking process and their knowledge status (Jones & Richey, 2000). A complete record of the design process articulates how the final product has been developed and how the designers accumulate knowledge in the design process. Third, breaking down a prototype into several components such as scenario, content, support, and system interface is helpful because it allows designers to focus their design and evaluation activities on some specific elements during each round of prototyping.

User participation in formative evaluation

The role of formative evaluation is to determine the strengths and weaknesses of a program in order to generate suggestions for improvement (Nieveen, 1999). It holds a prominent place in a prototyping approach, as it can 'provide the information that feeds the cyclic learning process of developers during the subsequent loops of a design and development trajectory ' (Van den Akker, 1999, p. 10). This study confirms the importance of user participation in a formative evaluation process.

User participation can help designers clarify design specifications. A system is designed for an intended target group of users, whose needs and expectations must be considered and integrated into the system during the prototyping process. However, the needs and expectations of the users were found to be rather vague at the beginning of this study. Also, the designer was uncertain about the characteristics of the support system. The user participation in the formative evaluation activities helped users clarify their requirements and the designer refine specifications of the support system.

User participation can effectively prevent a system from being designed solely for experts. During each round of prototyping, the designer carried some initial ideas and assumptions, while the experts advocated some theoretical models or guidelines. However, the initial ideas, models, or guidelines did not always work well in practice because of an existing gap between theory and practice (Richey et al., 2004). By receiving users' feedback early on, 'designers are less likely to invest too much time and money on an instructional product that is not meeting learner or stakeholder needs' (Lohr et al., 2003, p. 42). This study verifies that user participation can help ensure that a product does not deviate too far from the user's needs.

Finally, aspects related to sampling in a formative evaluation need to be carefully considered when selecting proper participants. First, in view of triangulation (Miles & Huberman, 1994), representative users with different characteristics should be selected. Second, the selected users should be those who are highly motivated or interested in the prototype, otherwise they may be inert or inactive, and consequently fewer comments and suggestions can be collected. Third, feedback from peers who can make frank or critical comments without causing designers to lose face should be encouraged. A variety of participants such as subject teachers, curriculum and instructional designers, and CBL experts were involved in each formative evaluation activity and results showed they contributed a number of valuable comments and suggestions, which helped the designer to improve the specifications of the system.

From revision decisions to design principles

Making revision decisions is an important part of the prototyping approach. It is often an uphill battle because designers need to analyze various views and make the correct decisions. This study indicated that making revision decisions was a complicated process that needed careful deliberation in order to balance facts, suggestions, or wishes that were sometimes contradictory to one another. Meanwhile, the process of making revision decisions provided the designer an opportunity to accumulate the body of knowledge and professional development (cf. Edelson, 2002).

Van den Akker (1999) suggested that knowledge gained from development research could be presented in a form of design principles: ‘If you want to design intervention X [for the purpose/function Y in context Z] then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis] and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R’ (p. 9). This format of design principles is compact, concise, and also helpful for designers in presenting their gained knowledge in a structured way.

However, striking a balance between being concrete and being abstract appeared to be difficult in this study. Nevertheless, McKenney (2001) attempted to address this issue by presenting design principles at three levels: foundational tenets, development guidelines, and product specifications. This representation of design principles seems to be more helpful in guiding designers through a development research process.

Suggestions for further research

The results of this study suggest that several areas can be addressed through additional research. For example, the quality of produced instructional scenarios can be further examined. Even though many intended target users and potential users had used the support system to produce initial instructional scenarios during the formative evaluation and assessment activities, this study has not indicated to what extent the system i) facilitates discussions between teacher-designers and computer programers and hence speeds up the development process of usable instructional scenarios, and ii) guides computer programers through the process of multimedia curricula development.

Furthermore, the quality of the multimedia curricula based on the produced instructional scenarios, and the effect of these curricula on students' performance and attitudes towards learning have not yet been covered in this study. There was no evidence showing whether the multimedia curricula could motivate students to learn, improve their creative thinking, or just increase their examination marks. This area needs to be further explored by teacher-designers, students, and even independent experts in follow-up research studies. Producing an instructional scenario using the support system is only one step towards developing an effective multimedia curriculum.

In conclusion, this study supports the notion that the evolutionary prototyping approach in a development research study is appropriate for designing complicated instructional systems because it can help designers approximate an optimal solution. Furthermore, the evolutionary prototyping approach also provides designers an opportunity to clarify and gain knowledge during the actual design processes.

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